Permobil White Paper

A systematic review of the evidence for power standing wheelchairs

permobil

Why users should have access to a power standing wheelchair

A white paper summarizing the evidence on standing in wheelchair users

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Table of Contents

List of abbreviations

ADL = activities of daily living

BMD = bone mineral density

CP = cerebral palsy

DMD = Duchenne muscular dystrophy

MS = multiple sclerosis

ROM = range of motion

SCI = spinal cord injury

1. Introduction

Power standing

Standing power mobility traditionally has been defined in a multitude of ways: power standing, integrated standing mobility, and power standing mobility are just a few. While there is no definite term to define the combination of power wheelchair base and standing systems in current research, the authors of this white paper will use the term power standing.

Power standing is defined as a system that encompasses the ability for a standing system (consistent of multiple actuators and power seat functions such as tilt, recline, elevating legs, and seat elevate) to be utilized in its full capacity upon a power wheelchair base. This combination of seat functions and power base allow the user to optimally achieve both a seated and standing position within the system, while enabling the user to access his/her environment with the use of mobility.

Background

The health risks of prolonged sitting are widely acknowledged[1]. In the most recent guidelines, people with mobility impairments are recommended to limit the amount of time spent sedentary (sitting or lying down), because an increasing level of evidence shows that replacing sedentary behavior with an activity of any intensity provides health benefits[2]. Studies in different population groups confirm that standing can be considered light activity in people with mobility impairments and is therefore suited to break up long intervals of sitting[3,4,5,6].

Aim of this white paper

To describe why a user should have access to a power standing wheelchair.

Clinical, functional, and psychosocial benefits of power standing are summarized, primarily from evidence identified in a systematic literature review.

Methodology

Systematic literature review

A systematic literature review was performed to identify all the clinical, functional and psychosocial effects of standing. A broad search was performed using PubMed/Medline identifying publications from 2010 and onwards. The PICO framework was used to define the search and used the following key words, for **Population**: wheelchair, disability, handicap, impairment or non-ambulatory; for **Intervention**: stand*, upright, frame, table, stander, power seat, weight-bearing, passive loading, prolonged muscle stretch, long leg braces, standing box; the search was not limited to any **Comparison** or **Outcome**.

As shown in Figure 1, this search identified 363 publications, which were systematically reviewed by title, abstract and full text, after which 41 publications were included. These 41 publications included 21 clinical trials, six reviews, one position paper, five qualitative and eight other studies. Additional relevant studies older than 2010 were included from the reference lists of the identified 41 publications. All references used are provided at the end of each section.

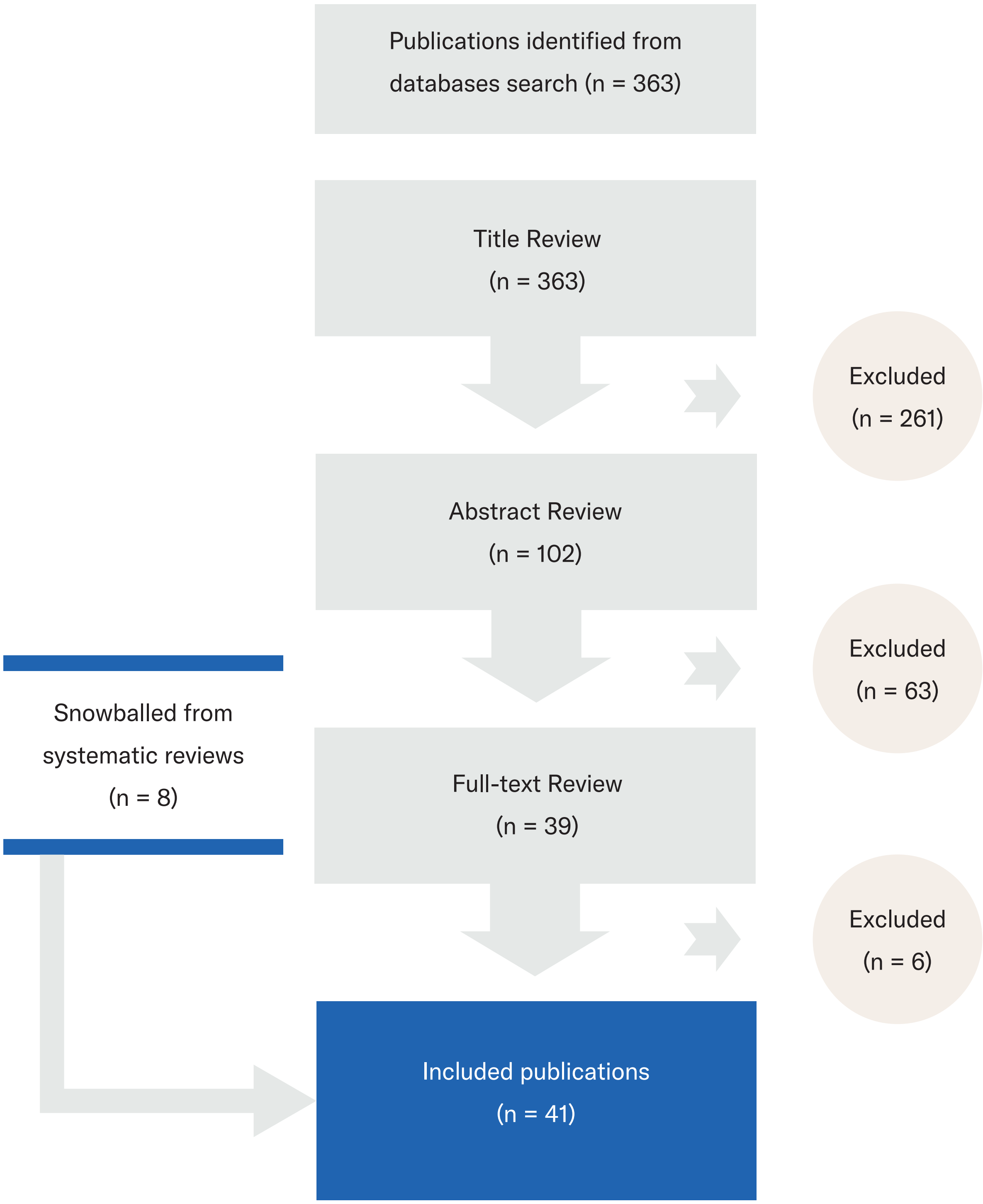

Figure 1. Flowchart of performed systematic review

Permobil Connect data

MyPermobil is an application that connects the user's phone to their power wheelchair and provides the users with information on the status of their battery, the distance they travel, and how often they have been repositioning. If permission is given from the user and after data is de-identified, the data on how the chair is functioning and being used are stored in databases.

This data gives unique device-measured insights from a large group of users worldwide into how Permobil power wheelchair users are using their power seat functions. An analysis on the Permobil Connect data was performed to show how frequent users stand up in their power wheelchair.

Survey

In an internal global Permobil survey performed in December 2020, 120 employees involved in sales and clinical education were asked about their views on users' needs for those using a power standing wheelchair. Results from this survey were added where appropriate to give additional insights.

