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PAPER

Rehabilitation: mobility, exercise & sports; a critical position stand on current and future research perspectives

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ABSTRACT

Background: Human movement, rehabilitation, and allied sciences have embraced their ambitions within the cycle of "RehabMove" congresses over the past 30 years. This combination of disciplines and collaborations in the Netherlands has tried to provide answers to questions in the fields of rehabilitation and adapted sports, while simultaneously generating new questions and challenges. These research questions help us to further deepen our understanding of (impaired) human movement and functioning, with and without supportive technologies, and stress the importance of continued multidisciplinary (inter)national collaboration.

Methods: This position stand provides answers that were conceived by the authors in a creative process underlining the preparation of the 6th RehabMove Congress.

Results: The take-home message of the RehabMove2018 Congress is a plea for continued multidisciplinary research in the fields of rehabilitation and adapted sports. This should be aimed at more individualized notions of human functioning, practice, and training, but also of performance, improved supportive technology, and appropriate "human and technology asset management" at both individual and organization levels and over the lifespan.

Conclusions: With this, we anticipate to support the development of rehabilitation sciences and technology and to stimulate the use of rehabilitation notions in general health care. We also hope to help ensure a stronger embodiment of preventive and lifestyle medicine in rehabilitation practice. Indeed, general health care and rehabilitation practice require a healthy and active lifestyle management and research agenda in the context of primary, secondary, and tertiary prevention.

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Supportive technology; multidisciplinary collaboration; ergonomics; exercise = medicine

➤ IMPLICATIONS FOR REHABILITATION

- Continued multidisciplinary (international) collaboration will stimulate the development of rehabilitation and human movement sciences.
- Notions from "human and technology asset management and ergonomics" are fundamental to rehabilitation practice and research.
- The rehabilitation concept will further merge into general health care and the quality there-off.

Background on "rehabilitation: mobility, exercise & sports"

The 6th RehabMove Congress finds its origin in the wheeled mobility research agenda of the 1980s and 1990s at the -then - Faculty of Human Movement Sciences, VU University, in Amsterdam and its (inter)national research networks. The 1st congress in our series between 17 and 19 October 1991, at the VU University Amsterdam, was therefore fully dedicated to wheelchair research work and advertised as: "Ergonomics of manual wheelchair propulsion" [1]. This first manual wheeled mobility research event was stimulated and sponsored by the European Union's COMAC-BME and the concerted action on "Mobility restoration for paralyzed persons," chaired by Prof Antonio Pedotti. Its proceedings were published by IOSpress and formed an example of the scientific work around manual wheelchair propulsion in the scientific world of those days, a true state-of-the-art work [1]. The scope of the subsequent four congresses gradually widened beyond the field of wheeled mobility, and entered much more so into spinal cord injury rehabilitation, adapted sports, and

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even later into the "exercise = medicine" philosophy in health and human movement sciences [2–9]. Now, travelling through science, practice, and industry between the 1st and the 6th RehabMove in 2018 for almost 30 years, the circle seems round with continued, promising, and important national and international collaborative research. That is, in networks of talented human movement, rehabilitation and sports scientists, physicians, engineers, vocational and physical therapists, psychologists, and patients, with many young innovative people creating new horizons in research and rehabilitation care. Research that: (1) boosts our understanding of optimization of cyclic locomotion [10–12] and functioning in wheeled mobility [13–17], human gait [18–21], and upper extremity functioning [22–27]; (2) stimulates the consequent understanding and development of assistive and rehabilitation technologies, and their critical human-machine interface dimensions [28,29]; (3) and stresses the important role of individualized training and practice, and the underlying motor skills within the 'human stress-strain-work capacity' model [30] in the context of rehabilitation, daily living and adapted sports.

An important framework that guides our notions, for both research and treatment in the context of rehabilitation, is the International Classification of Functioning, Disability, and Health model of the World Health Organization (Figure 1) [31]. Personal and environmental domains are critical to the potential of daily functioning, activities, and participation as a consequence of chronic health conditions. This is exemplified for wheelchair users with a spinal cord injury in Figure 1. This conceptual framework will be central in many respects below.

With the RehabMove organization being a collaboration among human movement scientists and rehabilitation researchers and professionals, the RehabMove2018 Congress covers three main themes: "mobility, exercise, and sports." Essentially our ambition is to provide cutting edge knowledge on and understanding optimal human motor functioning in the context of chronic disease or disability in daily life, and in its societal contexts, such as work, school, sports, and recreation. In the following the thematic coloring of our congress will be closely linked to the state-of-the-art on (wheeled) mobility, exercise, and sports, as exemplary issues. In addition, from a somewhat circular perspective, we emphasize the work in our groups, leading to a storyline that widens towards the broader perspective of health and active lifestyle as a preventive health care obligation in movement and rehabilitation sciences, and beyond. The following will give a few examples of the continued societal challenges and the need for continued research and translation of the findings into real-world applications.

