Systematic Review and Evidence-Based Clinical Recommendations for Dosing of Pediatric Supported Standing Programs

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Purpose: There is a lack of evidence-based recommendations for effective dosing of pediatric supported standing programs, despite widespread clinical use. **Methods:** Using the International Classification of Functioning, Disability, and Health (Child and Youth Version) framework, we searched 7 databases, using specific search terms. **Results:** Thirty of 687 studies located met our inclusion criteria. Strength of the evidence was evaluated by well-known tools, and to assist with clinical decision-making, clinical recommendations based on the existing evidence and the authors' opinions were provided. **Conclusions and recommendations for clinical practice:** Standing programs 5 days per week positively affect bone mineral density (60 to 90 min/d); hip stability (60 min/d in 30° to 60° of total bilateral hip abduction); range of motion of hip, knee, and ankle (45 to 60 min/d); and spasticity (30 to 45 min/d). **(Pediatr Phys Ther 2013;25:232–247)** *Key words: bone mineral density, child, disabled children/rehabilitation, dose–response relationship, dynamic weight-bearing, joint instability, physical therapy modalities/statistics and numerical data, range of motion, spasticity, systematic review, weight-bearing*

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INTRODUCTION AND PURPOSE

Children who ambulate less than 2 hours per day or are nonambulatory often experience painful and costly complications because of extended periods spent in seated, supine, and prone postures.[1] Supported standing programs have been used in various settings for more than 50 years in an effort to reduce and prevent complications and to optimize various aspects of function.[2] In spite of widespread clinical use, we lack evidence-based recommendations for effective program dosing.

In a systematic review of the pediatric- and adult-supported standing program literature,[3] the available evidence provided moderate support for a beneficial effect on bone mineral density (BMD) of the legs and spine; range of motion (ROM) of the hip, knee, and ankle; spasticity of the ankle; and bowel function. Therapists and individuals who used standers reported benefits from supported standing programs on weight-bearing, pressure relief, ROM, and psychological well-being. Findings were inconclusive for a positive effect on cardiopulmonary and bladder function, muscle strength, and alertness.

This article extends our initial systematic review[3] by using the literature to make specific clinical dosing recommendations for supported standing programs for children. In the absence of pediatric-specific evidence, the authors offer other considerations on the basis of expert opinion. The intent of this approach is to provide suggestions for clinicians to use in designing and implementing optimal evidence-based supported standing programs, but always in the context of professional clinical judgment and client/caregiver goals and preferences.

METHODS

As Figure 1 illustrates, we identified peer-reviewed literature and published abstracts from conference proceedings through multiple search engines (MEDLINE, CINAHL, GoogleScholar, HighWire Press, PEDro, Cochrane Library databases, and the American Physical Therapy Association's Hooked on Evidence) from January 1954 to August 2012. We included the earliest date to give an historical perspective, although the 1954 study was eliminated because it was adult specific. Search terms were "stander," "standing," "standing shell," "tilt table," "standing frame," "whole body vibration (WBV)," and "children," or "cerebral palsy (CP)." Preliminary inclusion criteria were (1) English language, (2) published in a peer-reviewed journal or official conference proceedings, and (3) included participants, birth through 21 years with atypical development, with or without a neuromuscular diagnosis, including CP. Overall, we identified 687 studies, and 87 met the preliminary inclusion criteria. Secondary inclusion criteria were as follows: (1) described a standing frame or similar device and (2) measured quantifiable outcomes. Thirty of the 87 studies met these criteria (see Figure 1). Sources that did not meet the secondary criteria were potential considerations in the authors' opinion-based comments.

We used the Oxford Centre for Evidence-Based Medicine (CEBM) Levels of Evidence (http://www.cebm.net/?o=1116) and the American Academy of Neurology (AAN) Levels of Evidence (http://www.neurology.org/site/misc/TableClassificationScheme.pdf) to evaluate the strength of the evidence as a basis for clinical recommendations. The CEBM and AAN evidence levels range from 1 to 5: level 1 is the highest level (systematic review of randomized controlled trials); level 5 is the lowest level (expert opinion without critical appraisal). The AAN levels include specific recommendations using clinically interpretable language. The CEBM levels are comprehensive but the CEBM did not offer specific advice on research using survey methodology. Many times, the literature did not provide sufficient information or did not fit clearly into one of the categories. For this reason, we made our best interpretation of the evidence levels for those articles that did not clearly fit the AAN or CEBM guidelines (see Tables 1 and 2). We further rated the evidence with a clinical relevance level system of red light (no evidence; stop), yellow light (minimal evidence; proceed with caution), and green light (moderate or strong evidence; go).