Anecdotal

Pictures and quotes from a Permobil wheelchair user who was followed closely after receiving his standing power wheelchair were added to visualise and explain the scientific evidence provided. All quotes from the anecdotal addition are printed in blue.

Clinical, functional and psychosocial benefits of standing

The overview of clinical, functional and psychosocial benefits that will be discussed in this white paper can be found in Figure 2. Based on quality, grading and the findings of the studies identified in the systematic review, a colour coding of the strength of the benefits have been allocated to each outcome.

Although not further discussed in this white paper, it must be noted that there are relations between clinical benefits, functional benefits, and psychosocial benefits as indicated by the arrows in this overview. Benefits in a certain domain could lead to or strengthen benefits in another domain.

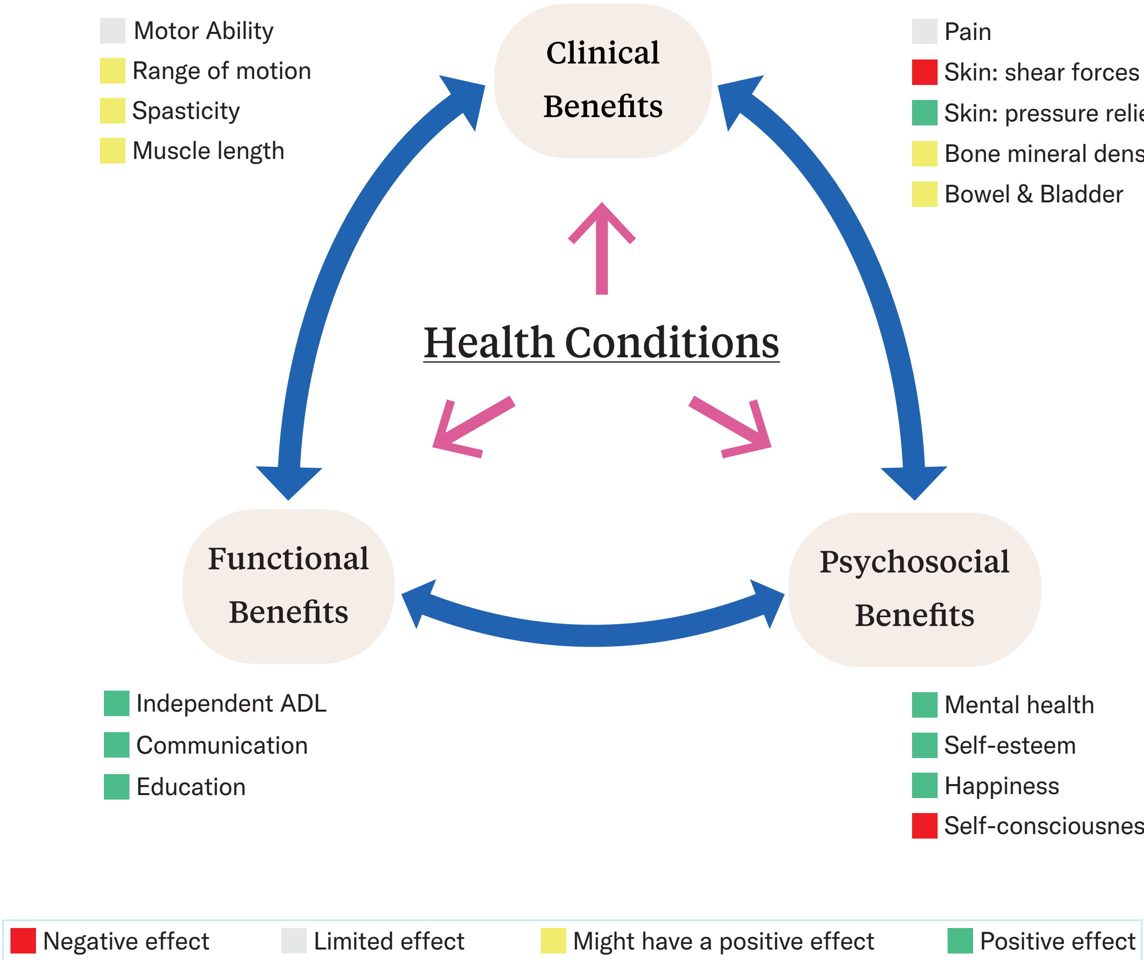

Figure 2. Overview of the white paper

Power standing vs. standing with other devices

A majority of the available literature has focused on standing with devices such as standing frames, while a limited number of studies focused on power standing. This white paper specifically aims to describe the clinical, functional, and psychosocial benefits of power standing.

For clinical benefits of standing, evidence from standing with all devices will be used, as the clinical evidence is considered to be comparable for standing regardless of the device. The biomechanical essence of standing is a significant load redistribution, which has shown to be achieved by power standing, both by reducing load on the seat as well as on the backrest[3].

For the psychosocial and functional impact of standing, the benefits of power standing are thought to be different compared to standing with other devices and therefore primarily evidence referring to power standing will be included. Literature on psychosocial and functional benefits while standing with other devices will be discussed to explain the differences with power standing.

Standing training in a walker

Standing in Permobil F5 Corpus VS

"It feels better not sit all day and get to stand because, sitting all day isn't really good for your back or really good for anything, so it is better."

"The difference is less people are involved and not getting hurt (like when transferring to a walker), it is safer and socially better, just not to have to make a whole scene basically rather than just stand up."

"I can stand independently, I don't have to wait for people because even if we did do like we used to do, it would be really hard to do it for this long, with the power wheelchair you can stand up whenever you want."

Mobility impairments

All mobility impairments are considered in this white paper. Some mobility impairments, such as spinal cord injury (SCI) have been more extensively studied than others. When no or very little research is available on a certain mobility impairment, it does not automatically mean that power standing may not be beneficial for this population group. For psychosocial and functional impact of power standing, we believe that the evidence is not dependent on the type of mobility impairment but is applicable to all power wheelchair users, regardless of the mobility impairment one has. For clinical benefits of power standing, potential differences between those with different mobility impairments will be discussed when appropriate.

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2. Clinical Benefits

Clinical benefits include effects on a meaningful aspect of how power wheelchair users feel or physically function because of standing. Besides the benefits, less favourable identified effects of standing will also be discussed.

The clinical benefits discussed include:

- Bladder and bowel function
- Bone mineral density
- Cardiorespiratory function
- Motor function
- Pain
- Pressure redistribution and pressure injuries
- Range of motion and muscle length
- Spasticity

Each clinical benefit will consist of a brief introduction to the topic, followed by a summary of the current available evidence, and clinical recommendation related to the evidence research listed prior. Furthermore, for each clinical benefit a list of scientific references is provided.

Bladder and bowel function

Urological function requires, among other things, a normally functioning nervous system[1]. Many people who require wheeled mobility devices have impaired nervous systems; thus, urological function and dysfunction are a focus of much concern among wheelchair users.

Of course, this population is very heterogeneous, and generalizations are bound to be ill-advised. However, it is correct to state that disturbances in urological function are very common in this group.