"Mobility, exercise & sports:" a case for supportive technology

Recently, the evaluation of research proposals for the "Mobility Unlimited Challenge" from the Toyota Mobility Foundation (http://

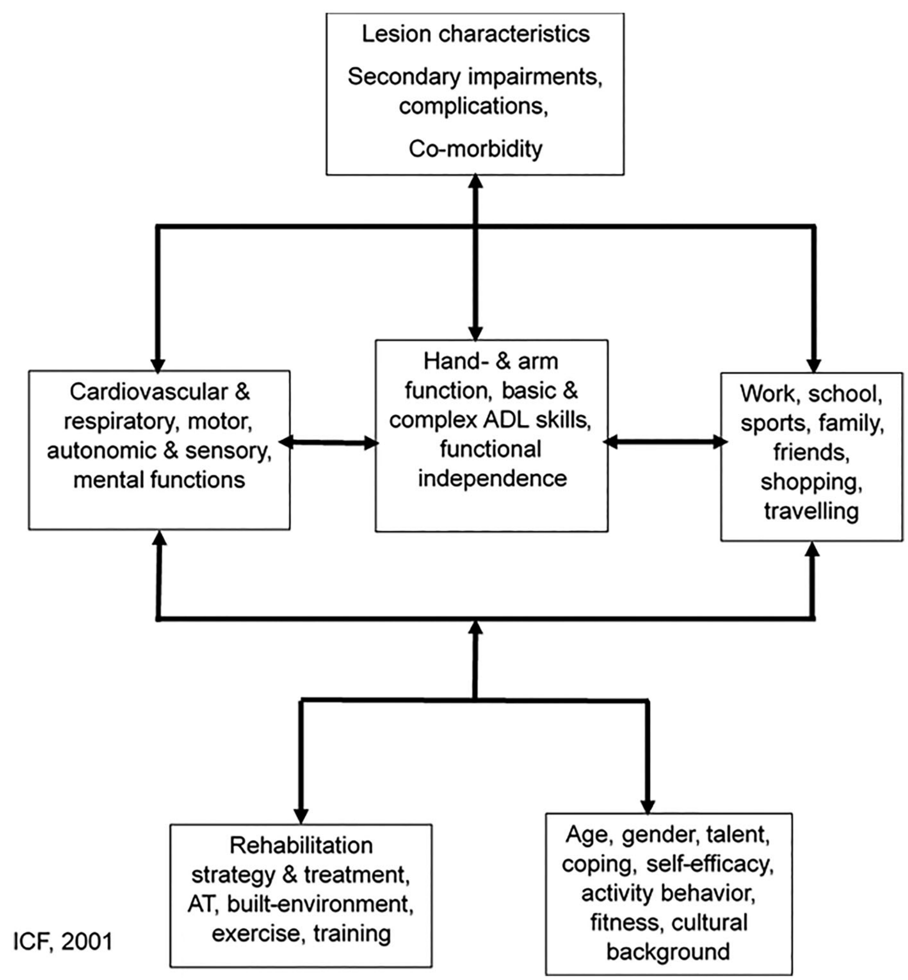

Figure 1. The WHO's model for the International Classification of Functioning, Disability and Health [31] and adapted to persons with a spinal cord injury (SCI) who are wheelchair-dependent (~80% of the population). Originally published in International Classification of Functioning, Disability and Health; Geneva: World Health Organization; 2001. Licence: CC BY-NC-SA 3.0 IGO).

toyotamobilityfoundation.org/; "Helping people move more freely; we believe in the power and joy of mobility for all") took place. A prestigious international opportunity for multidisciplinary research consortia to boost their innovative work on mobility challenges for people with lower limb disabilities with a substantial project grant. These inspiring project consortia work at the front end of engineering, rehabilitation, and medical sciences. The competition provides innovative cutting-edge mobility solutions for the twenty-first century in people with mobility limitations. With a great deal of high-tech engineering involved, "human factors" (a field that is equivalent to ergonomics, i.e. the study to optimize human functioning in the task, tool, environment and over the lifespan, while maintaining health, safety, efficiency, and comfort) [32] are a critical dimension. This is often fully secured with early involvement of end-users, apart from biomedical research inputs. Yet, the balance between innovative engineering solutions and optimal and healthy human functioning with that novel technology is often unstable. The use of supportive technology and its consequences on functioning and health on the short-term, mid-term or long-term are often not fully researched or understood and unexpected health consequences in its broadest sense may eventually emerge, as was recently mentioned for medical implants in a worldwide survey (In an even more serious context: recently, a group of worldwide research journalists, presented the "Implant files," a review of the health-threatening consequences of insufficiently evaluated medical implants: "a year-long investigation uncovered the harm caused by poorly-tested medical devices").

Supportive, rehabilitation and assistive technologies (for mobility, exercise, or sports) are many in number and diversity, at times simple and often complex in technology and design. These supportive technologies are deemed crucial in resolving mobility and other functional issues during and beyond the rehabilitation of persons with disabilities, in daily life, public environment, or labour (Figure 1). Recently, Magasi et al., using structural equation modeling [33], showed that quality of mobility devices in persons with disabilities (i.e., defined by qualitative research strategies and a literature survey using criteria as reliability, ease of maintenance, reparability, replaceability, and portability) very much affects individual participation. Simmons et al. in 1995 already concluded that wheelchairs could be potential mobility and activity restraints in aging nursing home residents, when not mechanically and/or ergonomically optimized to the individual [34]. Rehabilitation and assistive technology innovations are often driven by industry and not so much by critical consumers nor supported by extensive research. As we all realize, technology is assumed to play an increasingly important role in future human functioning, albeit in healthy persons or in those persons with a chronic disease or disability. With an increasing gadget-oriented society, industry-driven technologies and their innovations may be taken easily for granted. Yet, this is not necessarily the case from a scientific perspective, even in rehabilitation medicine and practice. The journal of "Revalidatie Nederland" (Dutch Association of Rehabilitation Centers; https://www.revalidatie.nl/), "Revalidatie Magazine," presented in 2017/2018 a considerable number of technology-oriented articles covering a wide array of technologies (i.e., smart housing, domotics, e-health, sensor technology, Grail, Caren, exoskeleton, electrical stimulation, etc.) that most certainly may befit a technology-based future of rehabilitation practice, treatment, care and individual independent living (Figure 2). Their working principles and human-technology or human-environment interaction characteristics are however not always well understood in the context of user-behavior, as such frequently lacking scientific foundation with regards to effectiveness in rehabilitation and/or daily life and the more so with respect to user-driven functionality and health-based consequences.

