Clinician Task Force and RESNA Position

On the Application of Supported Standing Devices:

Current State of the Literature

Approved by Clinician Task Force: 2/23/2023

Approved by the RESNA Board of Directors: 2/15/2023

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This is an official RESNA Position Paper on Clinical and Professional Practice. As such, it has been prepared in accordance with the specific guidelines and approval process defined by the RESNA Board of Directors for Position Papers. See the RESNA website for a complete description of this procedure. Key aspects of this procedure include: 1. Establishment of a Working Group of three or more experts to author the paper, using evidence from the published literature, documented best practices, and other input from experts in the field as the basis for the content. 2. Review of the draft by at least two subject matter experts from the relevant RESNA SIG or PSG, as well as all interested SIG or PSG members, and subsequent revisions. 3. Circulation of the revised draft to RESNA members and others for a 30-day public comment period, and subsequent revisions. 4. Review of the revised draft by the RESNA Board of Directors, and subsequent revisions. 5. Final approval of the paper by the RESNA Board of Directors.

Introduction

This paper intends to update previous position papers on standing devices published through the Rehabilitation Engineering and Assistive Technology Association of North America (RESNA).[1,2] The current paper expands the previous focus on wheelchair standing devices to all types of supported standing devices. The purpose of this paper is to educate and advocate for the appropriate use of standing devices to improve the health and function of people who have difficulty, or are unable to, independently stand for longer periods of time. Clinical reasoning is required to apply the information in this document to unique individual cases.

Background

Supported standing programs are regularly recommended by clinicians for wheelchair users as these individuals are at highest risk for many secondary conditions directly related to remaining seated for prolonged periods of time.[3] Peer-reviewed research describes the impact of supported standing dosage on activity of daily living performance, psychosocial well-being, and physical benefits such as maintained or improved range of motion, muscle tone, and vital organ capacity.[1,2,4-9] Furthermore, the supported standing intervention has been shown to be feasible and cost-effective to implement, as shown in a study examining a home standing program for persons with Multiple Sclerosis.[10] Health care professionals, families, and people with disabilities consider supported standing a standard of care and an essential component in the medical, habilitative, and rehabilitative care of individuals who experience difficulty ambulating.[11-13]

Definitions

Supported standing devices: maintain the person in a standing position. The device may also facilitate movement from a horizontal (supine or prone) position to standing (e.g. tilt table), or from a sitting position into a standing position (e.g. standing frame), with mechanical (non-powered) or electric (powered) assist. While in the supported standing position, the device may maintain the person in one space (static) or enable the user to move throughout a physical environment (dynamic). The supported standing device may be separate from a mobility device, requiring transfer into the device to use (such as a tilt table or standing frame), or a system integrated into a person's mobility device (such as a power standing system on a power wheelchair).

Supported standing devices that facilitate repetitive or reciprocal lower extremity movement, such as rocking, pedaling, or cycling, are beyond the scope of this review.

Device characteristic definitions

Device fit: may accommodate moderate to severe contractures (20-90 degrees hip and knee, 45 degrees ankle) and incorporate abduction (10-60 degrees total) with secondary supports. Some devices may allow for the addition or use of a back support or a cushion for skin protection and/or pressure redistribution purposes.

Standing Position: occurs when there is a shift from the supine or seated position of a person toward unweighting the seated surface and bear weight into the lower extremities. Static and dynamic supported standing devices allow for incremental transitions to achieve partial and full upright standing position, an important feature used to customize the device to the user.

Outcome Classification

International Classification of Functioning, Disability and Health framework (ICF): describes and organizes a standard language surrounding functioning and disability. Authored by the World Health Organization, the ICF is known worldwide as a guide for holistic healthcare and is recognized by the Center for Disease Control to use with individuals and populations in the United States.[14,15]

Study Purpose

This paper expands and updates the RESNA Position on the Application of Wheelchair Standing Devices[2] through the inclusion of literature from the last 20 years on supported standing in both wheelchair and non-wheelchair based devices. The objectives for the study were: 1) To update the current RESNA Position on the Application of Wheelchair Standing Devices, 2) Perform a scoping review to identify the current evidence related to supported standing to answer the question, "Does supported standing using a device result in changes in ICF outcomes (body structure, body function, activity, participation, environmental, personal attributes)?", and 3) Understand the current evidence related to supported standing in relationship with ICF outcomes, in order to 4) Advocate for health care insurance coverage of supported standing devices.

Method

Design

A scoping review was initiated to explore the extent and nature of research activity, as well as disseminate study results related to supported standing).[16,17] The purpose and method were approved by the RESNA board of directors and the Clinician Task Force (CTF) executive board.

Search Strategy

The search strategy was established and agreed upon by the coauthors. Two librarians consulted on the search terms utilized, and the research team agreed upon the final search terms utilized (Appendix A). MESH terms were explored; however, were unused due to the specialized nature of the search. The scoping review first searched terms in six databases: CINAHL, Scopus (including Medline), Web of Science, PsycInfo, Proquest and PEDro. All databases were searched using the same search terms and parameters. Indexed database results were imported into Zotero, then exported into Microsoft Excel.

Inclusion and exclusion criteria

Inclusion criteria were articles published in a peer reviewed journal between January 2000 and November 2020, in the English language. The study must have included outcomes and results for supported standing, without additional interventions (such as vibration or stepping). Supported standing devices included tilt tables, standing wheelchairs, standing frames, and standing shells, and they had to be used by a person with a disability.

Dissertation or thesis, opinion pieces, editorials, study trials or proposed studies, conference proceedings, and abstracts were excluded. Additionally, studies on exoskeletons, robotic devices, whole body vibration, parapodiums, treadmill devices, Functional Electrical Stimulation (FES), and rocking/stepping supported standing devices were not included unless the control group was supported standing in an included device. Systematic and scoping reviews were also excluded.

Data extraction and analysis

One researcher extracted the results and compiled the master spreadsheet with all results. Four researchers reviewed the titles and abstracts of the articles in the spreadsheet for duplications and rated the articles as relevant or not relevant, with each entry being reviewed by two researchers. All differences went to review by a third reviewer.

The full text articles for relevant titles and abstracts were extracted and each full article was reviewed by two researchers and rated to include or exclude. All differences were reviewed by a third researcher. Full articles were reviewed in detail for research design, study purpose, study population and sample size, diagnoses, type of standing devices. Standing dosage and outcomes were examined for quantitative studies as well, while thematic results were gathered for qualitative studies. Included articles were charted and study outcomes were categorized based on the ICF categories represented.[16] Relationships between the three most cited ICF subdomains were identified to determine which ones were discussed the most in the literature.[18]

Results

A total of 1,329 articles were retrieved and underwent review; Figure 1 provides the PRISMA diagram of the search process. A total of 42 articles were retrieved. Results included pediatric (n=21) and adult (n=21) populations, and quantitative or mixed methods studies accounted for 13 pediatric studies and 14 adult studies (Tables 1 and 2). Most pediatric studies utilized standing frames (n=14), followed by power wheelchairs with standing systems (n=4), consistent with adults (standing frame, n=18). Furthermore, all study outcomes were evaluated and categorized by ICF category, with all outcomes (except for one) within the Body Functions and Activities and Participation categories (Figure 2).