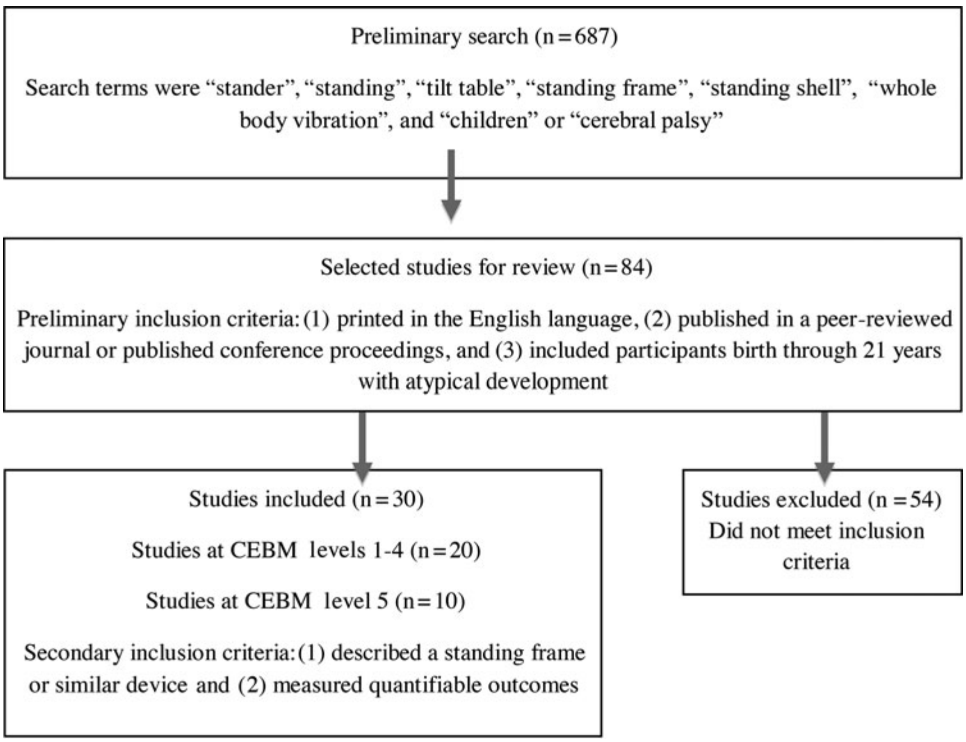

Fig. 1. Search strategies.

TABLE 1
Assignment of Levels of Evidence From Oxford Centre for Evidence-Based Medicine and American Academy of Neurology

Level of Evidence	Oxford Centre for Evidence-Based Medicine[a]	American Academy of Neurology[b]	Authors' Interpretation
1	Systematic review of randomized trials or n-of-1 trials	Prospective, randomized, controlled clinical trial with masked outcome assessment, in a representative population with: (a) Primary outcome(s) is/are clearly defined (b) Exclusion/inclusion criteria are clearly defined (c) Adequate accounting for dropouts and crossovers with numbers sufficiently low to have minimal potential for bias (d) Relevant baseline characteristics are presented and substantially equivalent among treatment groups or there is appropriate statistical adjustment for differences	
2	Randomized trial of observational study with dramatic effect	An observational study or survey with: (a) Primary outcome(s) is/are clearly defined (b) Exclusion/inclusion criteria are clearly defined (c) Adequate accounting for dropouts and crossovers with numbers sufficiently low to have minimal potential for bias (d) Relevant baseline characteristics are presented and substantially equivalent among treatment groups or there is appropriate statistical adjustment for differences	
3	Nonrandomized controlled cohort/follow-up study	An observational study or survey in a representative population that lacks one of the above criteria a to d	Neither system addresses survey research. We have designated well-constructed surveys that have undergone a pilot phase and used rigorous statistical analysis as level 3
4	Case series, case-controlled study, or historically controlled study	An observational study or survey with well-defined natural history controls or patients serving as own controls, in a representative population	Neither system addresses survey research. We have designated poorly constructed surveys or those that have not undergone a pilot phase and did not use rigorous statistical analysis as level 4. Neither system specifies that the article needs to be published in a peer-reviewed journal. Because we have chosen to include posters and platform presentations, we have designated these RCTs as level 4. As new systems emerge, these studies may need to be reclassified.
5	Mechanism-based reasoning	Expert opinion without explicit critical appraisal, or based on physiology, bench research, or "first principles"	

Abbreviation: RCTs, randomized controlled trials.
[a]From Oxford Center for Evidence-Based Medicine (http://www.cebm.net/?o=1116).
[b]From American Academy of Neurology (http://www.neurology.org/site/misc/TableClassificationScheme.pdf).

The World Health Organization's International Classification of Functioning, Disability, and Health, Child and Youth Version (ICF-CY) model (http://apps.who.int/classifications/icfbrowser/) was used as the categorizing framework because of its adoption by the World Health Organization as the international standard to describe and measure health and disability. The American Physical Therapy Association has endorsed the use of this model, and it is particularly helpful to describe body structure and function, activity, and participation. Arranging the dosage information by ICF category, we intended to guide clinicians to the currently accepted vernacular.

The systematic review results (evidence) and clinical dosing recommendations have been organized and reported using the following 3 ICF categories and selected subcategories: (1) body functions (b)—mental functions (b110 to b139), functions of the cardiovascular (b410 to b429) and respiratory systems (b440 to b449), functions of the digestive systems (b510 to b539), urinary functions (b610 to b639), and neuromusculoskeletal and movement-related functions (b710 to b789); (2) body structures

TABLE 2
Grading of Recommendations

Clinical-Relevance Level System (Added by Authors)	Oxford Centre for Evidence-Based Medicine[a]	American Academy of Neurology[b]	Summary/Authors' Comments
Green light (strong evidence; go)	Consistent level 1 studies	Established as effective; requires at least 1 level 1 study or at least 2 level 2 studies	Strong evidence
Green light (moderate evidence; go)	Consistent level 2 or 3 studies	Probably effective; requires at least 1 convincing level 2 study or at least 3 consistent level 3 studies	Good evidence
Yellow light (minimal evidence; proceed with caution)	Level 4 studies	Possibly effective; level 3 rating requires at least 2 convincing and consistent level 3 studies	Fair evidence; authors rated evidence as poor if only 1 level 4 study was found
Red light (no evidence; stop)	Level 5 studies or troubling inconsistent or inconclusive studies of any level	Data inadequate, insufficient evidence; effectiveness not established	Lack of evidence

[a]From Oxford Center for Evidence-Based Medicine (http://www.cebm.net/?o = 1116).
[b]From American Academy of Neurology (http://www.neurology.org/site/misc/TableClassificationScheme.pdf).

(s)—structure of the bone as related to BMD (s7400, s75000, s75010, s75020, s76001 to b76004), structure of the bone as related to hip stability (s75001), and skin and related structures (s8103 to s8105); and (3) activities and participation (d)—mobility (d410 to d489) and major life areas (d810 to d859).