Body function and structure (Bladder)

The bladder is an expandable sac-like organ that contracts when it is emptying. The inner lining of the bladder tucks into the folds and expands to accommodate urine. Healthy bladders hold urine until people have time to relieve themselves, but problems can arise for varying reasons[1].

Functional impairment

Bladder dysfunction is an abnormality of either the filling or emptying of the bladder. It may be caused by involuntary muscular activity in the muscles of the bladder wall, the muscles that control the starting or stoppage of the flow of urine out of the body (sphincters), or the muscles of the pelvic floor. Neurological impairment and certain medications can contribute to bladder dysfunction, and many wheelchair users have diseases or injuries to their nervous system[1].

Common urological dysfunction seen in wheelchair users are incontinence and infection, and the risk of infection becomes further increased in cases when there is incomplete emptying of the bladder.

Body function and structure (Bowel)

The large intestine and its resident bacterial population have key roles to play in determining our health and well-being[2]. It is much more than just a waste storage facility as it holds many important functions such as:

- *Reabsorption of water and mineral ions.*
- *Formation and temporary storage of feces.*
- *Maintaining a resident population of over 500 species of bacteria.*

Functional impairment

The formation of feces is triggered by peristalsis, the function that pushes the contents of the large intestine ahead. This movement often triggers a bowel movement, or at least the urge to have a bowel movement. Constipation is usually described as infrequent bowel movements (less than three per week). The sensations associated with constipation can include a constant feeling of needing to go, or a sensation of bloating or fullness[3].

As in the case with the urinary system, even the gastrointestinal system might be impaired in many wheelchair users, particularly those with neurological disorders. Both immobilization and paralysis contribute to the common problem of constipation[4].

There is a theoretical basis to believe that standing may improve bowel function. For example, standing may stretch the colon and stimulate bowel movement. Studies in able-bodied individuals without bowel dysfunction show that food empties from the stomach best when individuals alternate between sitting and standing and worst when individuals just sit, stand or lie down[5].

Summary of evidence

Results from studies using self-reported outcomes support potentially positive outcomes of standing on bladder and bowel function[6,7]. These findings consistently show that adults perceive improvements in their

bladder and bowel function after standing. Two out of three studies using objectively measured outcomes of bladder and bowel function, such as time to first stool, did not find any positive effects[8,9]. However, in both studies persons were also asked for their perceived benefits which indicated that the standing did help bladder and bowel function. When interpreting results from objective outcomes of bladder and bowel function it should be considered that these functions are difficult to quantify and are therefore difficult to measure[9].

Evidence-based clinical recommendations

- The effect of standing on bowel function is highly variable and different subgroups of people might respond differently[9]. The response to standing may be for example also affected by neurological status, diet, and other lifestyle habits.

Evidence in children and adolescents

Evidence in children and adolescents is only scarcely available. In one study, parents of adolescents with DMD in a power standing chair observed an improvement in digestive functioning[10].

Evidence in adults

Residents of a nursing home with a variety of neurological diagnoses showed statistically significant improvements in their anal wink reflex after standing[11]. In another study in adults with multiple sclerosis (MS) participating in a standing intervention, no improvements were seen in bowel frequency in the participants who reported having constipation[8]. However, in the same study reporting on self-reported qualitative findings, it was noted by participants who were unable to control their need to go to the toilet that after the standing intervention they regained this skill. In a study amongst persons with SCI, the effects of a standing program on bowel function showed that regular standing does not reduce time to first stool and no therapeutic effects of standing were found on any of the other objective measures. Participants did perceive that they benefitted from regular standing with close to half of participants stating that standing improved their bowel function[9].

Results of a survey amongst those with SCI showed that 21% reported decreases in urinary tract infections and improved bladder emptying with stander use[12]. Furthermore, the amount of reported standing was found to be related to more regular bowel movements, but not to a lower number of urinary tract infections. Two other survey studies amongst participants with SCI also reported on perceived benefits in bladder and bowel function with standing[13,14].

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Bone mineral density (BMD)

The human skeletal system is comprised of large amounts of minerals that make up the structure of our bones. These minerals provide the strength and structure to not only support the human body, but to assist the skeletal frame for mobility and function. Three mechanical components have been identified as important contributors to building strong bones during the bone remodelling process: the axial (gravitational) load, shocks, and muscle stress[1].

Body function and structure

Individuals continue to grow the skeleton and bone mass with peaks between the age of 25-30 years. After this peak, a slow but steady decline is initiated. Woman can experience an acceleration in this decline during and after menopause, when the ovaries cease the production of estrogen[1].

Functional impairment

Interruption in the production of bone minerals, often due to age and/or disease, can compromise our skeletal system placing individuals at risk of fracture. The loss of weight-bearing activities such as prolonged standing can increase the speed at which the density of the bone decreases[1].

Summary of evidence

For children, systematic reviews have concluded that supported standing programs were effective to positively affect lower limb bone mineral density[2,3,4]. A note was made that it was unclear whether the increases in bone mineral density found can prevent pathological fractures.

For adults, evidence of the impact of standing on bone mineral density was mixed[3,5,6]. Standing interventions showing the largest effect on bone mineral density were those with higher dose standing, started early after injury and continued in the long-term[5].

Evidence-based clinical recommendations

- Children who are not standing are at risk for low bone mineral density; therefore, standing may be an appropriate intervention to maintain or increase bone mineral density[4].
- Standing wheelchairs promote weight bearing (75% of body weight) comparable to those of other standing devices[7], which promotes bone health.

Evidence in children

Townsend et al. 2016 found a significant decrease in lumbar bone mineral density between baseline and early to mid-intervention in three of the four boys with DMD participating in a standing intervention in a Permobil power wheelchair[8]. This decrease in bone mineral density was transient in two boys and sustained in another. In the fourth boy, the bone mineral density was stable for the duration of the study. The context of one participant losing ambulation during the study and the use of long-term glucocorticoids can suggest that the 3-4 hours of supported standing per week may not be sufficient to counteract the loss of BMD associated with the loss of ambulation, but can help to maintain a relative stable BMD for the three boys without ambulatory function.

All other studies on children included those with cerebral palsy (CP). An increase of up to 50% in standing time was found to be related to an increase in vertebral but not tibial bone mineral density[9]. Furthermore, removal of a standing program for a period of two months had a deleterious effect on bone mineral density of the tibia[10]. One study found that standing time was not associated with bone mineral density[11], while another found that compliance to a standing program was positively correlated with increased calcaneal (heel) bone mineral density[12]. In comparing passive standing and standing with exercises, no significant differences in bone mineral density were found[13]. While another study found that passive standing resulted in stable bone mineral density and standing with exercise in an increased bone mineral density[14].

Evidence in adults

All studies in adults included persons with SCI. Twelve months after SCI a significant decrease of bone mineral density was found in the trabecular bone of the radius and in the tibia of persons with tetraplegia. In those with paraplegia, a decrease was shown only in the tibia bone mineral density. In a few participants, regular standing showed to possibly attenuate the decrease of bone mineral density of the tibia[15]. Similarly, it was found that those standing daily for at least one hour per day, had significantly higher bone mineral density in the lower extremities after two years in comparison to those who did not stand[16] and that beginning weight-bearing immediately following SCI, decreased expected rate of bone mineral density loss[17]. In those at least one year after injury, a study reported significantly higher bone mineral density in the proximal femur and lumbar spine with highest bone mineral density at proximal femur in those standing regularly compared to those who did not[18]. Another study found that standing decreased calciuria (calcium in the urine) more than compared to an exercising group, with those within the first six months post-injury benefiting more than those between 12 and 18 months post-injury[19].