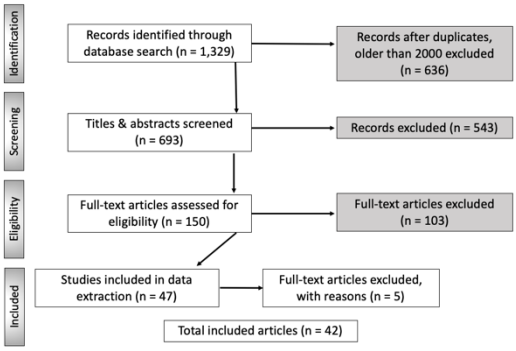

Figure 1: PRISMA Flow diagram for study selection

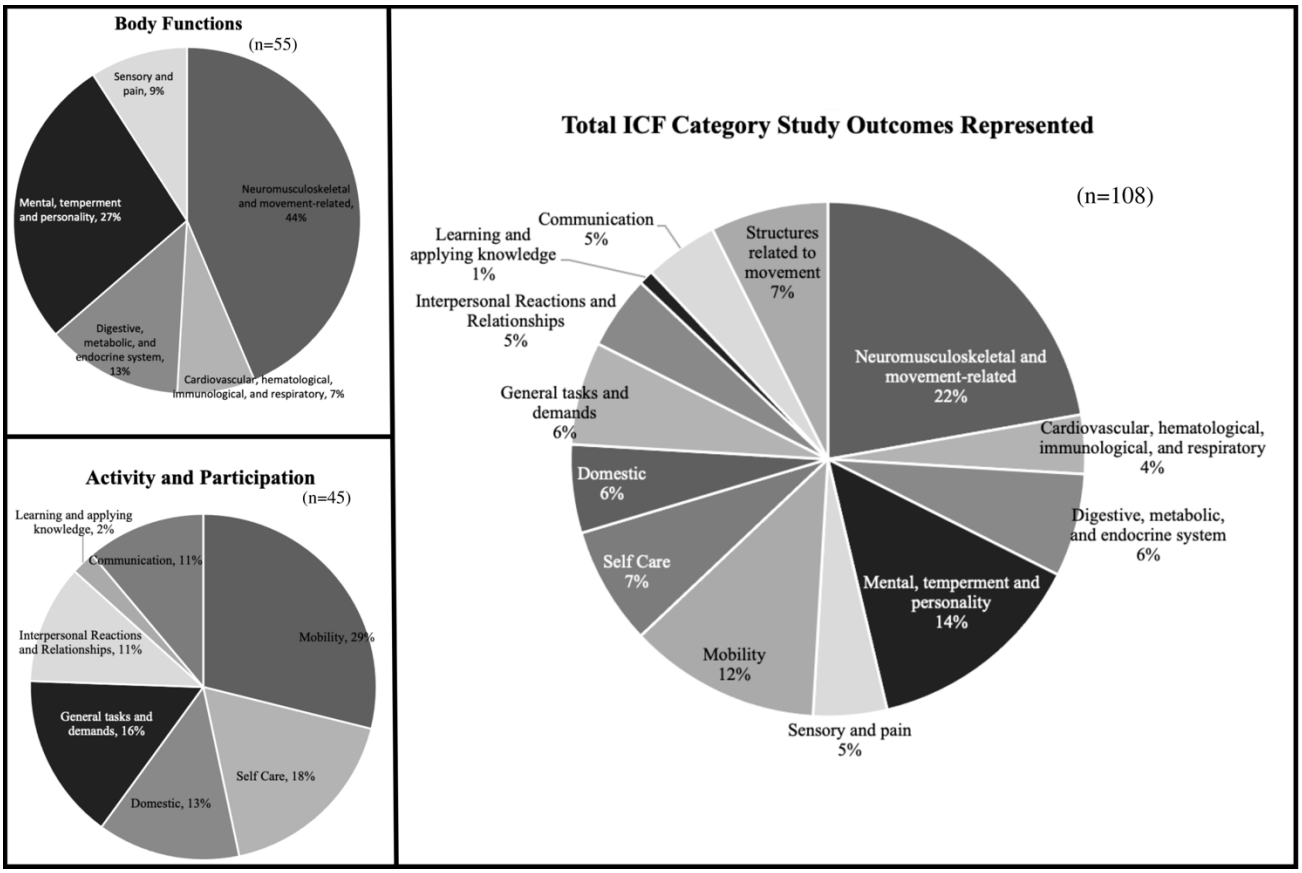

Figure 2: ICF Categories Represented in Study Outcomes by Percentage

Table 1: Studies with Pediatric Subjects

Author(s) (year), country	**Number of subjects, Primary diagnosis**	**Type of supported standing device(s)**	**Recommended frequency & duration of standing**
Audu & Daly (2017) West Africa	1, Cerebral Palsy	Custom, Upright supine	5 x week for 8 weeks
Bayley et al.(2020) Australia	14 adolescents and parents	Standing PWC	60 min, 7days/week for 16 weeks
Cankaya et al. (2017) Turkey	25, Spina Bifida	Standing frame	2 hours, 5 days/week for 8 weeks
Capati et al. (2020) United States	1, Cerebral Palsy	Supine stander	90 min, 5 days/week for 15 months
Caulton et al. (2004) United Kingdom	26, Cerebral Palsy	Standing frame	PT designated for 9 months
Damcott et al. (2013) United States	14, Cerebral Palsy	Commercial standing frame	30 min, 5 days/week for 15 months
Flodin (2007) Sweden	1, SMA Type 2	Standing frame with modifications	Progressively increased
Gibson et al. (2009) South Australia	5, Cerebral Palsy	Standing frame	1 hour, 5 days/week for 6 weeks
Goodwin et al. (2017) United Kingdom	91, Parents of children with Cerebral Palsy 460, Health care providers	Standing frame	30-60min, 7 days/week
Goodwin et al. (2019) United Kingdom	5, Cerebral Palsy & support team	Standing frames	Not described
Gudjonsdottir & Mercer (2002) United States	4, Cerebral Palsy	Static and Dynamic Standers	30 min, 5 days/week for 8 weeks
Herman et al. (2007) United States	19, spastic quadriplegia	Standing frame and Tilt table stander	30 min, 3-6 times/week for 2 weeks
Kecskemethy et al. (2008) United States	20, quadriplegic Cerebral Palsy	Standing frame	30 min, 6 times/week for 8 weeks
Macias-Merlo et al. (2015) Spain	13, spastic diplegic Cerebral Palsy	Custom standing frame with hip abduction	80 min, 5 days/week from 12-14months to 5 years of age
Macias-Merlo et al. (2016) Spain	26, spastic diplegic Cerebral Palsy	Custom standing frame with hip abduction	80 min, 5 days/week from 12-14months to 5 years of age
Martinsson & Himmelmann (2011) Sweden	97, Cerebral Palsy	Standing frame	1.5 hours, 5 days/week for 1 year
Rivi et al. (2014)	1, Cerebral Palsy	Standing frame	30 min, 5 days/week for 4 weeks
Schofield et al. (2020)	38, DMD and clinicians	Standing PWC	60 min, 5 days/week
Townsend et al. (2016)	4, Duchenne Muscular Dystrophy	Standing PWC	3.3 hours, 5 days/week for 6-12 months
Vorster et al. (2019)	12, Duchenne Muscular Dystrophy	Standing PWC	Variable, person-initiated
Wort et al. (2013)	536, Cerebral Palsy	Standing frame	Not described