RESULTS

Body Functions

Mental Functions (ICF b110 to b139). *Evidence (levels 4 and 5)*. Three studies[4-6] examined the effect of standing on mental function. Gudjonsdottir and Stemmons Mercer[5] used the Carolina Record of Individual Behavior to measure alertness in 4 children with CP while using a traditional stander and an experimental stander that rocked side to side. No change was noted between these 2 conditions, but the author stated there was a slight trend toward being more alert when standing in the stander that rocked side to side. On the basis of a survey,[4] approximately 90% of school-based physical therapists reported improved self-esteem as a very important or important benefit of a standing program. Psychological tests administered to preschool-aged children with CP using an array of adaptive devices, including prone standers, scored significantly higher in the adaptive equipment than when floor sitting or in a nonadapted chair.[6] These results are summarized in Table 3.

Clinical recommendation from the evidence. A minimum of 30 minutes of standing per day may be associated with an alert state and possibly improved academic performance.[5,6]

Other considerations (authors' opinions). Consider using a self-propelled, powered stander or standing wheelchair to promote eye-to-eye peer interactions. In the future, electroencephalography or functional near-infrared spectroscopy could be explored as a measure of the effect of standing on alertness.

Functions of the Cardiovascular (ICF b410 to b429) and Respiratory System (ICF b440 to b449). *Evidence*. There were no reportable pediatric studies.

Clinical considerations (authors' opinions). Standing programs must be progressed in a systematic manner with careful monitoring. Initial bouts should start at 5 to 10 minutes at 45° (more or less, as appropriate) and progressed to tolerance. If an interruption in service or schedule change occurs for as little as 3 to 8 days, regress the program with a shorter bout and at a lower angle with therapist judgment and careful monitoring.[7] Children who are medically fragile may have reduced lower extremity circulation. For the child who is just beginning a standing program or returns to standing after an interruption, monitoring blood pressure, heart rate, respiratory rate, and oxygen saturation is critical both initially and throughout the standing period (10- to 15-minute frequency).[7] Use pressure garments (eg, abdominal binder and support stockings), electrical stimulation for leg muscles, passive/assisted/active stepping or cycling, and/or WBV[8] to ameliorate autonomic dysreflexia, baroreflex, syncope, nausea, or dizziness, unless otherwise contraindicated.[3,8-10] Forty minutes of standing, 3 to 4 times per week, may reduce leg and foot swelling and decrease breathing difficulties and dizziness.[11] Repeated and progressive standing may improve functional circulation.[12] Cease standing activity if vital signs become unstable, for example, if oxygen saturation levels fall below 90%.[13]

Functions of the Digestive System (ICF b510 to b539). *Evidence (levels 4 and 5)*. Evidence was poor that standing device usage improved bowel function in children. On the basis of survey data from physical therapists working with school-aged children, 34% thought standing was "very important" for bowel and bladder function, whereas 50% thought it was "important."[4] A decrease in gastroesophageal reflux was noted in infants placed on a prone board at a 30° incline from vertical.[14] These results are summarized in Table 4.

TABLE 3

Mental Functions[a] (b110 to b139): Includes Alertness and Feeling of Well-Being[b]

Summary of Findings: Insufficient evidence; effectiveness not established; red light.

Author	Level of Evidence	Does This Study Support Improvement in This Category?	Are There Negative Findings?	Participants	Main Results	Dosage Used
Gudjonsdottir and Stemmons Mercer[5]	4	Maybe	No	4 children with cerebral palsy	2/4 children demonstrated a slight shift toward more active, alert states in the dynamic vs static stander	30 min/d for 8 wk
Miedaner and Finuf[6]	5	No	No	12 children with cerebral palsy	For 1 subject stander vs no positioning did not change performance on the Bayley Mental Scale	One session only
Taylor[4]	4	Maybe	No	386 school- based physical therapists	Promoting self-esteem was rated as a very important or important perceived benefit of standing by 90% or more of all respondents	30-45 min/d

[a]Entries are arranged in alphabetical order by the first author name.

[b]From the International Classification of Functioning, Disability, and Health, Child and Youth Version model (http://apps.who.int/classifications/icfbrowser/).

TABLE 4

Functions of the Digestive System[a] (b510 to b539): Includes Bowel Function and Reflux[b]

Summary of Findings: Insufficient evidence; effectiveness not established; red light.

Author	Level of Evidence	Does This Study Support Improvement in This Category?	Are There Negative Findings?	Participants	Main Results	Dosage Used
Bubenko et al[14]	5	Maybe—prone standers may have similar effect	No	Infants	Clinical observation that 30° prone decreased gastroesophageal reflux	No details given
Taylor[4]	4	Maybe	No	386 school-based physical therapists	On survey, 34% thought that standing was "very important" for bowel and bladder, whereas 50% thought it was "important"	30-45 min/d

[a]Entries are arranged in alphabetical order by the first author name.

[b]From the International Classification of Functioning, Disability, and Health, Child and Youth Version model (http://apps.who.int/classifications/icfbrowser/).

Clinical recommendation from the evidence. Prone positioning may be a useful part of a reflux management program. As a caution, avoid rigid materials that could create excessive abdominal pressure.[14]

Clinical considerations (authors' opinions). Daily standing for 30 to 60 minutes may decrease the use of suppositories and time spent for bowel care.[11,15-17]

Urinary System (ICF b610 to b639). *Evidence.* No reportable pediatric studies and no clinical recommendations for dosing were found.

Neuromusculoskeletal and Movement-Related Functions (ICF b710 to b789). *Evidence (levels 2 and 5).* The strongest evidence was for the positive effects of a standing program on hamstring ROM.[18] Standing maintained or increased ROM and even prevented knee flexion contractures.[19] When standing ceased, knee ROM decreased.[18] Standing also increased static and dynamic range of motion for plantar flexors.[20] Standing for children as young as 14 months resulted in improved hip ROM.[21] These results are summarized in Table 5.

Clinical recommendations from the evidence. Stand at least 45 to 60 minutes daily; 60 minutes is optimal to increase hip, knee, and ankle ROM.[18-20] Sixty degrees of total bilateral hip abduction improves abduction ROM, but an optimal angle has not been established.[19]

Other considerations (authors' opinions). Greater than or equal to 30° of total bilateral hip abduction may not be feasible initially because of discomfort. Introduce small increments of hip abduction in standing over time to tolerance. Use a knee support and footplate system that allows appropriate poisoning of the feet to ensure biomechanical alignment at the knee, ankle, and foot (see Figure 2).