AT+RT: A multitude, divers & growing number (>300.000) of supportive technologies, assistive devices, training, rehabilitation & measurement technologies.

RM in 2017, 2018: Smart housing, Domotics, Robotics, Sensors, Grail, Caren, Exoskeleton, Electrical stimulation……

Positive and enthousiastic stories, because it helps, expecting miracles! Sometimes they do!

But too often industry & gadget-driven, low innovative power & non-consumer market

And: often too much beliefs & little to no evidence-base!!

Figure 2. Some personal observations on supportive, rehabilitation, and assistive technologies (RT + AT), and their appreciation by professionals and rehabilitation institutes (Rehabilitation Magazine (RM)) in general.

This is understandable for many supportive technologies from a perspective of small industries that develop them: such industries lack financial resources for research and development (R&D), have to serve a very diverse user market, which requires a diverse range of technologies while lacking an adequate consumer market model. On another note, smaller industries can productively collaborate with knowledge and research centers to improve product quality and sustainability. Those networks effectively lead to innovation and new commercial products (e.g., Esseda wheelchair ergometer; https://www.lode.nl), that have a firm basis in scientific research. In that light, collaboration with experts in health economics can deliver economic predictive (Markov) models which can provide "headroom analyses," in the early stages of development. These predictive models help to determine a product's economic potential with respect to the potential healthy life years and based on our current understanding of human functioning in the context of supportive technologies [35,36].

The exploitation of ergonomics notions and human and technology "asset management" [37] is critical for supportive technology, especially in the context of health, functionality, and quality of life, but also cost-effectiveness. In our perspective, Asset Management can be defined as a set of procedures and tools of an organization/industry – but also a health care organization or rehabilitation center – to optimize the performances of physical assets in that organization over their life cycle. Assets can be products, devices, tools, but by all means also the human assets involved in the processes; in health care, both patients and professionals. As indicated with different textbooks, ergonomics of any assistive device or supportive technology is recognized and deemed critical in the context of optimal, that is, functional and healthy, human behavior in rehabilitation, and health care [28,38–40]. The use of the "Human-Activity-Assistive Technology model" (HAAT-model) is one of the contextual frameworks that help to model and oversee the complex interactions between human, task, and technology as well as human and social, cultural and physical environments; such a model stresses the importance of understanding human biology and psychology, and functioning at the individual level and beyond the mere technology and engineering [28]. Despite the few available textbooks and today's research efforts in often multidisciplinary consortia, the fundamental understanding of optimal (i.e., healthy & independent) human functioning in the context of assistive and/or rehabilitation technologies is still limited and not necessarily integrated in rehabilitation practice, industry or the personal fitting of assistive technology.

With an increasing health care demand in an aging population, and a tendency towards more self-management, not only the health care costs but also the quality cycle of rehabilitation care is under pressure, as is the professional understanding of its complexity at the individual level. Institutional choices on innovation and rehabilitation technology infrastructure must be based on evidence or at least with the best available knowledge in networks of multidisciplinary collaboration and in a context of cost-effectiveness.

A recent exemplary case stresses the importance of continued research, education, innovation, translation and implementation in the context of freedom of mobility for persons with a disability and the built living environment: a ramp of 15% for wheelchair users to get in and out of a train, is it a simple case of optimal supportive technology? Let's take this case to debate this in the next section.

Environmental ramp design: a simple case for supportive technology?

A ramp at for instance the train platform is a simple supportive technology in the public environment: a ramp helps to bridge different horizontal levels in the built environment, in buildings, pavement, or when going on/off train platforms. Recently, we were involved in a discussion involving a new train design that would require a 16% sloped ramp for wheelchair users to enter and leave the train. The potential impact of such a ramp on the upper body of a male wheelchair user of 90 kg using a well-maintained handrim-wheelchair (15 kg), while negotiating the ramp at a 0.2 m/s speed is depicted in Figure 3. This would require a continued production of almost 34 W in external power. Depending on the training status, lesion level, and age this would be in the range of 60–120% of the peak aerobic power output (W) of an average group of individuals with a spinal cord injury [41–44]. Power output (W) is the measure for external work of movement and wheeled mobility. Power output is a mechanical term for the task performed and in terms of human work, it is the counterpart of energy consumption of the individual, where energy consumption is often measured during steady-state whole-body exercise on an ergometer with the use oxygen uptake technology. Power output is the result of that exercise, delivering mechanical work (A) at a given speed (V) and a given resistance force (F), and where their product (FxV) equates to power output (W) by definition. In daily life, power output in wheelchair propulsion is the sum of internal and rolling resistance, gravitational force (up an incline or slope), and air friction. Recently, Bertocci et al. presented a biomechanical delineation of different slopes for public buses and their effects on push biomechanics in seven novice non-wheelchair users [45].

Depending on the slope and length, we tend to accept it as an optimal solution for many wheelchair users in buildings or public space, creating accessibility, independence, participation, and quality of life, as supportive technologies should inherently do. Yet, when looking more closely, it may well be the reverse and often be a considerable challenge for many manual wheelchair users.

Fear of falling, tipping, or simply not being able to negotiate the ramp by a lack of skill and/or mere power, that may greatly impact participation when we take the position of the individual wheelchair user as a starting point. Literature has dealt with that sufficiently, yet the reality is different and society and health care alike are changing, but potentially not always for the better. Despite the role of organizations for "user-centered design," "universal design," and "design for all", built environment provides many challenges for wheelchair users (http://www.