Note: SMA = Spinal Muscular Atrophy; DMD = Duchenne Muscular Dystrophy; PWC = power wheelchair

Table 2: Studies with Adult Subjects

Author(s) (year), country	Number of subjects, Primary diagnosis	Type of supported standing device(s)	Recommended frequency & duration of standing
Allison & Dennett (2007) United Kingdom	17, CVA	Upright stander	45 min, 5 days/week
Bagley et al. (2005) United Kingdom	167, CVA	Upright standing frame	26 mins x 7 days/week For 2 weeks
Baker et al. (2007) United Kingdom	6, Multiple Sclerosis	Upright standing frame	30 mins x 7 days/week for 3 weeks
Bernhardt et al. (2012) United States	12, paraplegia, Spinal Cord Injury	Standing frame	5 minutes, 1 time
Braun et al. (2016) Switzerland	28, CVA	Standing Frame (control group)	30 min, 3-5x/week 5 weeks
Collins et al. (2010) United States	170, Spinal Cord Injury	Not described	Not described
Dennett et al. (2020) United Kingdom	12, Multiple Sclerosis	Standing frame	Not described
Faghri et al. (2001) United States	14, Spinal Cord Injury	Standing frame	30 min, twice at least 24 hours apart
Ferrarello et al. (2015) Italy	75, CVA	STANDY standing frame	20min, 5 days/week for 3 weeks
Freeman et al. (2019) United Kingdom	140, Multiple Sclerosis	Standing frame	30 min, 3 times/week for 20 weeks
Gillespie et al. (2019) United States	1, CVA	Standing frame	380 min total standing over 18 days
Hendrie et al. (2015) United Kingdom	9, Multiple Sclerosis	Standing frame	30 min, 3 days/ week for 36 weeks
Hoenig et al. (2001) United States	1, paraplegia, Spinal Cord Injury	Standing frame	1 hour, 3-5 days/week
Krewer et al. (2015) Germany	50, vegetative or minimally conscious states	Tilt table	3-4 times a week for 3 weeks
Kyriakides et al. (2019) United Kingdom	40, Spinal Cord Injury	Standing frame	Not described
Lee et al. (2019) Korea	60, CVA	Supine Stander Standing frame	40 min, 7 days/week for 3 weeks
Nordström et al. (2013)	319, congenital, acquired, and other diagnoses	Multiple	None; most respondents stood 15-30 or 30-60min, 1 or more time/day
Nordström et al. (2013b) Sweden	15, progressive & non-progressive diagnoses	Tilt table Standing frame Standing wheelchair	Not described
Nordström et al. (2014)	284, congenital, acquired, and other diagnoses	Multiple	Not described
Riek et al. (2008)	5, Spinal Cord Injury	Custom standing frame	1 session
Shields & Dudley-Javoroski (2005)	1, Spinal Cord Injury	Standing WC	20 min, 5 days/week for 104 weeks

Note: CVA = Cerebral Vascular Accident

ICF Domain: Body Functions

Neuromuscular and Movement Related Functions

Research studies (n=24) in this ICF category focused on measuring supported standing's impact on specific components of body functions in the neuromuscular and movement related category including range of motion, posture and positioning, muscle spasms, spasticity, and muscle tone, and balance for adults, adolescents, and children. Age (and size) did not appear to matter to standing position and weight bearing, as studies with adult and children participants found that they bore approximately 75% of their weight through their lower extremities while in a standing frame.[19-21] Although type of standing device used may matter, as lower extremity weight bearing decreased for children using a tilt table or supine stander supported standing devices.[20,21]

Weight bearing through the lower extremities with an upright trunk in a supported standing position may influence the neuromuscular and movement related body functions positively. Hip and ankle range of motion was statistically significantly improved in supported standing over 'usual care' for adults with multiple sclerosis.[10,22] For children and adolescents, range of motion improved in the hip joints with supported standing programs[23-27] and knee extension,[24] although not consistently.[25] Frequently, reducing risk of joint contractures was a reported reason for engaging children in supported standing.[28] However, the benefits of supported standing are not limited to the lower extremities or children, as the standing posture improves shoulder joint positioning when compared to sitting rest posture, weight-relief raises, transfers and standing depression lifts[29] which supports overall upper body movement.[30] When lower extremity sensation is present, the effects of supported standing can be felt in muscles and muscle groups in adults.[30-32] Furthermore, the measurable impact on spasticity described differences contributing to statistically insignificant improvements in adults when measured by the Modified Ashworth Scale[22,33,34] and in a child with cerebral palsy measured with the Tardieu Scale.[23] Accordingly, meaningful reports of lowered muscle spasms were reported by supported standing participants anecdotally[30,35,36] and with statistically insignificant changes on the Penn Spasm Frequency Scale.[22]

In people with ambulatory disabilities, balance is often compromised. Many studies have focused on the impact of supported standing on balance in adults, specifically with populations of people recovering from an acute CVA[33,37,38] and living with multiple sclerosis.[10,39] For acute recovery from stroke, supported standing program length and/or intensity may matter. Allison et al.[37] participants scored statistically significantly higher on balance measures after 12 weeks of standing than controls receiving only conventional physical therapy. Three week programs demonstrated less conclusive results, with only statistically significant improvement in Functional Ambulation Category scores.[33,38] Although, Ferrarello et al.[33] reported they may not have had enough participants for statistical power, which may be substantiated as shown in Lee et al.[40] in which adults post-acute CVA statistically significantly improved their anterior-posterior and medial-lateral postural stability with and without concurrent functional electrical stimulation after a three week supported standing program (although each study also used different outcome measures). Longer supported standing programs (36 weeks and 20 weeks, respectively) for people with multiple sclerosis resulted in statistically significant changes in balance as well.[39,10] Similar to adults, a study with pediatrics and adolescents engaged in an 8-week standing program demonstrated statistically significant differences on multiple measures of motor function when compared to a control group.[41]

Functions of the cardiovascular, hematological, immunological, and respiratory systems

The function of cardiovascular and hematological systems were largely measured through heart rate and blood pressure assessment in two studies on people with spinal cord injury. Although heart rate is an autonomic function, factors such as the person's activity level, disability or injury type, and length since injury impacted its function. People with paraplegia who regularly stood in frames were likely to experience better heart rate variability when supine and sitting, hypothesized due to the postural changes between sitting and standing.[42] When standing in a frame, heart rate initially increased, although stroke volume and cardiac output decreased during the 30-minute standing duration.[43] The addition of FES while standing stabilized heart rate factors further.[43] Similarly, when moving from sit to stand, the blood pressure of people with complete spinal cord injury tended to decrease 7-9%, a statistically significant amount; although, this effect was mediated by the addition of functional electric stimulation during the transition and while standing.[43] Supporting the objective data, survey respondents ranked "improves circulation" (p. 350) first, when asked why they stand.[31]

Regarding the respiratory system, parents of children with Cerebral Palsy reported that the supported standing position improved their children's breathing.[28]