For those standing many years after initial injury, it did not improve bone mineral density[20]. Another study in those with chronic SCI found that standing for more than seven hours a week slightly increased BMD while standing for less than seven hours a week did not[21]. Randomized trial evidence found that functional electrical stimulation cycling was not better than standing at retaining bone mineral density[22] and when one leg was used as the control, there was a slight increase in the femur bone mineral density in the standing intervention leg[23].

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Cardiorespiratory function

The cardiorespiratory system is an intricate maze of veins and arteries responsible for supplying the human body with oxygenated blood and eliminating waste from blood that is returned.

Body function and structure

The heart and lungs make up the central portion of the system, responsible for pumping the fresh oxygenated blood throughout the body. Arteries carry blood from the heart through the lungs to the extremities and brain while veins return the used blood back to the heart and lungs to complete the cycle. This crucial system is also responsible for regulation of blood pressure[1].

Functional impairment

When injury occurs to the central nervous system, the cardiorespiratory system can become impaired as well. With loss of functional muscle and damage to the sympathetic nervous system, the system struggles to move fresh oxygenated blood from the heart and lungs to the body, as well as return the non-oxygenated blood waste back. As this process slows, the blood pressure will lower leading to difficulty with regulation such as orthostatic hypotension[2].

Summary of evidence

Very little is known about the effects of standing on cardiorespiratory function. In children no studies were available[3], whereas few studies were available in adults[4].

Evidence-based clinical recommendations

- Orthostatic hypotension should be monitored when standing 5,6,7 and considered when developing an individual standing sequence on a power standing wheelchair.

Evidence in adults

Two surveys amongst adults with SCI reported improved circulation and reduced edema after standing[8,9]. One side effect of standing is orthostatic hypotension, which was found to occur when standing was started early post-stroke[5] and in persons with SCI[6]. Frequent bouts of shorter duration of standing appear to increase tolerance over time[7].

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Motor function

Motor function, or the ability to perform activities utilizing the neurological system, is an extremely important part of mobility. Being able to perform functional activities of daily living while standing has multiple benefits (please see chapter on functional benefits)[1].

Body function and structure

The central nervous system consists of the brain and the spinal cord. Motor neurons in the central nervous system are responsible for movement, and when excited, trigger signals that travel from the brain through the spinal cord to the muscles to initiate function and mobility. These triggers can happen both involuntarily and voluntarily depending on the task at hand, as well as the response from the brain[1].

Functional impairment

When motor neurons are damaged, whether by disease or injury, signal transmission is interrupted. This interruption limits the information that is transmitted and received via the brain and spinal cord to the muscular system. Individuals who sustain damage or injury to the central nervous system often present with difficulty in movement of the extremities and motor impairments for functional tasks.

Summary of evidence

Evidence for the effectiveness of standing on motor function is inconclusive, and systematic reviews indicate that very few studies are available, mostly of low quality[2,3,4]. The studies have mostly involved adults with stroke and MS. Studies on those with recent stroke, including a large high-quality trial[5], indicate that the additional effect of standing to conventional therapy on motor function might be limited. Additional studies in those with MS[6,7] indicate that standing might have a positive effect on motor function although the clinical meaningfulness needs to be explored further.

Evidence-based clinical recommendations

- In those with newly acquired injuries, such as after a recent stroke, fatigue may be a barrier to participate in additional standing practice[8].
- Longer standing times have found to be related to greater imporovements in motor function, which indicates that there is a dose-response relation[6].

Evidence in children

Not available.

Evidence in adults

A large trial amongst those with a recent stroke showed that the addition of a standing intervention to conventional therapy did not improve motor function, autonomy, and mobility[5]. Although outcome measures improved significantly from baseline through the end of treatment, in a longer-term follow-up the extent of change was comparable for those only receiving conventional therapy and those additionally participating in a standing intervention. Three other smaller studies amongst those with stroke reported similar findings[8,9,10].

A large high-quality trial amongst those diagnosed with MS showed that a standing intervention increased motor function, although not to the degree that the researchers had defined as clinically meaningful. There was a large variability in the effects of standing on motor function, and longer standing times were associated with greater improvements[6]. In a small study amongst those with MS[7], it was shown that those who stood regularly improved on a motor function score. In the same study, qualitative findings indicated that the participants experienced improved mobility and transfers that might decrease the risk of falling following standing.

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Pain

Pain plays a major factor in the functional capabilities of those who use a wheelchair for their independent mobility, as it can lead to decreased functional independence as well as medical and psychosocial impairments.

Body function and structure

Pain is defined as a local or generalized sensation that is perceived by the body through pain receptors in the muscle and skin. These receptors then relay information to the brain via the spinal cord to initiate a pain response to diminish the sensation or the function until the pain subsides[1].

Functional impairment

Those that sustain injury or disease requiring the use of a wheeled mobility device often can demonstrate increased or decreased perceptions of pain. Those with increased sensations of pain might show reductions in functional activities and mobility in efforts to reduce the pain response. Conversely, individuals who present with decreased sensation to pain do not respond appropriately to a noxious stimulus which can lead to adversity, such as pressure injuries.

Summary of evidence

There is some evidence that standing can help to decrease pain and discomfort in both children and adults[2]. On the other hand, standing might be perceived as painful, in particular in the initial stages of standing, and is therefore important to monitor.

Evidence-based clinical recommendations

- Standing in a power wheelchair allows adjusting the position to manage pain and comfort level[3].
- It is important to monitor pain and comfort, particularly in the initial stages of standing and when children grow[3].
- With continuous standing, pain might ease[4].

Evidence in children

In a study on power standing involving adolescents with DMD[5], it was found that although adolescents experienced musculoskeletal pain on a regular basis, standing did not appear to be associated with any aggravation or reduction in muscle and joint pain. From the same study, qualitative findings showed that adjusting the wheelchair independently meant that adolescents could manage their own comfort level while standing. The tilt and recline function enabled adolescents to lean back and recline while still in a standing position to achieve stretch and comfort but working within available energy levels. Teachers also found adolescents managed fatigue and discomfort in the classroom by adjusting the chair to a reclining position in standing. Some adolescents reported no additional pain with power standing while others reported foot discomfort when first using the standing function. The discomfort was resolved by sitting and/or reducing the duration of standing[3].

Parents reported that 14% of children with CP experienced pain while standing in a standing frame[6]. In a qualitative study in a mixed sample of wheelchair users, children and parents reported to perceive standing as a treatment of body structures and functions, but at the same time as a source of pain[7]. In another qualitative study amongst children and adolescents with CP[8], it was reported that sitting for long periods was uncomfortable, and standing is an important position change related to pain management. Despite these benefits, pain was an issue for many of the participants. General pain, knee pain, and foot pain were all reported, especially after standing for longer periods. Pain did not necessarily dissuade from using the standing frame.