TABLE 5

Neuromusculoskeletal and Movement-Related Functions[a] (b710 to b789): Includes Range of Motion[b]

Summary of Findings: Strong evidence; established as effective; green light.

Author	Level of Evidence	Does This Study Support Improvement in This Category?	Are There Negative Findings?	Participants	Main Results	Dosage Used
Gibson et al[18]	2	Yes	No	5 nonambulatory children with cerebral palsy	Increased range of motion in hamstrings during standing; trend for hamstrings to shorten during nonstanding phases	1 h/d, 5 d/wk, 6 wk
Macias[21]	5	Yes	No	14 children with spastic diplegic cerebral palsy, 14-17 mo through 5 y of age	Adductor muscles did not lose range of motion in the group who stood in abduction	45 min/d in plaster cast in stander at 55-70° of abduction
Martinsson and Himmelmann[19]	2	Yes	No	97 children with cerebral palsy, 2-6 y old, GMFCS levels 3-5, children ambulatory with walker excluded	Hip and knee contractures were found only in control participants	30-90 min (60 min worked best), 5 times/wk for 1 y
McDonald[22]	5	N/A	No	An array of neuromuscular diagnoses including muscular dystrophy, spinal muscle atrophy, and arthrogryposis	Standing programs should be used daily to prevent or slow progression of contracture	Daily (no other information provided)
Salem et al[20]	2	Yes	No	6 children with cerebral palsy, GMFCS levels 2 and 3	Increase in peak dorsiflexion angle during midstance with standing	45 min/d, 3 times/wk in prone stander, 9 sessions; alignment was symmetrical
Stuberg[23]	5	N/A	No	Reviewed articles relating to children	Author concluded that the literature indicated decreased incidence of contractures in children with developmental disabilities who participated in standing programs	60 min, 4-5 times/wk is recommended, ensuring as much weight-bearing as possible through legs in as upright of a position as possible

Abbreviation: GMFCS, Gross Motor Function Classification Scale.
[a]Entries are arranged in alphabetical order by the first author name.
[b]From the International Classification of Functioning, Disability, and Health, Child and Youth Version model (http://apps.who.int/classifications/icfbrowser/).

Standing programs can be safely started as early as 9 to 10 months of age.[19,21,24,25] Standers that allow for hip extension (beyond neutral) may help combat hip flexor tightness, especially for children with muscular dystrophy, spina bifida, or spinal cord injury[22,23] (see Figure 3). To enhance passive stretch of the plantar flexors, add a 15° dorsiflexion wedge, with the subtalar neutral position maintained.[26] For tight hamstrings, knee immobilizers may help distribute pressure areas and assist in improving knee extension. For knee flexion contractures, use available devices, such as a contracture bracket (see Figure 4). Avoid direct pressure on the patella and tibial tubercle. Sling-style seat standers may accommodate moderate to severe spine and hip contractures or deformities.

Muscle Power Functions (ICF b730). *Evidence at levels 3 to 5.* One researcher[27] found increased electromyographic activity and postural responses in a child with spina bifida while in an orthotic standing shell. The majority of the studies in this category combined supported standing with WBV.[28-30] All studies except one used a platform that rocked side to side and vibrated. These results are summarized in Table 6.

Clinical recommendation from the evidence. Incorporate WBV, including rocking from side to side and vibration

Fig. 2. Footplates to ensure biomechanical alignment at the ankle and foot, especially with 15° to 30° angles of bilateral hip abduction. Photo used with permission and courtesy of Bruce Boegel.

Fig. 3. Sling style stander that allows trunk to be unsupported. Some children are able to lean backward and stretch hip flexors. Tape used to illustrate angle of femur and pelvis. Photo used with permission and courtesy of Bruce Boegel.

with standing for 10 minutes, twice per day, to increase muscle strength.[28,30]

Other considerations (authors' opinions). Adults with CP showed an improvement in Gross Motor Function Measure (dimensions D and E) and isokinetic muscle strength following a combined standing and WBV program when compared with exercise alone.[32] Standing in a device that allows for lower extremity movement (flexion and extension) may improve strength.[16] Use of a self-propelled stander may promote upper extremity and trunk strengthening.

Muscle tone Functions (ICF b735). *Evidence (level 2).* Two level 2 studies[20,33] used traditional standing frames and showed a decrease in lower extremity spasticity or tone. Children with CP showed a decrease in triceps surae and tibialis anterior spasticity after 30 minutes of stretch in a supported stander. The decrease in spasticity lasted 35 minutes after cessation of the stretch/standing.[33] Salem et al[20] showed statistically significant improvements in gait and decreased tone of the soleus following 45 minutes of daily sessions in a stander. These results are summarized in Table 7.

Clinical recommendations from the evidence. Stand for 30 to 45 minutes per day to decrease spasticity.[20,33]

Other consideration (authors' opinions). The effect on spasticity may last only for 35 minutes; therefore, follow standing with an activity that may improve with this short duration of decreased spasticity, such as dressing or walking.[33]

Fig. 4. Contracture bracket used to accommodate moderate to severe knee (−45°) contractures/deformities. Photo used with permission and courtesy of Steve Scribner. This figure is available in color in the article on the journal website, www.pedpt.com, and the iPad.

Body Structures

Structures of the Bone Related to Hip Stability (ICF s75001). *Evidence at levels 2 to 5.* In 1 study[19] and 1 abstract[21] authors noted participants standing in 55° to 70° of total bilateral hip abduction had improved acetabular and hip migration indices. Dalén et al[34] suggested that standing in neutral hip abduction in a Swedish Standing Shell might have had the opposite effect and actually

TABLE 6

Muscle Power Functions[a,b] (b730)

Summary of Findings: Good evidence; probably effective; green light.
Majority of studies (5/6) added WBV yellow light.