Functions of the digestive, metabolic, and endocrine systems

In the research, studies (n=7) focus on the interaction of standing with the metabolic system, and its role within the digestive process. Overall, energy expenditure in activities of daily living is lower in people with spinal cord injury than for adults without a disability. People with incomplete spinal cord injury found that static supported standing expended 1.17 metabolic equivalents (MET), as measured after participating for at least 5 minutes. [45] Static standing expended more energy than the person did while lying down at rest. [45]

The metabolic system influences the digestive system, as does the postural changes when moving from sitting to and from standing. Studies examined the influence of supported standing on the ease of which bowel movements were performed, as well as frequency and occurrence of constipation, a common comorbidity of individuals with neurological disorders. However, frequency of bowel movements in adults showed very little change during and following supported standing, although participants reported more control over their elimination.[39,46] Perhaps more notable, when engaging in supported standing bowel movements occurred more spontaneously[25,30,39,46] and with greater ease and less discomfort.[25,46,47] Similarly, parents (57%) reported that with supported standing, overall bladder and bowel function improved in children with cerebral palsy.[28]

Mental Functions

Cognition, from the state of being aware to executing complex functions, can be modified by supported standing in studies (n=15) as well. Using power wheelchair standing systems, cognitive function was an important component for people who chose to engage in supported standing, to learn the operation of safe power wheelchair use, and communicate concerns.[12] For people with the foundational cognitive skills, use of a power wheelchair standing device was associated with decreased hyperactivity[24] and increased independent activity initiation, which supports the development of planning and sequencing abilities, as well as other executive functions.[32,48,49] In contrast, static standing frames required caregivers to plan and facilitate activities for children when standing.[50] At lower stages of cognitive function, recovery may be stimulated for adults in a vegetative or minimally conscious state by using a tilt table for

repositioning and providing low-level sensory input, perhaps even more than supported standing with greater sensory input using a tilt table with a robotic integrated stepping device.[34] Similarly, in acute care when recovering from a stroke, participants who participated in supported standing programs improved their cognitive status at a statistically significant level as measured by the Mini-Mental Status Examination and Functional Independence Measure (FIM).[40,51] For non-verbal and non-ambulatory children with cerebral palsy, the experience of standing in a static or dynamic (but not independently driven) stander appeared positive by behavior, but the children demonstrated no to small differences by formal assessment on level of arousal, reactivity, goal directedness, or attention span directly after a 20-minute standing session.[52]

The brain directs a person's temperament and personality, agreeableness to activities as well as energy and motivation; all of which are subsets of the "mental functions" category within ICF body functions. Assessment measures of mood, emotion, and behavior found improvements after participation in supported standing in various devices,[24] supported by interview and questionnaire data.[28,30,31,39,44,48-50] Themes within the interview data varied slightly based on the type of standing device. In static standing devices, adults reported feeling more "normal" in their standing device, [30,39,44] although educators' views differed and conveyed that supported standing in the device could be distracting or isolating to others.[50] Participants who used wheelchair based standing systems reported more on the device's impact on their autonomy and independence.[24,48,49]

Sensory Functions and Pain

Overall sensory function was not addressed in the included studies, but pain has been studied (n=5) using the visual analog scale. People with complex disabilities or injuries often experience pain on a frequent basis, which likely is not associated with supported standing.[24] Standing in a device may initiate low back, leg, or foot pain, but not to the extent that it impacts engagement.[24,30,39] It is important to consider that the type of standing device may impact the onset of and management of pain, whether experienced prior to or concurrent with supported standing. People using power wheelchair standing systems were able to independently adjust their posture, either to reduce the impact of weight-bearing for a moment or alternatively to stretch tight muscles, both with positive results reported.[24,49] Furthermore, although lower extremity or back pain during and after standing is the most obvious measurement to obtain, evidence also suggested that engagement in consistent supported standing decreased pain with bowel movements.[25]

ICF Domain: Activities and Participation

Mobility

Mobility was represented in 13 studies. Pre-existing mobility status of the participants was often a consideration for participation in standing programs. Yet, it was not always as clearly defined as "ambulatory or non-ambulatory".[12] For individuals who use supported standing devices, lifting and carrying objects and moving around using equipment (often wheelchairs) were examined in research using standardized measures such as the Berg Balance Scale, Functional Ambulation Categories, Amended Motor Club Assessment, as well as person and caregiver self-reports. In acute care or inpatient rehab settings, supported standing programs aim to facilitate remediation of lower extremity function toward ambulation.[33,38,40,51] In addition to reports above (in the neuromuscular body function section) on the use of voluntary muscle control to balance, a supported standing program was thought to aid recovery from an acute

CVA improving total assist status to moderate assist for transfers, and minimal assist for wheelchair mobility.[51] Parents similarly felt that supported standing would prepare their child for acquiring developmental milestones related to trunk, head, and upper extremity control, standing, and walking,[28] a result of consistently applied weight bearing through the lower extremities for a period of time.[20]

The direct impact of supported standing on mobility in the home environment may be dependent on the type of standing device. A child's mobility assessment demonstrated improvements in moving around and lifting items after participating in a supported standing program.[23]

In interviews, a program using a static standing frame was described to improve transfer status, standing balance, and decrease falls,[30,35] although the impact on falls may not be a lasting effect, when assessed by objective measure.[10] In contrast, wheelchair based standing devices were shown to facilitate the sit to and from stand position throughout the day, and support access to the vertical environment, a key component of lifting and carrying. A data logger on a manual wheelchair with a standing system revealed 238 bouts (1 minute or longer) of standing in a five month period, regularly exceeding 20 minutes a day; although this particular device was reported to be difficult to maneuver, especially in the community.[36] Adolescents who used power wheelchair standing devices reported they were able to reach and carry items themselves, such as in the library at school, and perform tasks with greater independence in their home and community environments.[12,49]

Self-care

Overall, small improvements in independence with self-care were noted after participation in a supported standing program (n=8). Participants who engaged in supported standing in inpatient or subacute rehab when recovering from a CVA were observed to improve their self-care scores on the FIM and Modified Barthel Index,[38,40,51] consistent with Wee-FIM scores for children who stood supported for 12 weeks.[41] Additionally, participants reported improvements in self-care, including bathing, dressing, grooming (i.e. brushing teeth and hair), and toileting.[26,35,49,53]

Domestic

Engagement in domestic tasks were examined (n=6). Using static supported standing devices, participants reported more strength gains as a result of standing in upper extremities and trunk that allowed them to participate in household tasks seated in their MWC, although static activities (eg. chopping vegetables) were performed while standing in the frame as well.[39] Standing options on wheelchairs enabled increased independence with home management, including remodeling, meal preparation, reaching for items and putting them away.[36,49,53] Furthermore, the domestic task of caregiving for children with Cerebral Palsy, including managing bowel programs, dressing, and bathing, was reported to be easier when the child engaged in static standing.[25,46]