Evidence in adults

A study of individuals with MS[9] found that 41% of those participationg in a standing interventoin self-reported pain, compared to 22% in a non-standing control group. Another study in those with MS[4] found that participants experienced low back or leg pain at the initial stages of standing, but this eased after a few days and did not stop persons from standing. Adults with SCI reported in surveys to have some reduction in pain following supported standing[10,11].

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Pressure redistribution and pressure injuries

The integumentary system represents a large portion of the human body and acts as the first means of defense for the human body to the environment around us[1].

Body function and structure

While the integumentary system comprises of hair, nails, and skin, the most important component is the skin. The skin is the largest organ of the human body and plays a vital role in our protection against the environment. The integumentary system also helps us differentiate between hot and cold, hard and soft touch, and pressure[1].

Functional impairment

Pressure management and skin and tissue integrity are crucial for those who have sustained injury or present with a disease that results in the use of wheeled mobility. Pressure injuries and skin/tissue breakdown occur when an individual has an impairment that results in the inability to sense pressure. Those that utilize wheeled mobility devices are at an increased risk of pressure injuries due to immobility and prolonged sitting activities.

Summary of evidence

Data from experimental studies show that standing leads to offloading and to an altered reactivity of skin temperature and thus has the potential to decrease the risk of pressure injuries[2,3]. Although direct evidence is limited, one can conclude that standing enables pressure redistribution and thereby reduces the risk of pressure injuries in adults[4].

Evidence-based clinical recommendations

- Compared to tilt and recline pressure redistribution, standing was found to be the only configuration that decreased loads off the seat and backrest simultaneously[2].
- Sliding between the body and the backrest/seat might occur while transitioning from sitting to standing and vice versa[5].

Evidence in children

No evidence was found that standing positively affected skin integrity in children[6]. A qualitative study amongst adolescents with DMD reported that a power standing wheelchair supported regular stretching and skin pressure management[7]. Surveys amongst those with SCI also suggest that standing may help decrease the risk of pressure injuries[8,9,10].

Evidence in adults

In an experimental lab study amongst those with SCI standing has shown to offload and unweight the ischial tuberosities. Standing and recline offered similar seat load reductions. Standing also reduced loading on the backrest[2]. Another experimental lab study amongst those with SCI showed that standing altered the reactivity of skin temperature, which is suggested to be related to decreased risk of pressure injuries, but further studies are necessary to confirm this relation[3].

Shear forces

A study involving individuals with SCI showed that without an anti-shear mechanism, it was found that without an anti-shear mechanism there is a risk of shear forces both when standing up and sitting down in a power wheelchair[5]. The risk of shear forces was also pointed out in a pre-clinical study[11]. Shear forces can potentially increase the risk of pressure injuries and therefore require careful attention.

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Range of motion (ROM) and muscle length

Range of motion is the amount of flexion and extension through which a joint can move[1]. Each joint has an optimal passive and active mobility to assist with movement. When a joint or joints in the human body moves through the full range of motion on a consistent basis, limitations in movement and contractures can be avoided. Often due to injuries or diseases, individuals who utilize wheelchairs are at risk of losing full range of motion.

Body function and structure

Several factors may decrease the ROM including joint inflammation, paralysis of the muscles acting across the joint, spasticity. Wheelchair users commonly experience one of more of these ROM-limiting factors. When limitations of ROM are present, the joint, muscles, and tendons can shorten and cause the deformity referred to as contracture[1].

Functional impairment

Loss of ROM can potentially result in a variety of dififculties including pain and discomfort and reduced repositioning abilities. For individuals with limited standing or walking function, maintaining ROM is important to maintain function and independence. For individuals who are non-ambulatory, maintaining ROM enables them to utilize power standing for the benefits described in this white paper.

Summary of evidence

The literature shows support that power standing could benefit range of motion and muscle length both in children and in adults with a diversity of mobility impairments[2,3,4,5,6]. Although no negative effects of standing on ROM and muscle were reported, not all studies found clinically significant results.

Evidence-based clinical recommendations

- Standing with full hip extension might reduce hip flexor tightness[7,8]; therefore, it is important that a standing wheelchair is able to support a standing angle that enables full hip extension.
- Start standing as early as possible after onset or diagnosis of mobility impairment since, standing appears less effective in individuals with long-standing contractures[9].
- Improvements in hip range of motion with standing were found for children as young as 14 months[10]. This further supports the need to start with early power mobility with standing function and continue throughout the course of life.

Evidence in children and adolescents

A vast majority of research on the effects of standing on ROM in children and adolescents has been performed on children with CP. One study reported on ROM after power standing in adults with DMD[11], which reported that joint angles measured via video showed no changes after a standing intervention. Another study assessed muscle length after power standing use and noted improvements in hip and knee flexor muscle length in those with DMD[12].

Studies amongst those with CP show positive effects of a standing program on the hamstring ROM[13], and on increasing or maintaining hip abduction ROM, compared to not standing[14,15]. Furthermore, standing was found to maintain or increase ROM and prevent knee flexion contractures[16] and increase static and dynamic ROM of the plantar flexors[17]. Another study involving children with CP reported increases in passive ROM in abduction, extension, and external rotation after a 4-month standing intervention, although changes in ROM were larger after dynamic compared to static standing[18].

Evidence in adults

For persons with stroke, standing was found to be more effective than no treatment and as effective as night-time splinting in preventing ankle contractures[19]. In those with acquired brain injury, the evidence suggests that daily standing can eliminate plantar flexion contractures[20,21]. Another study reported that standing is at least as effective to treat ankle contractures as electrical stimulation and ankle splinting, however the defined five degrees of clinically important difference was not reached[22]. In persons with MS, standing has been shown to improve hip and ankle ROM[23,24]. Furthermore, the stretching effect of standing increased the ankle plantar flexor torque, and people with MS experienced a strong sensation of stretch while standing[25]. For those with SCI, there is evidence that standing contributes to increased ankle and leg muscle length and ROM[26,27,28,29,30].

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Spasticity

Spasticity can be defined as the presence of involuntary muscle contractions, either sustained or sporadic, resulting from the lack of control of the upper motor neurons. The presentation of spasticity can range from mild stiffness to constant painful spasms[1].

Body function and structure

Muscle tone is the sustained contraction of muscles and is required to maintain posture. Individuals with diagnoses affecting the central nervous system may experience increased or abnormal muscle tone resulting from the lack of inhibition from upper motor neurons. Spasticity is a common comorbidity in individuals with congenital neurological and musculoskeletal disorders, as well as individuals who sustain trauma to the neuromuscular system (e.g. SCI)[1].

Functional impairment

For individuals who require wheelchairs for functional mobility, spasticity introduces a wide range of challenges. For manual wheelchair users, spasticity may inhibit or decrease upper extremity motor control resulting in the decreased ability for adequate propulsion. For individuals utilizing power wheelchairs, increased spasticity can make accessing the joystick challenging. For all wheelchair users, spasticity can result in postural asymmetries and increase the likelihood of skin breakdown[1]. Standing offers active mobilization and stretch.