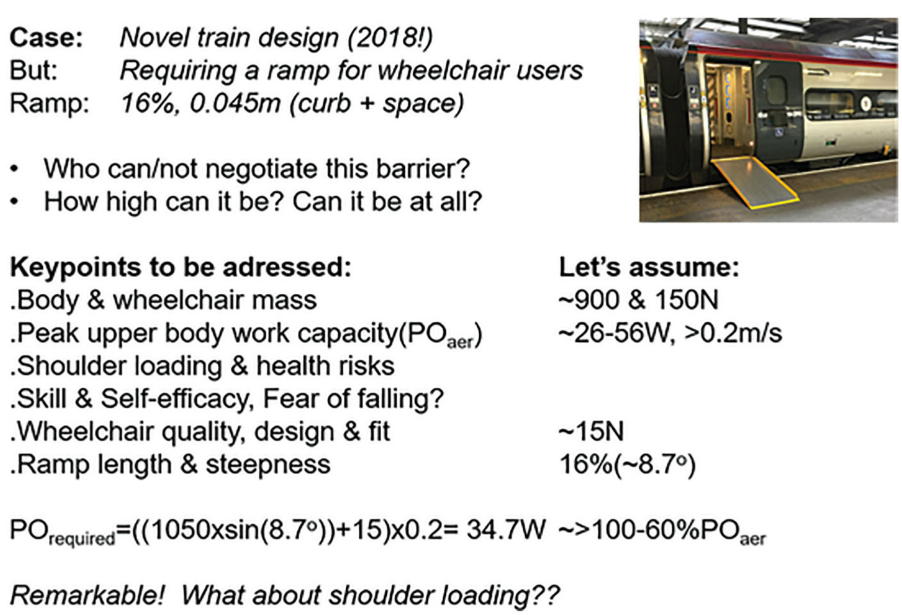

Figure 3. A biomechanics summary of the physical stress (PO(W)), strain and work capacity (POaer (W)) for a virtual handrim-wheelchair user force (F) with a spinal cord injury who is negotiating a 16% ramp: he/she may not be able to negotiate the ramp due to a lack of sufficient peak power (POaer). This is apart from the potential risk for shoulder injuries in the majority of manual wheelchair users.

universaldesign.com/; http://designforall.org/). The issue of "wheelchairs and slopes or ramps" has been subject of scientific study and debate in a diversity of international wheelchair studies [46] (a quick scan on Pubmed using "wheelchair slope" as a search term, generates over 60 publications, addressing physiology, biomechanics, skill etc. of slope issues in wheelchair users). Clearly, we must keep in mind the complexity of the physical environment for wheelchair users in general and for those with limited abilities or skills (e.g., those with a (high) spinal lesion). In this context we would like to add the following other notions to the debate of mere power production during daily life: skill, self-efficacy, both critical in any rehabilitation case and obviously wheelchair quality and the role of power assist.

Motor skill, practice, and exercise

Motor skill is crucial in rehabilitation, daily life, and adapted sports, especially in fully new motor modalities of transportation such as in those with a spinal cord injury, where 80% are wheelchair dependent. With growing pressure on health care costs, however, skill seems not to be of high priority in rehabilitation and the importance of motor skill in this context is hardly understood. In principle, the better trained are better off in societal participation, so are the more skilled. The basis is in propulsion skill and capacity [47–50]. The slope of 16% will be a "piece of cake" for most wheelchair athletes one would assume. This will be true for a complex skill such as negotiating a slope, climbing a curb, or making a wheelie. These are expected to be trained in rehabilitation, yet only available to those with a sports career and a good understanding of wheelchair mechanics and maintenance, athletes often are in the possession of lighter and "better maintained wheelchair material." This is however not at all true for the majority of wheelchair users and nor for all wheelchair athletes, as was indicated by Flies-Douer [51].

The energy cost of locomotion is generally viewed as an indicator for physical strain and can be minimized through training, practice, and skill acquisition of the user, as well as ergonomic optimization of the task, tuning the technology or environment to the user or optimizing task characteristics. This is true in prosthetic walking or manual wheelchair use. Apart from the user-skills, talent, and ability, material quality and ergonomics are key! On another note, physical work capacity in a task will affect the physical strain of that task, and the higher the work capacity in a task, the lower the relative strain. Training of aerobic, anaerobic, strength, and flexibility elements are the key operators here. Underlying training and practice mechanisms is also the skill change that one may expect as a consequence of motor adaptation and learning. In cyclic motion patterns, motor skill improvement can be monitored elegantly with oxygen uptake or energy cost measures (walking, running, wheelchair propulsion) and expressed in the economy, cost index, or gross or net mechanical efficiency.

Energy minimization is an underlying driver for any cyclic motor behavior. This was advocated for by Sparrow and Newell in the 1990s [10,11] and later Almasbakk, Whiting, and Helgerud [52]. Recent experimental motor learning work in gait and wheeled mobility stress this important notion [17,20,47,48,53,54]. The consequences of amputation and prosthetics or of a stroke on the energy cost and biomechanics of gait have been well described [21,54,55], yet the awareness for processes of adaptation and (re)learning of motor skill in rehabilitation practice still require considerable research and implementation efforts. Obviously, the question, "what is neuro-physiologically driving the inherent minimization of energy cost in the motor learning of cyclic motions in a biological system?" remains one of the holy grails of exercise physiology, biomechanics, motor control, and learning.

Wheelchair skills: self-efficacy and perceived importance

Among the questions in rehabilitation that are not asked enough, is the question 'what specific daily skills are thought most essential for the functioning of the individual'. This was explored by Fliess-Douer for 24 daily life wheelchair skills (e.g., one handed-wheelie, transfer into/out of the car, crossing a steep slope, wheeling 5 min on a treadmill) in a questionnaire-based study providing an understanding of wheelchair skill and their perceived importance ("essentiality") for daily functioning [51].