General Tasks and Demands

Studies (n=7) reveal that people use supported standing to perform activities they uniquely desire to participate in outside of self-care and domestic tasks, and that standing may also contribute to the person's ability to organize their routine and handle stress. Parents appreciated their child's engagement in activities when using a standing frame.[28] In a supported

standing position, participants engaged in many activities, such as dart-throwing, decorating and arranging flowers, playing fetch with their dog, and shopping in the community.[31,35,36,53] Similar to domestic tasks, when using a wheelchair mounted standing system people performed dynamic tasks and described independence with tasks from setup through completion, whereas static standing devices were related more to participation in an actual task. For adolescents, independence improved with science lab and art class tasks at school when using a power wheelchair standing system, and specifically when collecting needed equipment such as library books.[49] Studies reveal that adolescents using power wheelchair standing systems also reflected on improved mental health.[24]

Interpersonal Reactions and Relationships/ Communication/ Learning and Applying Knowledge

Supported standing programs involvement in interpersonal relationships, communication, and learning, emerged largely from interview data (n=11, with one study represented in all three areas, and one in two). Interpersonal reactions and relationships were reflected upon by adult participants with multiple sclerosis, who reported decreased participation in activities, feelings of responsibility for their parental role, and resulting guilt from their altered involvement, that revolved around their relationship roles due to their disability.[35] The usage of the supportive standing made the participants feel as if they had greater impact and an active role in their lives.[35] In rehabilitation, a participant who engaged in supported standing improved their comprehension and expression scores by one point during their stay.[51] Separately, these feelings were not substantiated by people recovering from a CVA who utilized a standing frame for two weeks or their caregivers by assessment.[54]

The impact of supported standing on communication and learning was more often addressed in pediatric and adolescent studies, although peer relations were described as well. Power wheelchair standing system use was associated with decreased hyperactivity and improved peer and caregiver relations.[24,49] For nonverbal children and those with Cerebral Palsy, communication improved in static standing frames as the standing posture enabled eye contact, peer interaction, and increased communication and vocalizations.[25,28,52]

ICF Domain: Body Structures

Structures Related to Movement

Lower extremity body structures have been studied (n=8), showing evidence that supported standing positively impacts bone health. In children with Cerebral Palsy, participation in supported standing programs over early childhood years has shown to reduce the percentage of hip migration experienced, with or without other intervention such as surgery.[55,56] Similarly, pediatrics may be more at risk for fractures if they do not participate in a supported standing program.[57] These results are supported by clinician and parent reports.[28] This may be related to weight-bearing impact on stressing the bone, which may improve bone mineral density; although, this metric may depend on the location for which the BMD measurement is observed. Lumbar BMD in adolescents with DMD maintained or decreased with supported standing intervention over 6-12 months,[53] but maintained or improved in children with cerebral palsy, especially when the standing time increased over the intervention period.[52,58] Lower extremity BMD was examined more often, although various components of BMD were measured. In children with cerebral palsy, the results of lower extremity BMD tests were inconsistent, maintaining or improving BMD minimally during supported standing programs.[52,58,59]

Discussion

Overall, the results largely focused on measuring functional outcomes related to body functions and activities and participation. The contrast between the amount of body function and activity and participation outcomes related to the body structures is expected, as rehabilitation and restorative program outcomes predominantly focus on functional outcomes (changes in the way the body moves, thinks, and does), rather than diagnosing or measuring direct impact on body structures themselves.

The studies utilized a variety of populations and outcome measures. Most pediatric studies focused on children with Cerebral Palsy, while the majority of adult studies utilized populations of people with Spinal Cord Injury. Outcomes were greatest in number in the neuromuscular function subdomain, a logical domain to examine the effects of supported standing, and the measuring devices utilized were mostly established and commonly used assessments. Yet, systems for assessing outcomes related to muscle tone and spasms may benefit from more objective and sensitive measures, as measurement method may have contributed to differences that did not achieve the statical significant improvements in this area [22,23,33,34] as other studies have reported statistically significant results.[1,60] Similarly, in the related subdomain of digestive function, greater use of objective and systematic measures during the intervention and also during a baseline period prior to the intervention period, may evaluate the impact of supported standing more succinctly.

Represented ICF categories were expected, with one major exception: the body function related to functions of the skin and related structures. Although the impact of standing on the hematological system indirectly addressed skin integrity,[31,43] it was not directly measured. However, related literature reports that people with ambulatory disabilities, supported standing is related to decreased pressure injuries[60-62] and temperature reductions in the skin.[63] Furthermore, the supported standing position has been identified as the only pressure relief position which reduces load at both the seat and back at the same time.[64] This oversight appears to be related to search term usage, as we did not directly explore pressure injuries or skin integrity related to wheelchair use, and primarily focused on search terms related to supported standing devices.

Type of supported standing device and ICF outcomes

The overall impact of the supported standing device is important to explore further, as health care funding varies and may only cover one type of standing device, or nothing at all. In this review, the type of supported standing device utilized in the study impacted the research and clinical outcomes in various ways. Supported standing devices such as upright standers, standing frames, supine standers, and tilt tables, as well as dynamic standing devices such as power wheelchairs with standing systems, were represented in the reviewed studies. The results revealed that all types of devices supported an improved health or function, and positively impacted the person's medical status; however, with similarities and differences. For example, the cognitive measures revealed the benefit from engagement in supported standing, but different devices were appropriate for different populations. People with low level cognitive states benefited from supported standing in tilt table or static standing frames, which improved global awareness,[34] while people with higher level cognitive skills utilized dynamic supported standing devices, allowing them to execute tasks from the planning and set-up through completion and clean-up.[32,48,49]

Comparing and contrasting the devices' impact on activities and participation, both types of supported standing devices positively impacted task participation. People in supported

standing devices engaged in activities and found meaning in their participation.[30,35] Yet, dynamic supported standing devices provided a platform for the study participants to engage fully with less external assistance and also at the same level as peers, without further environmental modifications.[36,49,53] The contribution of powered, dynamic supported standing devices to facilitate task performance under the activities and participation domain of the ICF continues to be emphasized in current research.[65]

The increased environmental accessibility with dynamic supported standing devices also impacted health in a variety of ways. In literature, supported standing is considered 'exercise' for a pediatric or adult wheelchair user [66-68]; however, with lower metabolic expenditure than an ambulatory person may experience.[45] Engaging in functional activities while standing has potential to exponentiate the wheelchair user's metabolic expenditure.[45] Furthermore, the dynamic device allowed them to control their position as sitting or standing. This is important in activity engagement, but also the frequent transitions between sitting and standing are considered to impact bone health more than prolonged, but less frequent, standing.[69] If the person is appropriate for a dynamic supported standing device, the research shows that performance and participation in daily tasks are likely to improve as a result of having control over their standing movement, instead of statically standing.

Healthcare funding sources should consider these outcomes when examining policy and coverage, as the unique device characteristics relate directly to utilization. The person's individual context, their abilities and preferences, available storage space, and financial situation should be factors in the choice,[28,70] and a wide variety of device options should be available through healthcare funding sources to accommodate various situations.

Standing Dosage

The amount of standing time, or dosage, required to impact physical and psychosocial well-being will be dependent on the individual's personal context, including their medical status, environment, standing device, and more. The evidence supports initial engagement in supported standing as close to the initial need as possible. From the developmental stage of weight bearing at 9 months (adjusted age), clinical practice guideline recommendations report in favor of supported standing for infants and children with or at high risk for Cerebral Palsy.[11,71,72] For acquired conditions, supported standing programs may more effectively achieve results if implemented early in recovery.[73] When implementing a supported standing program for people who have not stood for a period of time, an accommodation stage may be required, titled by Townsend et al.[53] as a "safety and tolerability trial" (p. 4) in which the person slowly builds their tolerance for standing and determines if a standing program is a feasible option. Accommodation periods are very appropriate to explore, should be communicated about with the patient, and ideally built into the clinical process when matching a person with a home standing device.