Summary of evidence

Evidence indicates a beneficial effect of power standing on spasticity, however the available evidence is limited both to the number of available studies and the quality of these studies[2,3,4,5,6]. Literature reviews on the effects of standing in children were able to include few studies from which they concluded that the stretching achieved with standing might result in a temporary reduction of spasticity[2,5]. For adults, evidence, although weak, pointed towards a positive effect of standing on spasticity[4,6].

Evidence-based clinical recommendations

- Standing can improve spasticity in those who frequently have spasticity but might be limited in those persons in which spasticity is not frequent[7].
- The effects of standing on spasticity might only last for about half an hour and might therefore need to be combined with other therapy[8]. Power standing incorporates standing into daily activities resulting in a higher standing frequency and facilitates independent execution with reduction for the need to transfer (independent or assisted) to a secondary standing device.

Evidence in children and adolescents

Three studies were identified all focusing on standing in children with CP. One study indicated no differences in spasticity after an intervention with four months of standing[9], whereas the other two studies found a decrease in lower extremity spasticity or tone, in particular directly after standing[10,8].

Evidence in adults

A study in adults with SCI showed that after standing the spasticity of the extensors in the hips and knees reduced[11]. In a case-series report of persons with SCI or MS, no effects of standing were found[12]. In two small studies with persons with MS, improvements of spasticity in some participants have been reported, but no overall significant reductions were found[7,13], and similar results were found in those with traumatic brain injury (TBI)[14]. In surveys of people using standing devices, participants reported to experience beneficial effects of standing on spasm frequency[15,16,17].

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3. Functional Benefits

Introduction

The design of living and workspaces in the Western world is typically based on the assumption a person can stand, e.g., kitchen bench/counters and cooking surfaces, bathroom sinks, storage cupboards, handles, and light switches. Since the default position of wheelchair users is to sit, this consequently means that typical living and work spaces are inaccessible. Power standing allows a person to access a wider range of unmodified spaces[1]. Besides independent activities of daily living (ADLs), functional benefits also include communication and education. Functional benefits can be achieved as an indirect or direct result of standing. Direct benefits refer to immediate impact of power standing on function, whereas indirect benefits refer to the longer-term impact of clinical and psychosocial benefits which lead to functional benefits.

Most of the direct functional benefits of standing are typical for power standing, and do not apply to standing with all other devices that, unlike power standing require a transfer. Consequently, power standing allows users to perform multiple times per day for shorter periods. Our Permobil Connect data of F5 Corpus VS users shows that there is a large variability in power standing use, both between users and within users. When it comes to the frequency of power standing, data shows that users frequently stand up multiple times per day. Permobil Connect data on 121 F5 Corpus VS users who had been using the standing function during the last six months were analysed. In 49% of the days in which users were standing, they were standing two or more times in the day. On 10% of these days, users were even standing at least five times per day. These results, showing that F5 Corpus VS users stand up multiple times per day, indicate that they are likely using power standing for functional benefits.

Amount of times per day F5VS users stand up

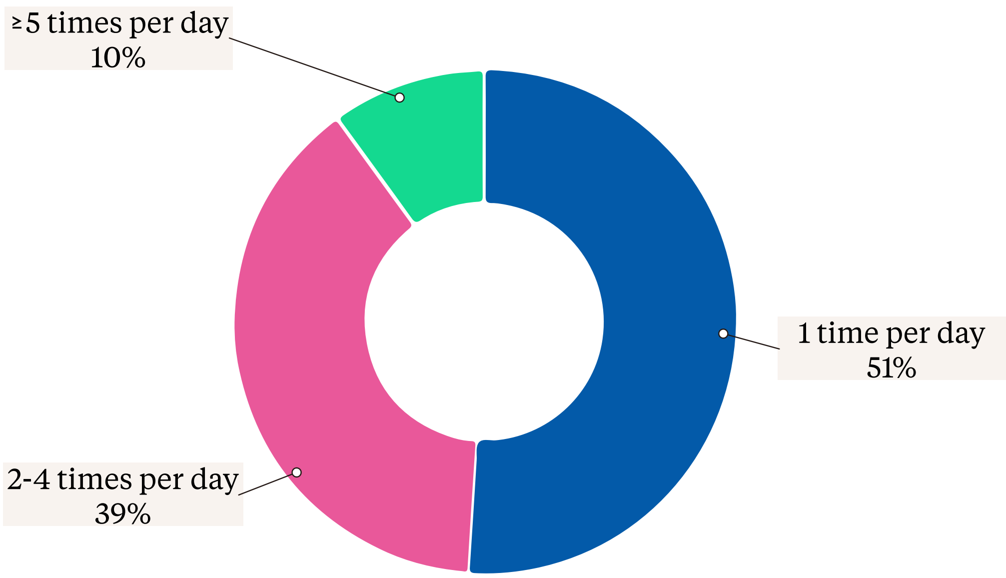


Figure 3. Results of an analysis of Permobil connect data of 121 F5 Corpus VS users, showing the proportion of time they have been standing up more than once on days that they have used the standing functionality.

NOTE: Data not available to show how long they were standing.

Reaching things on shelves or desks used to be a struggle. He could not even get a glass of water by himself, instead he had to always wait for someone to come and help.

"It is possible to get my own glass of water because I can stand up and reach the sink and not be so low to the ground like previously with other chairs.

Functional benefit as an indirect result of clinical benefits of standing can typically be achieved by standing regardless of the device used. For example, when standing leads to a decrease in spasticity, this might lead to functional improvements such as bathing, comfortable wheelchair sitting, and mobility[2].

Summary of evidence

Power standing leads to functional benefits in ADLs, communication and education[1,3,4,5]. Evidence from both questionnaires and interviews show an increased independency with power standing at home and at school[3,4,5]. Power standing wheelchairs might lead to more functional benefits compared to other standing devices because of less restrictions in daily use[3,5,6,7].

Evidence-based recommendations

- Including new physical activity behaviors in everyday life seem to be easier when started early on, in childhood or in a sub-acute phase after injury, compared to changing behaviours in adulthood or in the chronic phase after injury[8,9,10]. This implies that users might benefit from having a power standing wheelchair as their first chair to achieve most functional benefits.
- Wheelchair users typically have many home modifications which are accompanied by high costs[11]. In considering a power standing wheelchair and its costs, it might thus be worth to reflect on the costs that could be saved with the standing ability since less home modifications would be necessary.