Author	Level of Evidence	Does This Study Support Improvement in This Category?	Are There Negative Findings?	Participants	Main Results	Dosage Used
Brogren[27]	5	Maybe	No	3 children with spina bifida	Increased electromyographic muscle activity in standing shell	Single bout in "standing shell"
Rauch[31]	5	Supports addition of WBV	No	4 children with cerebral palsy	Increased cross-sectional area of calf muscle	Two sessions/wk for 6 mo; no further details provided
Semler et al[30]	3	Supports addition of WBV with lateral oscillation	No	8 children with osteogenesis imperfecta types 3 and 4	Improved muscle force in all subjects as documented by an increased tilting angle (median = 35°) or by an increase in ground reaction force	Tilt table with vibration platform, 9 min, 2 times/d, 5 d/wk, 6 mo
Semler et al[29]	3	Supports addition of WBV with lateral oscillation	No	6 children: 4 with osteogenesis imperfecta, 1 with cerebral palsy, and 1 with dysraphic defect of the lumbar spine	Improved muscle force in all subjects as documented by an increased tilting angle (median = 35°), improved functional scores	Tilt table with vibration platform, 9 min, 2 times/d, 5 d/w, 6 mo
Stark et al[28]	4	No, too many simultaneous interventions	No	78 children with bilateral spastic cerebral palsy	Improvement in muscle force and mass	Total program included 6 mo of robotic walking, strengthening, tilt table with WBV platform and lateral oscillations

Abbreviation: WBV, whole body vibration.
[a]Entries are arranged in alphabetical order by the first author name.
[b]From the International Classification of Functioning, Disability, and Health, Child and Youth Version model (http://apps.who.int/classifications/icfbrowser/).

increased hip subluxation. Two research groups[24,25] noted that standing, when combined with other interventions, improved hip biomechanics.

No evidence indicated that supported standing would be contraindicated if the participants had 1 or both subluxed or dislocated hips.[25,35] In 1 case, a trochanteric girdle was used to prevent acute bilateral hip subluxation during supported standing.[36] Supported standing, as 1 part of a comprehensive hip management program, was shown to possibly prevent repeated need for hip surgery.[24] These study authors also agreed that hip deformity, dislocation, and subluxation could only be prevented or reduced if the children with CP were positioned properly in their wheelchairs, standers, and sleep systems throughout the 24-hour period. Hägglund et al[24] also recommended frequent, twice per year, and vigilant monitoring of hips with immediate surgical or pharmaceutical intervention as needed. These results are summarized in Table 8.

Clinical recommendation from the evidence. Standing daily for 60 minutes in 60° of total bilateral hip abduction may improve hip biomechanics.[19]

Other considerations (authors' opinions). In all equipment, gently try to maximally straighten hips (to neutral, with no flexion) and knees (without hyperextension) and fully load the femur and tibia. Sit-to-stand devices that do not allow a fully upright position (hip and knee extension without pressure on the knees or shins) may be less effective in fully loading the legs and hips.[37,38] A force plate or scale may be mounted to some foot platforms to monitor weight-bearing. The caregiver should not be able to move the feet/shoes after achieving upright standing. Consider 30° to 60° of total bilateral hip abduction, based on tolerance, to improve hip biomechanics, although the optimal amount of abduction has not been established.[21,24,25] If the participant has had a previous pathological fracture, use extreme caution during the loading and unloading to and from the standing device. Following a fracture or

TABLE 7

Muscle Tone Functions[a,b] (s735)

Summary of Findings: Strong evidence; established as effective; green light.

Author	Level of Evidence	Does This Study Support Improvement in This Category?	Are There Negative Findings?	Participants	Main Results	Dosage Used
Salem et al[20]	2	Yes	No	6 children with cerebral palsy, GMFCS levels 2 and 3	Decrease in soleus muscle tone	45 min/d, 3 times/wk in prone stander, 9 sessions; alignment was symmetrical
Tremblay et al[33]	2	Yes	No	22 children with cerebral palsy	Decrease in spasticity of triceps surae and tibialis anterior as measured by torque and electromyography	Single session, 30 min, tilt table with ankles positioned in dorsiflexion

Abbreviation: GMFCS, Gross Motor Function Classification Scale.

[a]Entries are arranged in alphabetical order by the first author name.

[b]From the International Classification of Functioning, Disability, and Health, Child and Youth Version model (http://apps.who.int/classifications/icfbrowser/).

surgical procedure (including muscle and/or tendon lengthening), obtain medical clearance before using a standing device.[39] Children with moderate to severe gross motor delays, greater than 25%, should begin a supported standing program at about 9 to 10 months of age, adjusted for prematurity as appropriate. This is based on our knowledge that children who are typically developing begin pulling to stand on their own between 8 and 12 months of age. Discontinue standing if pain occurs, especially concurrent with skeletal deformity, as this could indicate a dislocated hip and warrants medical attention. Adjust all equipment at least every 6 months.[24]

Skin and Related Structures (ICF b8103 to b8105). *Evidence at level 4.* Pressure relief from sitting was the highest perceived benefit, and many therapists (58.7%) rated it as very important.[4] For children with conditions that result in compromised motor and sensory function, pressure relief may be a reasonable goal for a standing program (see Table 9). However, no evidence that standing positively affected skin integrity in children and no clinical recommendations for dosing were found.

Other considerations (authors' opinions). Ensure that transfers and sit-to-stand mechanisms (if used) do not produce shear forces on the spine and sacrum. A sit-to-stand device with a seat that pivots/rotates or a standing wheelchair stander might be ideal to decrease shear forces during transfers, as described (but not measured) by Sprigle and colleagues[40] (see Figure 5). A stander that uses a hydraulic lift mechanism with a sling style seat may be the best choice. Make sure that the user's buttock area and undergarments are clean and dry. Choose fabrics that keep the skin cool and moisture free.[40] The administrator of the standing program should inspect skin areas of concern for pressure points (typically, ischial tuberosity and sacrum). Use frequent, short bouts of supported standing and/or incorporate weight shifts to avoid skin breakdown due to prolonged pressure. This is especially important to consider in the school setting when a student may be placed in the standing position for the class period.