Recommended standing dosage for effecting body functions varies for range of motion, muscle tone and spasms, and balance. Studies on adults have shown changes in lower extremity range of motion when standing 30 minutes, three times a week,[10,22] while in pediatric studies, children stood three to five times a week for 60 to 90 minutes per day.[23-27] Changes in muscle tone or spasms appeared to require more frequent standing, at least thirty minutes a day for five to seven days a week;[22,23,33,34] while balance changes occurred with standing dosages in between those for range of motion and muscle tone.[10,33,37,38-40] While many of these studies recommended daily supporting standing durations, many broke the standing time up between two or more sessions within the day. These results add to previous systematic reviews on supported standing,

where pediatric supported standing 30 to 90 minutes a day was recommended to impact neuromuscular body functions[8] and adult supported standing 30 to 60 minutes a day was recommended for activities of daily living participation and body functions.[9]

For activities and participation, positive outcomes may occur with less standing duration. Additionally, frequency of standing may rise while duration may decrease with dynamic standing devices.[36]

Precautions

The population of people who use supported standing devices should be aware of potential risks to standing, although actual occurrences of incidences in the reviewed studies were rare. Dicianno et al.[2] reported precautions of orthostatic hypotension and fracture risk for people with poor bone health. Additionally, the person should be assessed for standing tolerance prior to trial in a supported standing device. This should consider joint mobility, to ensure that the person can accommodate an upright or nearly upright position, in both their lower extremities and trunk, to ensure that the stander can accommodate unique positioning needs.[2] Skin integrity should be examined prior to performing the sit to stand motion, to reduce risk of shearing.[2]

Limitations

This study presents potential limitations. The search terms and inclusion criteria used to recruit articles may have unintentionally excluded desired articles, such as those regarding pressure injuries and the integumentary body structure. Articles written in only the English language may have limited important international studies. Similarly, selection bias during the title and abstract and full article reviews may have limited the articles included. Some of the included studies lacked methods inhibiting generalizability, for example, the inclusion of four pediatric and three adult case studies. Future studies should include detail on the type of stander utilized, the standing position, and measure amount of weight bearing through all support surfaces including the feet.

Summary

Supported standing programs contribute to the health and wellness of people who are unable to or have difficulty ambulating, impacting their body functions and structures as well as their activities and participation. Examining dosage across the studies indicated that the best outcomes were met with frequent standing, and that the supported standing device must fit the person's body, daily routine, home, and community environments to ensure that they can maximize use without undue reliance on others. Supported standing programs are an evidence-based strategy to support prevention of comorbidities accrued from prolonged sitting.[3] The use of supported standing devices is well established in the literature and should no longer be considered experimental or a convenience. Third party payors should fund supported standing devices that are and are not incorporated into a mobility device, to ensure access to appropriate supported standing equipment that is specific to the beneficiary's needs.

References

1. Arva J, Paleg G, Lange M, et al. RESNA position on the application of wheelchair standing devices. *Assist Technol*. 2009;21(3):161-171. doi:10.1080/10400430903175622
2. DiCianno BE, Morgan A, Lieberman J, Rosen L. RESNA position on the application of

wheelchair standing devices: 2013 current state of the literature. Resna.org. Published December 23, 2013. https://www.resna.org/Portals/0/Documents/Position%20Papers/RESNAStandingPositionPaper_Dec2013.pdf.
3. LaBerge NB, Detterbeck A, Nooijen CFJ. Comorbidities and medical complexities of mobility device users: a retrospective study. *Disabil Rehabil Assist Technol*. 2021;Sep 2:1-8
4. Craig J, Hilderman C, Wilson G, Misovic R. Effectiveness of stretch interventions for chilidren with neuromuscular disabilities: evidence-based recommendations. *Pediatr Phys Ther*. 2016;28:262-275. doi: 10.1097/PEP.0000000000000269
5. Glickman LB, Geigle PR, Paleg GS. A systematic review of supported standing programs. *J Pediatr Rehabil Med*. 2010;3(3):197-213. doi: 10.3233/PRM-2010-0129
6. Masselink CE, LaBerge N, Detterbeck A. Policy analysis on power standing systems. *Prev Med Rep*. 2021;24:101601. Published 2021 Oct 12. doi:10.1016/j.pmedr.2021.101601
7. Newman M, Barker K. The effect of supported standing in adults with upper motor neurone disorders: a systematic review. *Clin Rehabil*. 2012;26(12):1059-1077. doi:10.1177/0269215512443373
8. Paleg GS, Smith BA, Glickman LB. Systematic review and evidence-based clinical recommendations for dosing of pediatric supported standing programs. *Pediatr Phys Ther*. 2013;25:232-247.
9. Paleg G, Livingstone R. Systematic review and clinical recommendations for dosage of supported home-based standing programs for adults with stroke, spinal cord injury and other neurological conditions. *BMC Musculoskelet Disord.* 2015;16:358. doi:10.1186/s12891-015-0813-x
10. Freeman J, Hendrie W, Jarrett L, et al. Assessment of a home-based standing frame programme in people with progressive multiple sclerosis (SUMS): a pragmatic, multi-centre, randomised, controlled trial and cost-effectiveness analysis. *Lancet Neurol*. 2019;18(8):736-747. doi:10.1016/S1474-4422(19)30190-5
11. Morgan C, Fetters L, Adde L, et al. Early Intervention for Children Aged 0 to 2 Years With or at High Risk of Cerebral Palsy: International Clinical Practice Guideline Based on Systematic Reviews. *JAMA Pediatr*. 2021;175(8):846-858. doi:10.1001/jamapediatrics.2021.0878
12. Schofield C, Evans K, Young H, et al. The development of a consensus statement for the prescription of powered wheelchair standing devices in duchenne muscular dystrophy. *Disabil Rehabil*. 2022;44(10):1889-1897. doi:10.1080/09638288.2020.1810786
13. Spinal Cord Injury Centre Physiotherapy Lead Clinicians. Clinical guidelines for adults following spinal cord injury. 2019. Published October 1, 2019. Retrieved October 12, 2022. https://www.mascip.co.uk/wp-content/uploads/2020/09/SCI-Standing-Clinical-Guidelines-Report-2019.pdf
14. World Health Organization. The international classification of functioning, disability and health (ICF). Published 2001. Accessed January 27, 2022. http://www.who.int/classifications/icf/en/.
15. Center for Disease Control and Prevention. The ICF: an overview. Accessed September 10, 2022. https://www.cdc.gov/nchs/data/icd/icfoverview_finalforwho10sept.pdf.
16. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. *Int J Soc Res Methodol.* 2005;8(1):19-32. Doi:10.1080/1364557032000119616
17. Peters MD, Godfrey CM, Khalil H, McInerney P, Parker D, Soares CB. Guidance for