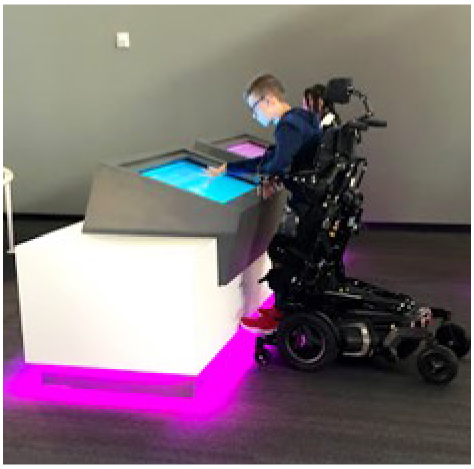
Functional benefits of power standing

ADL

A power standing wheelchair provide mobility while also enabling standing to become a functional part of the day. The user can perform a variety of activities while standing, thereby combining functional with clinical and psychosocial benefits. Power standing can be performed both indoors and outdoors, and can aid productivity and integration at work, school, and church. It can also enhance independence, for example when shopping. Being able to perform standing from one's wheelchair also minimizes transfers, thereby enhancing safety, conserving energy, and reducing dependency[1]. Furthermore, power standing wheelchair users can benefit in a variety of (unmodified) community settings to enhance their independence, improve vocational requirements, and enable recreational activities. Such situations include the ability to access vending machines, high elevator buttons and coffee shop counters; standing up to access drawers and other necessities at work, enabling users to do jobs which need to be performed from a standing position, and standing up with others for a ball game[1].

Vorster et al. 2019 and Bayley et al. 2020 performed a quantitative study (questionnaires and assessments) and qualitative study (interviews) on power standing in adolescents with DMD[3,4]. Both the quantitative and qualitative findings supported a higher level of independence. For adolescents standing in a power wheelchair, everyday tasks, such as cooking, could be performed without asking for assistance. Furthermore, personal care routines were generally faster and required less use of hoists and transfers. After the introduction of a power standing wheelchair, parents also noted a decreased demand of their care, and teachers more time to focus on teaching. The most discussed personal care activity was using the standing function to pass urine. The standing function enabled adolescents to manage toileting independently for longer and passing urine in standing was easier and faster.

Another qualitive study focusing on children with different diagnoses using a power standing wheelchair, stressed that giving children the ability to stand when and where they desired increased children's independence in performing a variety of tasks, such as washing hands, or reaching for objects, etc. Performing in a play, singing in a choir, playing with friends, working at a grocery store, partaking in chemistry lab, doing chores at home and in the yard, and eating at restaurants with high-top tables were all mentioned as situations where children's participation could benefit from power standing. Furthermore, it was also valued how standing and the ability to independently transition into standing allowed children to feel more involved in certain activities[5].



At the museum, this user is able to stand at the kiosk and actually use it. His dad says that in today's environment a lot of the stuff is for people who are standing, especially self-service stuff. The screens of the kiosk are at an angle so if the person is not right on them, they can't see.

He was able to see over a bridge in Georgia just like everybody else. Before the rails were always in the way so that he couldn't see, or he had to look through the slats.

Communication and education

People seated in wheelchairs are positioned at a lower level than their standing counterparts, which forces an upward gaze to achieve direct eye contact. Power standing could, similarly to seat elevation, improve visual orientation and line of sight which can provide direct eye contact for memory, socialization, cognition, communication and even safety in navigation[12,13].

"It is easier to socialize when looking at somebody face-to-face and not looking up at them. Unlike if you are sitting down and have to look up at the person, it just doesn't feel the same cause you are not looking right at them. It feels more natural when you are looking right at a person rather than looking up at them."

"It is easier to get people's attention if they can physically see you better...."

Vorster et al. 2019 also found that power standing enabled more autonomous participation in physical, social, and educational activities[3]. The capacity to stand at their choosing was useful in social settings with family and at school. Being eye to eye with their friends, hearing conversations, being able to see more clearly, and feeling better able to cope in crowded situations were all mentioned by participants as advantages to standing. Parents also observed that the standing function facilitated better hearing and communication with others. Standing was beneficial for both teaching and ceremonial activities at school. Lastly, power standing enabling faster toileting at school, which helped reduce missed time from class.

Typical activities or tasks during power standing

As part of a global survey, 120 Permobil employees involved in sales and clinical education of power wheelchairs were asked what activities or tasks users typically do when standing in the F5 Corpus VS wheelchair. Results are shown in Figure 4. The most rated activity was ADLs for which 83% of respondents indicated this is a typical activity in a power standing wheelchair. Socializing was the second more ranked activity, followed by training/exercise/therapy in third.

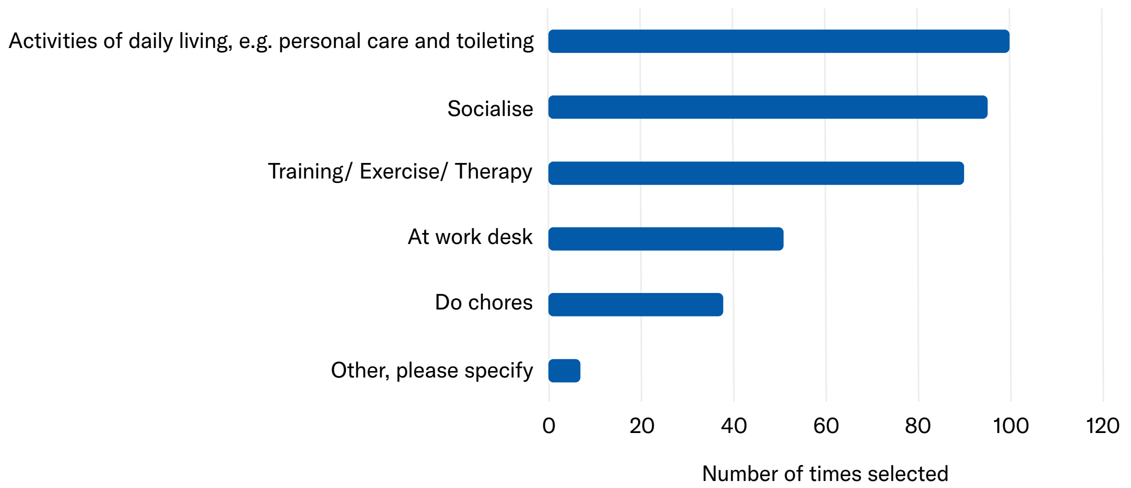


Figure 4. Responses from 120 Permobil sales reps and clinical educators who were asked the question: "What activities or tasks do users typically do when in a stand-still standing position in the F5 Corpus VS wheelchair?" Respondents answered all those that applied.

In a similar question, asking about which standing activities require users to be able to drive in a power wheelchair, the most commonly rated activities were driving around at home (77% of respondents), socializing, and ADLs (see Figure 5). This stresses the advantages of power standing which includes the ability to drive, and thereby expands the number of activities and tasks that one is able to perform while standing.

Figure 5. RResponses from 120 Permobil sales reps and clinical educators who were asked the question: "Which of the following activities or tasks require users to be able to drive while they are in the standing position?" Respondents answered all those that applied.

Power standing vs. ActiveReach™

ActiveReach, or the anterior tilt function, changes the seat angle orientation in relation to the ground in the sagittal plane and angles the seat forward (definitions used: up to -45 degrees is anterior tilt, and standing is >-45 degrees of anterior tilt). Once anterior tilt is activated, the seat-to-back angle further adjusts to place the individual in a semi-standing position. ActiveReach also benefits reach and the performance of ADLs[14]. However, the safety equipment needed for ActiveReach, in particular the chest strap, might cause some limitations to the user's ability to reach in the horizontal direction[14].