Body Structure of the Bone as Related to BMD (ICF s7400, s75000, s75010, s75020, and s76001 to s76004). *Evidence at levels 2 to 5.* These results are summarized in Table 10. Several researchers reported evidence for various bony sites; however, the amount of weight-bearing through the tibia and femur was neither measured nor controlled. In addition, the amount of time spent standing in many studies, less than 60 minutes per day, may have been too short to affect BMD. A dosage from 4 to 5 hours[23] to 7.5 hours[41] per week was needed to maintain/increase BMD. On the basis of animal studies, as reviewed by Stuberg,[23] short bouts of 10 to 15 minutes for a total of 60 minutes per day should have equal or superior benefits to a single bout lasting 60 minutes.

In children with CP, a 50% increase in supported standing time resulted in a 6% increase in vertebral BMD, with no change in proximal tibial BMD.[42] However, 20 of the 26 participants did not reach the goal of a 50% increase in standing time. Twelve of the 26 participants actually decreased their standing time in the intervention phase.

Researchers in 1 study[45] found that combining standing with WBV produced nearly an 18% increase in BMD of the tibia. Stark et al[28] reported similar results, whereas Ruck et al[43] found that BMD increased in the control group and decreased in the WBV group. Children who are not standing are at risk for low BMD; therefore, standing may be an appropriate intervention to increase BMD. However, other factors need to be considered: overall physical

TABLE 8

Functions of the Bone as Related to Hip Stability[a] (s75001): Includes Hip Stability, Acetabular Index, Femoral Head Angle, Migration Percentage, Hip Subluxation, and Hip Dislocation[b]

Summary of Findings: Fair evidence, possibly effective; yellow light.

Author	Level of Evidence	Does This Study Support Improvement in This Category?	Are There Negative Findings?	Participants	Main Results	Dosage Used
Hägglund et al[24]	3	Maybe, when combined with comprehensive medical management and 24-h positioning program	No	212 children with cerebral palsy, followed until 9-16 y of age	No child at GMFCS level 1 developed hip migration percentage >40%, whereas 18 of 28 children at GMFCS level 5 developed hip migration percentage >40%	No dosing information provided in this study, but from Martinsson and Himmelmann[19] we know it was 30-90 min 5 times/wk
Macias[21]	5	Yes	No	14 children with spastic diplegic cerebral palsy, from 14 to 17 mo until 5 y of age	The adductor muscles did not lose range of motion in the group who stood in abduction	45 min/d in plaster cast in stander at 55-70° of abduction
Martinsson and Himmelmann[19]	2	Yes	No	97 children with cerebral palsy, 2-6 y old, GMFCS levels 3-5, children ambulatory with walker excluded	Straddled weight-bearing after surgery had the largest decrease in hip migration percentage; children using straddled weight-bearing at least 1 h/d for prevention also improved significantly	30-90 min (60 min worked best), 5 times/wk for 1 y
Pountney et al[35]	4	Yes	No	59 children with cerebral palsy	Children who used sitting, standing, and lying positioning equipment before hip subluxation maintained more hip integrity than other groups	Prone standers used daily for an average of 30 min/d
Pountney et al[25]	4	Yes	No	39 children with cerebral palsy	The frequency of children with hip problems was significantly less in the intervention group in comparison to the historical control	3 y of daily use of prone stander
Ruys[36]	5	N/A	No	Single, 12-y-old with hypotonic athetotic cerebral palsy	Addition of trochanteric girdle to long leg braces set in abduction prevented the child from acute hip subluxation in standing	20 min/d

Abbreviation: GMFCS, Gross Motor Function Classification Scale.

[a]Entries are arranged in alphabetical order by the first author name.

[b]From the International Classification of Functioning, Disability, and Health, Child and Youth Version model (http://apps.who.int/classifications/icfbrowser/).

activity levels and intensity, adequate nutrition, calcium and vitamin D levels, thyroid hormone levels, effect of antiseizure and other medications that could cause calcium to leach, adequate daily exposure to sunlight, and BMD-building medications.[47-49]

Clinical recommendation from the evidence. Although the level 2 to 4 studies supported the use of standing devices to positively affect BMD at some sites, but not all, none of the published level 3 to 4 studies included findings relevant to clinical dosing recommendations.

Other considerations (authors' opinions). Standing for 60 to 90 minutes, 5 times per week, may be a minimum threshold for positively affecting BMD.[41] This may mean that some portion of the program should occur at school in addition to home. Avoid discontinuing standing programs during school breaks.[44] When transitioning to a new school, group home, or program, a physical therapist should assist with continued access to standing equipment and training of new personnel. The onset of puberty may be a critical period to maintain or begin

TABLE 9

Skin and Related Structures (s8103 to s8105): Includes Wounds (All Stages) and Pressure[a]

Summary of Findings: Poor evidence, data inadequate; yellow light.

Author	Level of Evidence	Does This Study Support Improvement in This Category?	Are There Negative Findings?	Participants	Main Results	Dosage Used
Taylor[4]	4	Maybe	No	386 school-based physical therapists	"Provide pressure relief from sitting" was the highest-rated perceived benefit of standing	30-45 min/d

[a]From the International Classification of Functioning, Disability, and Health, Child and Youth Version model (http://apps.who.int/classifications/icfbrowser/).