conducting systematic scoping reviews. *Int J Evid Based Healthc*. 2015;13(3):141-146. doi:10.1097/XEB.0000000000000050
18. Choukou MA, Best KL, Potvin-Gilbert M, et al. Scoping review of propelling aids for manual wheelchairs. *Assist Technol*. 2021;33(2):72-86. doi:10.1080/10400435.2019.1595789
19. Bernhardt KA, Beck LA, Lamb JL, Kaufman KR, Amin S, Wuermser LA. Weight bearing through lower limbs in a standing frame with and without arm support and low-magnitude whole-body vibration in men and women with complete motor paraplegia. *Am J Phys Med Rehabil*. 2012;91(4):300-308. doi:10.1097/PHM.0b013e31824aab03
20. Herman D, May R, Vogel L, Johnson J, Henderson RC. Quantifying weight-bearing by children with cerebral palsy while in passive standers. *Pediatr Phys Ther*. 2007;19(4):283-287. doi:10.1097/PEP.0b013e318156cc4d
21. Kecskemethy HH, Herman D, May R, Paul K, Bachrach SJ, Henderson RC. Quantifying weight bearing while in passive standers and a comparison of standers. *Dev Med Child Neurol*. 2008;50(7):520-523. doi:10.1111/j.1469-8749.2008.03021.x
22. Baker K, Cassidy E, Rone-Adams S. Therapeutic standing for people with multiple sclerosis: Efficacy and feasibility. *Int J Ther Rehabil.* 2007;14(3):104-109. doi:10.12968/ijtr.2007.14.3.23523
23. Audu O, Daly C. Standing activity intervention and motor function in a young child with cerebral palsy: A case report. *Physiother Theory Pract*. 2017;33(2):162-172. doi:10.1080/09593985.2016.1265621
24. Bayley K, Parkinson S, Jacoby P, et al. Benefits of powered standing wheelchair devices for adolescents with Duchenne muscular dystrophy in the first year of use. *J Paediatr Child Health*. 2020;56(9):1419-1425. doi:10.1111/jpc.14963
25. Capati V, Covert SY, Paleg G. Stander Use for an Adolescent with Cerebral Palsy at GMFCS Level with Hip and Knee Contractures. *Assist Technol*. 2020;32(6):335-341. doi:10.1080/10400435.2019.1579268
26. Gibson SK, Sprod JA, Maher CA. The use of standing frames for contracture management for nonmobile children with cerebral palsy. *Int J Rehabil Res*. 2009;32(4):316-323. doi:10.1097/MRR.0b013e32831e4501
27. Macias-Merlo L, Bagur-Calafat C, Girabent-Farres M, Stuberg WA. Standing programs to promote hip flexibility in children with spastic diplegic cerebral palsy. *Pediatr Phys Ther*. 2015;00:1-7. doi:10.1097/PEP.0000000000000150
28. Goodwin J, Colver A, Basu A, et al. Understanding frames: A UK survey of parents and professionals regarding the use of standing frames for children with cerebral palsy. *Child Care Health Dev*. 2017;44(2):195-202. doi:10.1111/cch.12505
29. Riek LM, Ludewig PM, Nawoczenski DA. Comparative shoulder kinematics during free standing, standing depression lifts and daily functional activities in persons with paraplegia: considerations for shoulder health. *Spinal Cord*. 2008;46(5):335-343. doi:10.1038/sj.sc.3102140
30. Dennett R, Hendrie W, Jarrett L, et al. "I'm in a very good frame of mind": a qualitative exploration of the experience of standing frame use in people with progressive multiple sclerosis. *BMJ Open*. 2020;10(10). doi:10.1136/bmjopen-2020-037680
31. Nordström B, Näslund A, Eriksson M, Nyberg L, Ekenberg L. The impact of supported standing on well-being and quality of life. *Physiother Can*. 2013;65(4):344-352. doi:10.3138/ptc.2012-27
32. Nordström B, Nyberg L, Ekenberg L, Näslund A. The psychosocial impact on standing

devices. *Disabil Rehabil Assist Technol.* 2014;9(4), 299-306. doi: 10.3109/17483107.2013.807443
33. Ferrarello F, Deluca G, Pizzi A, et al. Passive standing as an adjunct rehabilitation intervention after stroke: a randomized controlled trial. *Arch Physiother*. 2015;5(2). doi:10.1186/s40945-015-0002-0
34. Krewer C, Luther M, Koenig E, Müller F. Tilt table therapies for patients with severe disorders of consciousness: A randomized, controlled trial. *PLoS One*. 2015;10(12). doi:10.1371/journal.pone.0143180
35. Hendrie WA, Watson MJ, McArthur MA. A pilot mixed methods investigation of the use of Oswestry standing frames in the homes of nine people with severe multiple sclerosis. *Disabil Rehabil.* 2015;37(13):1178-1185. doi: 10.3109/09638288.2014.957790
36. Shields RK, Dudley-Javoroski S. Monitoring standing wheelchair use after spinal cord injury: a case report. *Disabil Rehabil*. 2005;27(3):142-146. doi:10.1080/09638280400009337
37. Allison R, Dennett R. Pilot randomized controlled trial to assess the impact of additional supported standing practice on functional ability post stroke. *Clin Rehabil.* 2007;21(7):614-619. Doi:10/1177/0269215507077364
38. Braun T, Marks D, Thiel C, Zietz D, Zutter D, Grüneberg C. Effects of additional, dynamic supported standing practice on functional recovery in patients with sub-acute stroke: a randomized pilot and feasibility trial. *Clin Rehabil*. 2016;30(4):374-382. doi:10.1177/0269215515584801
39. Hendrie WA, Watson MJ, McArthur MA. A pilot mixed methods investigation of the use of Oswestry standing frames in the homes of nine people with severe multiple sclerosis. *Disabil Rehabil*. 2015;37(13):1178-1185. doi:10.3109/09638288.2014.957790
40. Lee JB, Kim SB, Lee KW, Lee JH, Park JG, Lee SJ. Combined therapy with functional electrical stimulation and standing frame in stroke patients. *Ann Rehabil Med*. 2019;43(1):96-105. doi:10.5535/arm.2019.43.1.96
41. Çankaya Ö, Günel MK. Investigating the effects of standing training on body functions and activity for nonambulatory children with myelomeningocele. *Int J Physiother.* 2017;4(1):19-24. doi:10.15621/ijphy/2017/v4i1/136158
42. Kyriakides A, Poulikakos D, Galata A, Konstantinou D, Panagiotopoulos E, Chroni E. The effect of level of injury and physical activity on heart rate variability following spinal cord injury. *J Spinal Cord Med*. 2019;42(2):212-219. doi:10.1080/10790268.2017.1383709
43. Faghri PD, Yount JP, Pesce WJ, Seetharama S, Votto JJ. Circulatory hypokinesis and functional electric stimulation during standing in persons with spinal cord injury. *Arch Phys Med Rehabil*. 2001;82(11):1587-1595. doi:10.1053/apmr.2001.25984
44. Nordström B, Näslund A, Ekenberg L. On equal footing: adults' accounts of the experience of using assistive devices for standing. *Disabil Rehabil Assist Technol*. 2013;8(1):49-57.
45. Collins EG, Gater D, Kiratli J, Butler J, Hanson K, Langbein WE. Energy cost of physical activities in persons with spinal cord injury. *Med Sci Sports Exerc*. 2010;42(4):691-700. doi:10.1249/MSS.0b013e3181bb902f
46. Rivi E, Filippi M, Fornasari E, Mascia MT, Ferrari A, Costi S. Effectiveness of standing frame on constipation in children with cerebral palsy: a single-subject study. *Occup Ther Int*. 2014;21(3):115-123. doi:10.1002/oti.1370
47. Hoenig H, Murphy T, Galbraith J, Zolkewitz M. Case study to evaluate a standing table for managing constipation. *SCI Nurs*. 2001;18(2):74-77.
48. Flodin E. Interactive design – The desire for autonomous upright mobility: A longitudinal