Being able to negotiate different forms and levels of ramps, is perceived as important for daily functioning. The learning of those skills appears to happen much more through peers, while clinical and ambulant rehabilitation as a learning environment lags very much behind in different western countries, also in the Netherlands. Fear and "avoidance of acting" will be the consequence, and self-efficacy in wheelchair skills – being aware of your ability to perform them – will fall behind [56]. The perceived importance or essentiality of specific wheelchair skills among other international Paralympic wheelchair athletes, as well as the notion from whom they learned the important skills were nicely worked out by Fliess-Douer [51].

Slopes and transfers were among the five most prioritized of the 24 manual wheelchair skills, while the perceived level of wheelchair mobility gained during rehabilitation ranged between 10-36%. Many skills were learned from peers and only after rehabilitation [51]. Being able to do a wheelie is essential in taking a curb, negotiating a ramp downwards and for instance negotiating a small space between ramp and train floor or platform. Those skills are deemed to be increasingly less trained in today's rehabilitation practice due to time and financial constraints (In 2018 a fundraising initiative started by Handicap.nl to train wheelchair skills to 200 chronic wheelchair users on an annual basis! (See: https://handicap.nl/projecten/rolstoeltraining-met-wheelchair-skills-en-handicapnl/ (Dutch))). More detailed training of essential daily life wheelchair skills and its monitoring should be an integral part of rehabilitation practice, clinical or ambulatory, thus building independence and participation in a truly effective manner. Systematic monitoring thereof with outcomes such as propulsion technique (e.g., with 3D measurement wheels), mechanical efficiency during submaximal steady-state wheeling on the treadmill, a wheelchair skills test battery and task-specific wheelchair work capacity will help identify those who can become independent in a true sense [57–62]. Being part of motor skill learning and control, this is a matter of practice, and skill-building will help overcome the fear of falling or tripping and becoming self-evident in an array of skills. This will further boost independence and participation. Although the above makes a case for manual wheeled mobility, its plea is deemed equally important for the functionality and use of other assistive devices or in other groups of persons with a chronic disability, such as those with stroke, amputation, or cerebral palsy. Yet again, putting it into practice and accepting its importance, is not self-evident in today's rehabilitation practice. The congress is one way to create awareness of those changing panels in rehabilitation practice and health care and is potentially the multidisciplinary and collaborative venue to change and start turning these developments. Researchers should keep in mind that they can contribute here and should make a difference.

Upper body overuse, power assist, smart monitoring, and prevention

Frequently encountering ramps in the public space may lead to local musculoskeletal overloading [24,63], increased dependence, and societal isolation, which is the opposite of a barrier-free society. The challenges -in short- of any ramp are driven by the mechanics of the slope of the ramp, a curb or space somewhere in between, but also by, and the quality of the wheelchair, the work capacity of the wheelchair user, the body weight and the skill level and self-efficacy to use a wheelchair. In any case, training and practice of skills and capacities are fundamental.

Another way to negotiate a ramp of 16% in those with limited work capacity, and thus preventing shoulder overload and limited radius of action, is the use of power assist technology in handrim wheelchairs. Power assist technology is deemed to reduce physical strain, including shoulder loading [64,65]. Today's technology is however rather crude in its power control, it is non-individualized and lacks smart technology and learning ability. This may impact actual ramp negotiation in safety and ease. As is shown by De Klerk et al., current power-assist technology requires a learning phase (PAPAW) [13], as does regular handrim-wheelchair propulsion (RHW) (Figure 4). This is expressed here for able-bodied novices during steady-state wheelchair propulsion practice on a motor-driven treadmill in increased gross mechanical efficiency, reduced heart rate, and perceived exertion, as well as a drop in stroke frequency and the magnitude of two-dimensional left-right movement on the treadmill. Transfer effects between the two modes were non-significant (Figure 4).

Smart technology may support the learning curve; beyond that smart data-driven learning algorithms may individualize support characteristics among individuals and over time. Using the available force-sensing technology, understanding of individual work capacity, as well as detailed anthropometry and