Fig. 5. Sit-to-stand or standing wheelchair stander might be ideal to decrease shear during multiple transfers. Photo used with permission and courtesy of Bruce Boegel.

a supported standing program.[39] Consult with an experienced nutritionist to ensure adequate intake of calcium, vitamin D, and other nutrients.[39] Ensure adequate daily exposure to sunlight or equivalent, especially during winter months.[39] Consult with an experienced physician about effects of other medications on BMD.[39] Consult with an experienced physician to consider the use of BMD-increasing medications.[39] A previous pathological fracture places the child at the highest priority for receiving a rehabilitative standing program.[39] Multiple short bouts that include loading and unloading, for example, sit-to-stand transfers, may be more valuable than static standing alone.[23] Ensure that the child is weight-bearing symmetrically by adjusting positioning devices with maximal, but comfortable, hip and knee extension.[37,38] Use as few postural supports and straps as needed to fully load the legs.[37,38]

Activities and Participation (Mobility d410 to d489 and Major Life Areas d810 to d859)

Evidence at levels 2 to 5. As shown in Table 11, the use of a stander may have increased the speed of feeding,[50] improved interactions with peers and caregivers,[2,51] promoted social interaction,[4] and eased the burden of care.[18] For gait, the use of a stander improved the base of support[21] and increased walking speed,[20,43] including an improved stride length, stride time, stance phase time, and double support time.[20] The use of a supported standing program was also shown to improve scores on the Gross Motor Function Measure.[28,31] Standing also improved scores on standardized tests[6] and slightly improved some work output.[52]

Clinical recommendation from the evidence. Standing combined with WBV for 60 minutes, 5 times per week, may improve function in children with CP.[28]

Other considerations (authors' opinions). Pair standing with an activity or participation by using a toy, communication device, or other learning tool. To promote participation in upright activities, use a stander to place the child at eye level with peers. Choose a self-propelled or power-driven standing wheelchair to promote movement activities with peers.

CONCLUSIONS AND DISCUSSION

The strongest evidence-based literature supported the use of standing devices to positively affect BMD at some sites (but not all), lower extremity ROM, hip biomechanics, and spasticity. Whole-body vibration appears to be a promising addition, but more studies are needed to look at the optimal parameters (hertz, amplitude, oscillation, etc).[29] In only 2 studies[19,41] was dosing for pediatric supported standing programs directly addressed. Martinsson and Himmelmann[19] showed positive benefits of 60 and 90 minutes of supported standing per day on hip migration, but no changes at 30 minutes per day. Katz et al[41] demonstrated positive results on BMD with 10 hours of supported standing per week, but not when the dosage fell below 7.5 hours per week.

TABLE 10

Functions of the Bone as Related to BMD[a] (s7400, s750000, s75010, s75020, and s76001 to s76004): Includes BMD of the Spine, Pelvis, Hip, Femur, Tibia, Ankle and/or Foot[b]

Summary of Findings: Good evidence, probably effective; green light.

Studies that included WBV are noted green light.

Author	Level of Evidence	Does This Study Support Improvement in This Category?	Are There Negative Findings?	Participants	Main Results	Dosage Used
Caulton et al[42]	3 (downgraded due to 20/26 participants did not increase standing by 50%)	Yes	No	26 children with cerebral palsy	Increase in vertebral but not tibial BMD with 50% increase in standing	4.5 h/wk on average
Dalén et al[34]	4	Yes	No	18 children with severe cerebral palsy	Standing time was not associated with BMD	40 min/d (range 4-164 min)
Gudjonsdottir and Stemmons Mercer[5]	4	Maybe	No	4 children with cerebral palsy	2 children increased BMD in lumbar spine, 2 decreased; for proximal femur, BMD increased in 1 subject and remained the same in another; all 4 had increased BMD at distal femur	30 min/d, 5 d/wk, 8 wk
Katz et al[41]	5	Yes	No	11 children with tetraplegic cerebral palsy, 9-20 y old	Compliance was positively correlated ($r = 0.62$) with increased calcaneal BMD	2 h/d, 5 d/wk for 6 mo, 7.5 h/wk was the minimal needed dosage to see a positive effect
Rauch[31]	5	Supports addition of WBV	No	4 children with cerebral palsy	Improved lumbar spine and tibial BMD	Two sessions/wk for 6 mo, no further details provided
Ruck et al[43]	2	No, does not support addition of WBV	Maybe (1% of WBV sessions stopped because of pain or fatigue)	20 children with cerebral palsy	No change in BMD at the lumbar spine, increased BMD at distal femoral diaphysis in controls and decreased in the WBV group	9 min, 5 times/wk, side-alternating WBV for 6 mo
Stark et al[28]	4	No, as many interventions were applied at the same time	No	78 children with bilateral spastic cerebral palsy	BMD showed a significant difference in total of 2.3%; BMC/cm showed a significant difference in total of 5.74%	Total program included 6 mo of robotic walking, strengthening, tilt table with WBV platform and lateral oscillations
Stuberg[44]	5	Yes	No	20 nonambulatory children with developmental delay (18 with cerebral palsy)	Removal of the standing program for a period of 2 mo was found to have a deleterious effect on BMD at the tibia	≥60 min/d, 3-4 sessions/wk
Stuberg[23]	5	N/A	No	Reviewed articles relating to children	Author has concluded that the literature indicates decreased incidence of fractures in children with developmental disabilities who participate in standing programs	60 min, 4-5 times/wk is recommended, ensuring as much weight-bearing as possible through legs in as upright position as possible

(*continued*)

TABLE 10

Functions of the Bone as Related to BMD[a] (s7400, s750000, s75010, s75020, and s76001 to s76004): Includes BMD of the Spine, Pelvis, Hip, Femur, Tibia, Ankle and/or Foot[b] (*Continued*)

Author	Level of Evidence	Does This Study Support Improvement in This Category?	Are There Negative Findings?	Participants	Main Results	Dosage Used
Ward et al[45]	2	Yes, supports addition of WBV	No	22 ambulatory children with disabling conditions	Improvement in proximal tibial BMD in the WBV group, trend for improvement in the spine in the WBV group; diaphyseal bone and muscle parameters did not show a response to treatment	90-Hz frequency of WBV for 10 min/d, 5 d/wk for 6 mo; compliance was 44% (average was 4.4 min/d)
Wilmshurst et al[46]	4	Yes	No	27 children with cerebral palsy	Less BMD was associated with greater degree of immobility and non–weight-bearing	Nonambulatory group was "regularly weight-bearing in a frame"

Abbreviations: BMD, bone mineral density; WBV, whole-body vibration.
[a]Entries are arranged in alphabetical order by the first author name.
[b]From the International Classification of Functioning, Disability, and Health, Child and Youth Version (ICF-CY) model (http://apps.who.int/classifications/icfbrowser/).