case study. *Technol Disabil.* 2007;19(4):213-224. doi:10.3233/TAD-2007-19407
49. Vorster N, Evans K, Murphy N et al. Powered standing wheelchairs promote independence, health and community involvement in adolescents with Duchenne muscular dystrophy. *Neuromuscl Disord*. 2019;29:221-230.
50. Goodwin J, Lecouturier J, Smith J, et al. Understanding frames: A qualitative exploration of standing frame use for young people with cerebral palsy in educational settings. *Child Care Health Dev*. 2019;45(3):433-439. doi:10.1111/cch.12659
51. Gillespie J, Callender L, Driver S. Usefulness of a standing frame to improve contraversive pushing in a patient post-stroke in inpatient rehabilitation. *Proc (Bayl Univ Med Cent)*. 2019;32(3):440-442. doi:10.1080/08998280.2019.1593763
52. Gudjonsdottir B, Mercer VS. Effects of a dynamic versus a static prone stander on bone mineral density and behavior in four children with severe cerebral palsy. *Pediatr Phys Ther*. 2002;14(1):38-46.
53. Townsend EL, Bibeau C, Holmes TM. Supported standing in boys with duchenne muscular dystrophy. *Pediatr Phys Ther*. 2016;28(3):320-329. doi:10.1097/PEP.0000000000000251
54. Bagley P, Hudson M, Forster A, Smith J, Young J. A randomized trial evaluation of the Oswestry Standing Frame for patients after stroke. *Clin Rehabil*. 2005;19(4):354-364. doi:10.1191/0269215505cr874oa
55. Macias-Merlo L, Bagur-Calafat C, Girabent-Farrés M, Stuberg WA. Effects of the standing program with hip abduction on hip acetabular development in children with spastic diplegia cerebral palsy. *Disabil Rehabil.* 2016;38(11):1075-1081. doi:10.3109/09638288.2015.1100221
56. Martinsson C, Himmelmann K. Effect of weight-bearing in abduction and extension on hip stability in children with cerebral palsy. *Pediatr Phys Ther*. 2011;23(2):150-157. doi:10.1097/PEP.0b013e318218efc3
57. Wort UU, Nordmark E, Wagner P, Düppe H, Westbom L. Fractures in children with cerebral palsy: a total population study. *Dev Med Child Neeurol.* 2013;55:821-827. doi:10.1111/dmcn.12178
58. Caulton J, Ward K, Alsop C, Dunn G, Adams J, Mughal M. A randomized controlled trial of standing programme on bone mineral density in non-ambulant children with cerebral palsy. *Arch Dis Child.* 2004;89(2):131-135. doi:10.1136/adc.2002.009316
59. Damcott M, Blochlinger S, Foulds R. Effects of passive versus dynamic loading interventions on bone health in children who are nonambulatory. *Pediatr Phys Ther*. 2013;25(3):248-255. doi:10.1097/PEP.0b013e318299127d
60. Eng JJ, Levins SM, Townson AF, Mah-Jones D, Bremner J, Huston G. Use of prolonged standing for individuals with spinal cord injuries. *Phys Ther.* 2001;81(8):1392-1399.
61. Dunn RB, Walter JS, Lucero Y, et al. Follow-up assessment of standing mobility device users. *Assist Tech*. 1998;10(2):84-93. doi: 10.1080/10400435.1998.10131966
62. Walter SJ, Sola GP, Sacks J, Lucero Y, Langbein E, Weaver F. Indications for a home standing program for individuals with spinal cord injury. *J Spinal Cord Med.* 1999;22(3):152-158. doi: 10.1080/10790268.1999.11719564
63. Cotie LM, Geurts CLM, Adams MME, MacDonald MJ. Leg skin temperature with body-weight-supported treatment and tilt-table standing training after spinal cord injury. *Spinal Cord.* 2011;49:149-153.
64. Sprigle S, Maurer C, Sorenblum SE. Load redistribution in variable position wheelchairs in people with spinal cord injury. *J Spinal Cord Med.* 2010;33(1):58-64. doi:

10.1080/10790268.2010.11689674
65. Gohlke JH & Kenyon LK. Exploring powered wheelchair standing device use in children and adults: a longitudinal case series. *Disabil Rehabil Assist Technol.* 2022. doi: 10.1080/17483107.2022.2120101
66. Antonio TS, Urrutia F, Larrea A, Espín V, Latta MA. Variations in vital signs associated with postural changes when using a stand-up wheelchair in patients with spinal cord injury. *Adv. Intell. Syst.* 2019;794:818-823. Doi:10.1007/978-3-319-94947-5_80
67. Israeli-Mendovic H, Mendlovic J, Katz-Leurer M. Heart rate and heart rate variable parameters at rest, during activity and passive standing among children with Cerebral Palsy GMFCS IV-V. *Dev Neurorehabil.* 2014;17(6): 398-402. doi: 10.3109/17518423.2014.895439
68. Vershuren O, Peterson MD, Leferink S, Darrah J. Muscle activation and energy-requirements for varying postures in childen and adolescents with Cerebral Palsy. *J Pediatr*. 2014;165:1011-6.
69. Gannotti ME, Liquori BM, Thorpe DE, Fuchs RK. Designing Exercise to Improve Bone Health Among Individuals With Cerebral Palsy. *Pediatr Phys Ther*. 2021;33(1):50-56. doi:10.1097/PEP.0000000000000765
70. Peredo DE, Davis BE, Norvell DC, Kelly PC. Medical equipment use in children with disabilities: A descriptive survey. *J Pediatr Rehabil Med*. 2010;3(4):259-267. doi:10.3233/PRM-2010-0138
71. American Academy for Cerebral Palsy and Developmental Medicine. Care Pathway: Central Hypotonia. Accessed October 18, 22. https://www.aacpdm.org/publications/care-pathways/central-hypotonia
72. National Institute for Health and Care Excellence. Spasticity in under 19s: management. Published July 25, 2012. Updated November 12, 2016. Accessed October 18, 2022. https://www.nice.org.uk/guidance/cg145.
73. Abdelrahman S, Ireland A, Winter EM, Purcell M, Coupaud S. Osteoporosis after spinal cord injury: aetiology, effects and therapeutic approaches. *J Musculoskelet Neuronal Interact*. 2021;21(1):26-50.

Appendix A: Search terms

((“supported standing”) OR (“standing wheelchair”) OR (“standing frame”) OR (standing AND “assistive technology”) OR (stander AND (therapy OR “cerebral palsy” OR “muscular dystrophy” OR “spinal muscular atrophy” OR "assistive technology” OR “brain injury” OR “multiple sclerosis” OR “acquired brain”)))