Power standing vs. standing with other devices

Vorster et al. 2019 reflected on the advantages of power standing compared to using other standing devices. They concluded that the power wheelchair allowed continuing independence for daily tasks or components of daily tasks, including providing the individual with control over the decision of when to stand[3]. The acceptance and utility of standing frames on the other hand, can be limited by the burden of transfers into the standing frame as the child becomes heavier. For caregivers, the standing function reduced the need for transfers that can be particularly difficult when in confined spaces in the community. Thus, an additional benefit of the standing wheelchair includes possible protection of caregiver health and safety. Another study noted how power standing can eliminate the need to transfer to a separate stander, thereby allowing children the choice of standing or sitting without having to transfer into another piece of equipment[5]. The same study stressed how eliminating the need to transfer in order to be able to stand also benefits caregivers. Parents found that transferring children to and from a separate stander became increasingly difficult as their children grew, which resulted in the children standing less frequently[5].

Goodwin et al. 2019 highlighted the complexity of standing frame use in the educational setting, including priorities regarding therapy versus education, young people's autonomy, working within logistical boundaries and the competence and confidence of classroom staff[6]. One barrier for frequent standing with a frame is that a child has a standing frame at nursery/school, but not at home. Another study highlighted the importance to integrate the standing in a meaningful activity for children, otherwise it would be perceived as too boring[7]. Integrating shorter periods of standing might be easier in a power wheelchair compared to standing with another device.

With a power wheelchair this user could visit the arcade and for the first time enjoy the games which required him to be in a standing position.

"Before I used my power standing wheelchair, I was not independent because I had to rely on other people more than I do now, because I can just stand up. It is important because I think you can get more things done when you can do it on your own rather than having other people help you...or to wait for other people to help you."

Mother:

"He can stand for longer times and more frequently because he doesn't have to wait for me to have time to help him with that or to just stand along to help him. He doesn't need help with any of that now...and he stands up more solid now when he does the transfers."

Functional benefits of all standing devices

In children there are indications that standing can increase the speed of feeding[15] and that standing independently might ease the burden of care[16]. Furthermore, opportunities for increasing social interactions with standing have been discussed[7,17,18,19].

In adults with SCI, there is evidence to support the impact of standing on self-care[20], the ability to carry out ADL, gain and maintain employment, as well as to be independent[21]. In adults with MS, standing improved personal and domestic ADL such as washing, dressing, cooking, leisure activities, and transfers[22].

Functional benefits of standing

We can also learn about functional benefits of standing for wheelchair users from knowledge not specific for wheelchair users, such as office-workers. Office-workers are known to spend 60% of their time sitting, 28% standing, and 12% walking, with minimal differences in how the time is spread between time at the workplace, working days, and non-working days[23]. As it was found that most of the day is spent sitting because it is a habit, this implies that the remaining part of the days (40%) are organised into activities which need to be performed in an upright position or because the environment is built for standing. One could therefore hypothesize that power standing makes it easier to be a part of these kind of activities which require individuals to be in an upright position.

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4. Psychological Benefits

Introduction

Requiring a wheelchair for mobility can come with its challenges. Environments need to be accessible, the culture needs to be understanding of disability, and activities need to be wheelchair compatible[1,2]. These challenges can have complicated solutions that can negatively impact mental health, happiness, self-esteem, well-being, and quality of life.

One third of persons with SCI are known to have moderate to severe mental health problems[3]. Mental health disorders are also prevalent in individuals with cerebral palsy (CP)[4]. Depressive disorders and symptoms are extremely common among individuals with MS, and contribute to overall disease burden and detract from quality of life[5].

The research for power standing is unique in that alongside the medical and functional benefits, there are often qualitative statements relating to the psychosocial benefits. For example, standing up in church to join in singing a hymn, or standing at a sports game to be able to see their favourite player score a goal, or simply standing to shake hands with a guest in their home. These benefits might be challenging to quantify as it can concern activities that relate to a cultural norm as opposed to a specific functional activity, and what may be meaningful for one person may not be for the next.

The psychosocial benefit of standing is often overlooked as part of funding guidelines; however, the frequency of how often they are reported suggests that the potential impact of standing on a person's wellbeing should be considered.

"It is kind of cool to be able to stand and sing, because you know that is how you do it, and that is the proper way to do it."

"It makes me happy that I can do some stuff on my own now."

...just to know that people see you and they may listen to you makes me more confident rather than sitting down."

"They seem to acknowledge you more when they can see you and it feels more normal...you are standing there and talking. You know when they are looking down, and I am sitting down kind of looking up at them, it just seems kind of weird to say something."

Summary of evidence

Standing has a positive impact on mental health and quality of life[6,7,8,9,10]. Power standing benefits children's self-esteem[6,11,12]. Younger persons report on mixed feelings about standing with some reporting it helped them fit in, but others reporting it makes them stand out[6,13].

Evidence-based recommendations

- A frequently reported reason given for standing (by 64% of users) is to improve well-being[9].
- Being able to drive fast while standing has the ability to make adolescents feel extremely special[6].

Children

Findings from a quantitative study (questionnaire and assessments) and qualitative study (interviews) on power standing in adolescents with DMD[6,7] showed that when receiving the standing power wheelchair, most participants reported to feel happy or excited and enjoyed doing things without seeking help from others. Parent groups observed that the greater independence and capacity to be in control provided their children with more confidence and improved self-esteem. They observed their children to be happier and more content, more mature, and self-confident. Parents also described fewer episodes of grumpiness, frustration, and anger[6]. Positive findings on mental health were confirmed by improved scores on positive mood, reduced hyperactivity, and better peer relations[7]. In a qualitative study focusing on children with different diagnoses using a power stander[11], similar psychosocial benefits were described, with parents noting increases in self-esteem and describing the benefits of being able to stand face-to-face with others. Additionally, it was perceived that power standing positively influenced how other people perceive a child using a wheelchair. A survey study also confirmed the improved self-esteem, as reported by a large majority of school-based physical therapists[12].

On the other hand, adolescents with DMD also reported to be self-conscious of standing in front of others and did not enjoy appearing different and being the center of attention. These negative emotions were confirmed by the parents[6]. Comparable results were found by Goodwin et al.[13], reporting on mixed views on the social impact of standing by young people with cerebral palsy, with some feeling excluded from their peers, and others feeling as though standing frames helped them to fit in.

Adults

In a randomized controlled trial among persons with MS, comparing a group participating in a standing intervention to a group receiving usual care, it was shown that quality of life was higher amongst those standing[8]. Another study amongst persons with chronic SCI or MS[14] reported that after participating in a standing intervention, 67% continued to stand and reported to feel healthier because of it, which suggested a positive psychological impact. In a study amongst persons with stroke, standing did not lead to improvements in depression or anxiety[15]. A survey gave further insight into quality of life amongst a large group of persons with varied medical diagnoses using a standing device, with about ¼ of them having a power standing wheelchair[9]. Persons reported that standing contributed positively to their well-being and improved their quality of life. In different surveys amongst adults with chronic SCI, standing was also related to an increase in well-being or quality of life[16,17,18].

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