Although standing devices were shown in this review to be medically useful, further research and discussion is needed. Improving BMD has not been shown to improve activity and/or participation. Some authors[39,41] allude to low BMD resulting in pain. If so, this might justify supported standing because children who are nonambulatory and have already experienced a pathological fracture are at greater risk for additional fractures.

In spite of the questions that remain after this evidence-based review, we think enough support exists for the use of a standing device as part of a comprehensive 24-hour postural management and activity program for children who are not active in an upright position, nonambulatory, and/or minimally ambulatory, provided no contraindications exist. Therapists recommending a 24-hour postural management program should consider including both a passive standing component, using a prone, supine, and/or upright stander, and an active component using a stander that steps, vibrates, oscillates, sways, turns, bounces, moves from sit-to-stand under users' own power, allows users to self-propel, and so on, or other devices that combine weight-bearing and movement such as a gait trainer/support walker.

The ICF-CY model encourages practitioners and therapists to focus on activity and participation. When we look to improve body functions and structure, it should always be in the context of improving activity and participation within the individual's environment. To meet these goals for a child who is nonambulatory, Gross Motor Function Classification Scale levels 4 or 5, using a standing device, may be an excellent starting point.

Although further research on dose–response relationships between pediatric supported standing programs and desired outcomes is certainly needed, current evidence indicates that children with neuromuscular dysfunction who were not physically active could benefit from standing 5 days per week under the following conditions: (1) to improve BMD, 60 to 90 min/d; (2) to improve hip biomechanics, 60 min/d in 30° to 60° of bilateral hip abduction; (3) to increase ROM, 45 to 60 min/d; and (4) to minimize the effects of spasticity, 30 to 45 min/d. Future research should define minimal and optimal doses for desired outcomes in defined pediatric populations.

Continued challenges remain to fully define an ideal supported standing program. Overall, the dose–response relationship for supported standing is not defined for some outcome variables that have been assessed. Survey and qualitative studies reflect a belief that standing improved cardiopulmonary function, alertness, bowel function, and participation. The effect of supported standing on these outcomes, however, has not yet been systematically studied.

Limitations of this current review included very minimal pediatric dosing literature, lack of higher levels of evidence from which to extract potential dosing recommendations for any population, and authors' subjectivity in the choices for search and classification parameters, interpretation of the literature, and for the specific clinical recommendations/author comments. Given these limitations, clearly more research, ranging from higher-level research studies to well-described case reports, is necessary to define important outcomes, describe clinical reasoning,

TABLE 11

Activities and Participation—Mobility[a] (d410 to d489): Includes Walking, Assisted Mobility, Wheelchair Use, Gait Trainer Use, Transfers; and Major Life Areas (d810 to d859): Work and School[b]

Summary of Findings: Good evidence, probably effective; green light.
Studies that included WBV are noted green light.

Author	Level of Evidence	Does This Study Support Improvement in This Category?	Are There Negative Findings?	Participants	Main Results	Dosage Used
Bakewell[1]	5	Yes	No	Children	Enables children to interact more easily with their peers and the environment	None given
Gibson et al[18]	2	Yes	No	5 nonambulatory children with cerebral palsy	Feedback from caregivers suggested that transfers and activities of daily living became slightly easier after phases of standing frame use	1 h/d, 5 d/wk for 6 wk
Macias[21]	5	Yes	No	14 children with spastic diplegic cerebral palsy, 14-17 mo until age of 5 y	There was a widening of the base of support with improved functional step generally seen	45 min/d in plaster cast in stander at 55°-70° of abduction
Miedaner and Finuf[6]	4	Yes	No	12 children with severe spastic cerebral palsy	All participants completed more Bayley Scale items when positioned with assistive devices than with unpositioned.	One session only
Noronha et al[50]	3	Maybe	No	10 children with spastic diplegic cerebral palsy	Significantly faster simulated feeding while in a prone standing position	One session only
Rauch[31]	5	Supports addition of WBV	No	4 children with cerebral palsy	Improved standing (Gross Motor Function Measure dimension D)	Two sessions/wk for 6 mo; no further details provided
Ruck et al[43]	2	Yes, supports addition of WBV	Maybe (1% of WBV sessions stopped because of pain or fatigue)	20 children with cerebral palsy	Group with WBV increased walking speed by a median of 0.18 m/s	9 min, 5 times/wk, side-alternating WBV for 6 mo
Salem et al[20]	2	Yes	No	6 children with cerebral palsy, GMFCS levels 2 and 3	Improvement in stride length, gait speed, stride time, stance phase time, and double support time	45 min/d, 3 times/wk in prone stander, 9 sessions; alignment was symmetrical
Stark et al[28]	4	No, as many interventions were applied at the same time	No	78 children with bilateral spastic cerebral palsy	Improvement in gross motor function measure	Total program included 6 mo of robotic walking, strengthening, tilt table with WBV platform, and lateral oscillations
Taylor[4]	4	Maybe	No	386 school-based physical therapists	"Promote social interaction" was the second-highest rated perceived benefit of standing	30-45 min/d
Wilton[51]	5	NA	No	Children with cerebral palsy	Improved participation by being upright with peers	Specifics not supplied

Abbreviations: BMD, bone mineral density; GMFCS, Gross Motor Function Classification Scale; NA, not applicable; WBV, whole body vibration.
[a]Entries are arranged in alphabetical order by the first author name.
[b]From the International Classification of Functioning, Disability, and Health, Child and Youth Version model (http://apps.who.int/classifications/icfbrowser/).

and determine the effect of standing programs on the participation of children with whom we work.

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