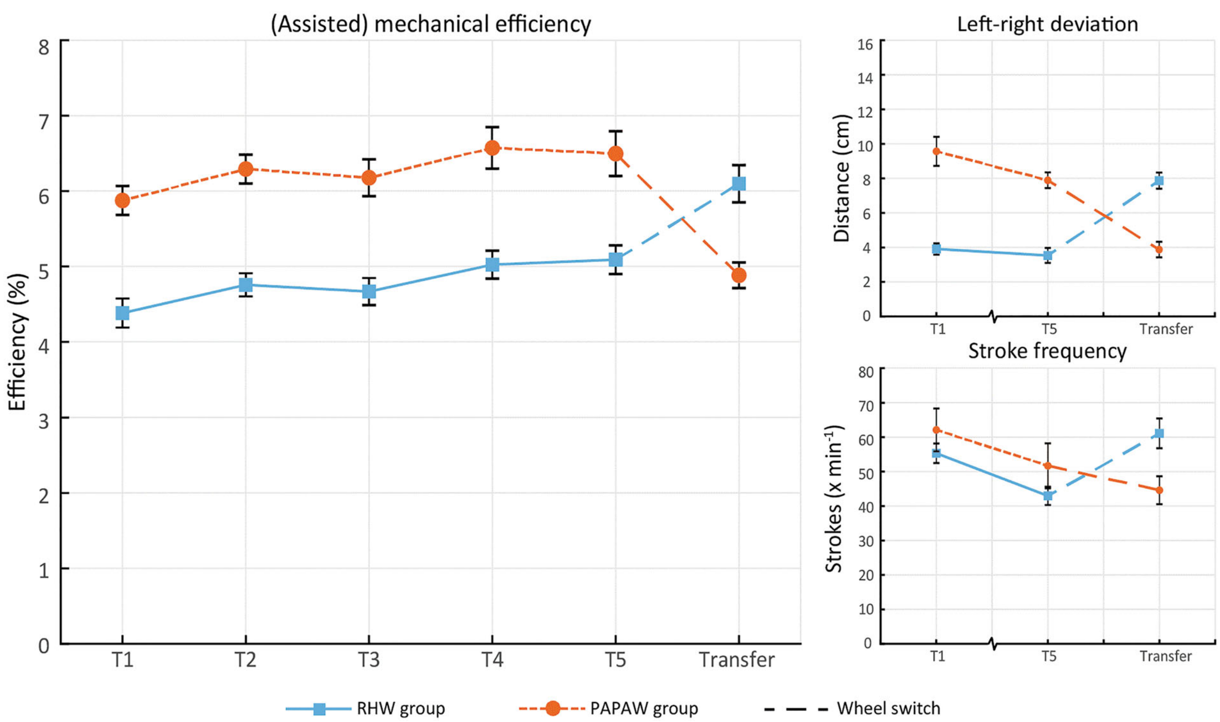

Figure 4. Averages (±SEM) of (assisted) mechanical efficiency, heart rate, left-right and forward-backward deviation and stroke frequency of each session of low-intensity practice for a regular handrim-wheelchair group (RHW; $n = 12$) and a power-assist wheelchair group ((PAPAW; $n = 12$) on the level treadmill. All subjects are healthy novices without prior wheelchair experience. This figure was adapted from De Klerk et al. [13] and "this article is distributed under the terms of the Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The Creative Commons Public Domain Dedication waiver (http://creativecommons.org/publicdomain/zero/1.0/) applies to the data made available in this article, unless otherwise stated."

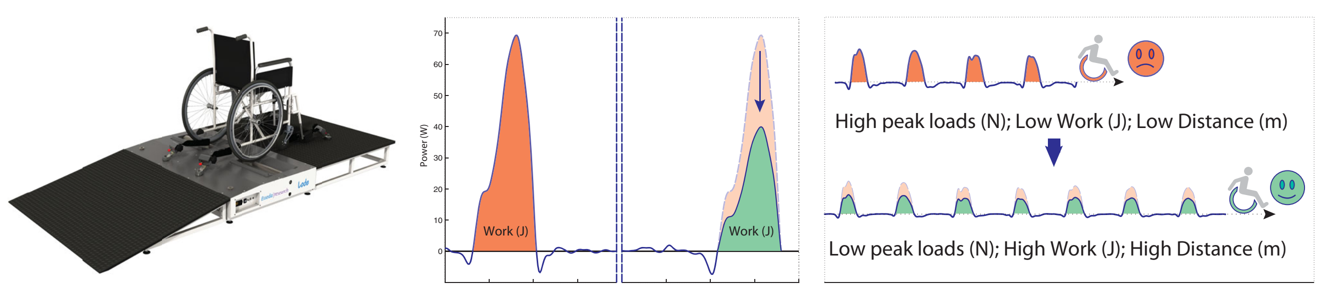

Figure 5. Esseda (Lode BV, Groningen, The Netherlands) in left panel and the potential role of sensor-based smart power-support and monitoring for new generations of power-assist wheelchairs (bottom) and regular handrim-wheelchair propulsion (top) at the right panel.

biomechanical modelling may help detect “red zones” in shoulder loading on the one hand [66,67], and risks of inactivity and sedentariness on the other hand. The smart platform would simultaneously allow individual coaching. The individual fine-tuning would be helped with a computer-controlled wheelchair ergometer that allows the use of the individual wheelchair, and systematically testing of (sub)maximal aerobic, anaerobic and isometric wheeling capacities [58] using, for instance, the recently designed “Esseda” ergometer (Figure 5), and the individualized setting of the smart platform in the power assist wheelchair. The smart platform would be equally important in the development of regular and “light” versions of power-assisted wheelchairs or in non-power supported handrim-wheelchairs; in the latter simply using sensor technology and the platform to monitor and coach the user on balanced active healthy behaviour.

Due to individual risks of musculoskeletal upper body overuse, falls, and “trips”, the lack of individual capacity (strength, power), individual wheelchair skill, and self-efficacy or confidence in many wheelchair users, we basically would advise against any ramp in the physical environment. It does impair activities and participation in society in many ways for many wheelchair users, thus decreasing individual independence. But on another note, we must accept that acceptable ranges of slopes and ramps are a necessity in the wider physical environment as long as we deny the inclusive design in building and societal infrastructure. Having ramps in today’s society does provide accessibility to many, yet denies accessibility to others with very limited physical abilities or resources. Then it goes at the cost of individual independence and participation for instance for those with a walking disability, in many wheelchair users, for example, those with spinal cord injuries, especially the high lesions, the low trained persons, the elderly. The consequence for them can be no other than asking for “Help!” choose alternatives or simply to stay at home, which is opposite to the “participatory society” we are asked to live in today. The Dutch public transportation system solved in a considerable number of places the accessibility issue for wheelchair users, individuals with walking impairment, and those with strollers or other rolling objects by making level transfer options to the street. So, it can be part of the design in public transportation and the physical environment. Other than the USA, we do lack an Americans with Disabilities Act (1990, 2009) in the Netherlands and other European countries, however, and measures around the accessibility of public space are left up to the “market” and local governments in the first place.

Societal and health care context in “mobility, exercise & sports”

With an estimated 1% of the World’s population being dependent on wheeled mobility (while 1 in 7 people has a disability for that matter) [68], rehabilitation, as well as industry and society, are to be receptive for the potential barriers and challenges that lay ahead in lives of people who are dependent on wheelchairs (http://www.who.int/topics/disabilities/en/), especially concerning a healthy active lifestyle (Figure 6). Manual wheelchair propulsion is biomechanically straining and inefficient in terms of coordination, often leading to upper extremity discomfort and injury [27]. On another dimension, inactivity due to the manual wheeled mobility lifestyle and the underlying disability, potentially impact cardiovascular health as a consequence of consistent physical inactivity or disuse.

A seemingly avoidable imbalance of stress, strain, and capacity will impact the daily functioning of the user. Vehicle mechanics and technology, ergonomics of user-wheelchair interfacing and design, and user abilities are key to individual freedom of mobility and range of action, that is, priorities for functioning, participation, and quality of life. Premium technology and individualized ergonomic fitting, beyond quality wheelchair materials and propulsion skills, are required to healthy and functionally productive living. Such a highly individualized set of priorities needs not only to be considered in the context of wheeled mobility but evidently also in, for example, those individuals with limitations in gait, those who use prosthetics or exoskeletons, or in individuals with upper body impairments, prosthetics or robotics. These persons require knowledgeable professionals and coaches in early rehabilitation, especially where rehabilitation and health care systems are continuously changing and where health insurance costs dominate the quality debate, and health and well-being itself seem to be at risk. As such, there is a need for consistent long term evidence-based monitoring and advice on functioning and health. Supportive and monitoring technologies will have a place here, especially in a society where patients and clients rapidly outnumber caregivers and professionals.

“Human and technology asset management” in the context of rehabilitation and health care is fundamental to quality care, treatment, and outcomes. Yet, in a participation-modeled society, it becomes more and more a challenge, and often the personal responsibility based on self-management and self-organization. If not supported by individualized smart technology, this complex personal challenge however will allow only the happy few to be successful. Preservation of health and preventing secondary health risks of wheeled mobility – or any other assistive device for that matter – can indeed be supported by eHealth [69], using sensor technology and smart knowledge-based algorithms. For instance, with the current scientific understanding, propulsion technique, mechanical loading, and cardio-respiratory strain may be monitored and advised on during the day with the help of wheel-hub based torque sensors and onboard smart machine learning algorithms that use individualized bandwidths of healthy (active) behavior. In short, such future “onboard” platforms of smart technology are expected to provide opportunities on individualized monitoring, coaching, and feedback, that helps to create a healthy living environment and lifestyle.

From laboratory to field testing in “mobility, exercise & sports?”

This requires rehabilitation, movement, and sports sciences to move research from the laboratory to the fields of clinical practice, daily activities, and sports. Such ecologically more valid studies and measurements would benefit experimental validity and generalization of the outcomes. It would accommodate assistive technology research for wheeled mobility, exoskeletons, prosthetics, or other supportive technologies alike. Yet, with merging all research out-off the lab, we would miss a degree of standardization and accuracy on the other hand, which must be compensated for by the data-driven nature of the large information streams that often come available. The ethical notions of human research and the privacy of information are challenges that require careful consideration in the currently boosting information-driven big-data society.

With the growing industry-driven availability of smart sensor technologies and their improved measurement quality and the miniaturization thereof, there is indeed a growing tendency for field testing, ambulant measurement in rehabilitation, daily life [70,71] and in adapted sports [72]. For instance, physical activity,

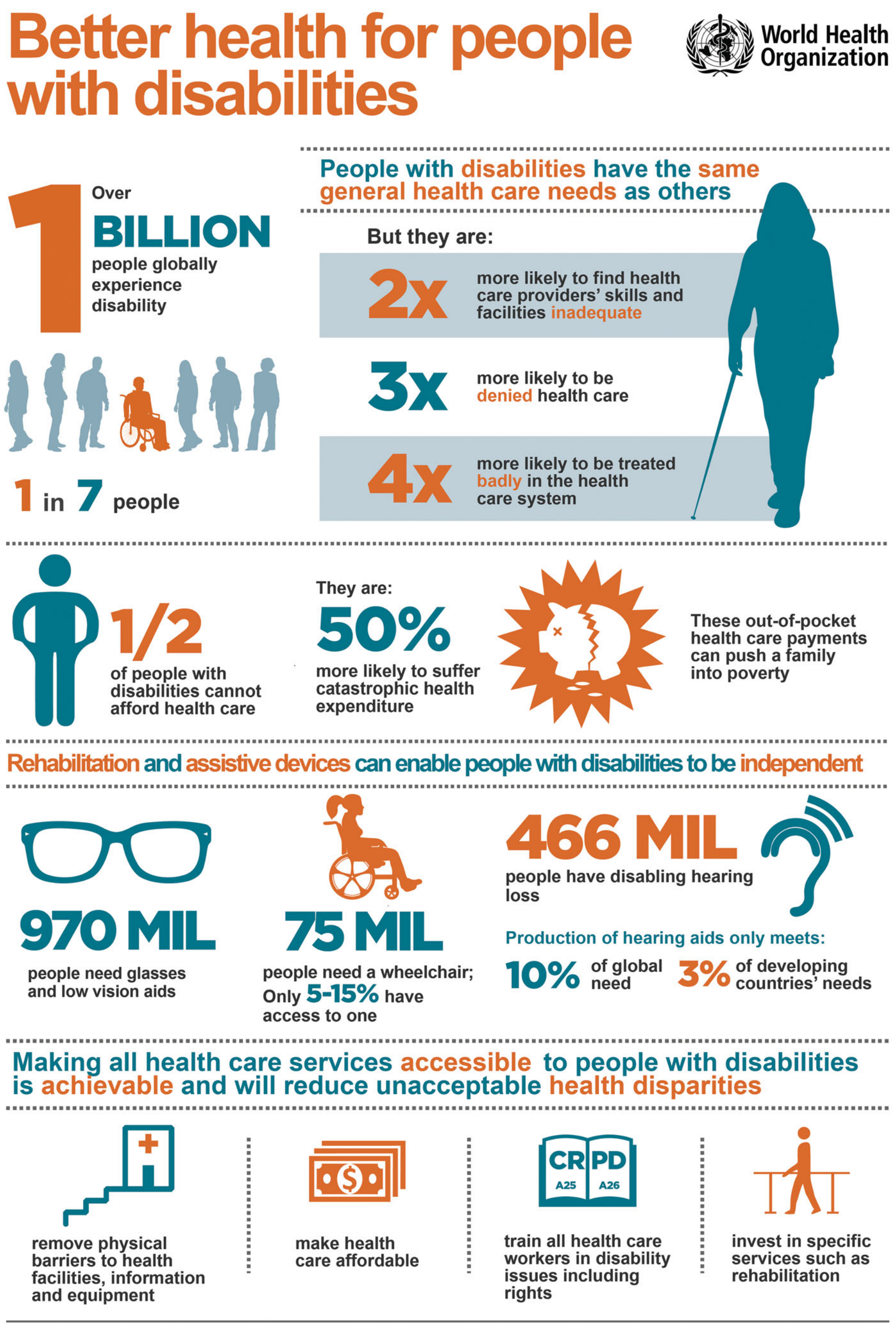

Figure 6. Global disability demographics following the World Health Organization. Published in World Report on Disabilities. Geneva: World Health Organization; 2011. Licence: CC BY-NC-SA 3.0 IGO.

productivity, skin pressure, humidity, temperature, stress are all concepts that are within the grasp of sensor-based information streams, often in daily life through our smartphone connectivity. The use of 1D, 2D, or 3D accelerometers for the monitoring of physical exercise are commercially available through our phones or smartwatches. Their accuracy and reliability are questionable in many cases. The combination of accelerometers with inertial sensors and gyroscopes (IMU's; https://www.sensorsmag.com/components/overview-mems-inertial-sensing-technology) are employed, for example, in human gait studies or in the in-field behavior of wheelchair basketball athletes during games. These are just two of these developments that allow analyses of kinematic and kinetic performance and behavior in addition to the more traditional field testing with mere observation or with local GPS systems or video recording [72,73]. IMU instrumentation on wheelchairs can help optimize the role of wheelchair fitting based on in-field behavior of the wheelchair-athlete combination [74], and the same may hold for the role of classification [75]. However, so far, no information on the mere power output in wheeled mobility during the field testing is available other than through 3 D measurement wheels. A "PowerTap" (https://www.powertap.com/) is an instrumented hub that befits chain-driven wheels of bicycles as well as handcycles and allows the continued measurement of external speed, heart rate, and power output. Power output (W) is critical to interpreting any bodily signal that is measured in the athletes or users during propulsion. Such technology is not yet available for field measurements in handrim wheelchair, but is used worldwide in hand cycling and (disabled) cycling. It helps to monitor individual field performance and training, but also allows the athlete to be coached on power-based training schedules. In the context of clinical rehabilitation as well as adapted wheeled sports such devices would support our understanding of daily activity and "work done" in a wheelchair and would allow dose-response relations at the group and individual level when combined with lab-based peak aerobic exercise testing and/or sprint testing.

Such technologies may be highly useful for athletic classification in wheeled sports. Athletic classification is critical in both Paralympic individual and team sports. A valid and evidence-based classification is yet not available in any of the Paralympic sports. Different initiatives have been taken where the underlying questions are complex and require substantial research efforts [76]. Recently, the UCI (Union Cycliste Internationale) sponsored two research projects in cycling and hand-cycling, respectively, in a collaboration between Swedish and Dutch research groups [77]. Altman and colleagues showed the important role of the trunk in wheelchair rugby classification [78]. Again IMUs can play a role in the individual player characteristics in the context of classification in wheelchair team sports [75] that goes beyond that of more traditional field test outcomes at the group level [72]. IMUs may also help in understanding the performance-side of classification in the field and running events in athletics or a skill-driven sport like handigolf [76], where talent, skill, training, and disability interact with demographics into performance and where IMU-based motion and acceleration patterns may help dissect classification from that.

Performance capacity and monitoring of training in adapted sports or rehabilitation practice benefit from standardized exercise testing under homogeneous conditions and testing constraints. Lab-based protocols are basically the gold standard, both in the aerobic and anaerobic energy domains. Task-specific aerobic exercise testing has become an increasingly common modality in rehabilitation practice [79], while anaerobic testing, for example, Wingate testing, slowly migrates from purely experiment-based work towards clinical and athletic applications [80]. Anaerobic capacity is deemed to be highly essential in the functionality of the daily life of rehabilitation populations, yet it is only rarely specifically trained [81]. Similarly, the study of motor skill and technique in wheeled mobility would benefit from standardized lab-measurements as presented by Leving et al. [82,83], but also by data-driven notions advocated by Van der Slikke et al. [74,84,85]. Merging both approaches would benefit our deepened understanding of (athletic) motor skill, motor learning, and performance capacity in the context of disability, classification, and training regimes.

Other issues of a research agenda for "mobility, exercise & sports"

Typical sport and physical activity behaviors throughout the world are changing, with people becoming less physically active and more sedentary [86]. A pandemic of inactivity and sedentariness potentially results in rising incidences of cardio-metabolic disease and other chronic diseases. Rehabilitation has an important role here in populations after disease or trauma. New guidelines have emerged lately for specific patient groups (e.g., cerebral palsy [87], spinal cord injury [27,88], but also more recently in a general perspective of disability and active lifestyle developed and published by the British government (Figure 7) [89]. Evidence-based guideline development is one step ahead, using such guidelines a second. This requires many to change towards a more active healthy lifestyle. This requires professional guidance, coaching, and, where possible, monitoring of dose and responses. Krops et al. recently developed a physical activity stimulation program for "hard-to-reach individuals with a disability" [90]. Van der Ploeg et al. [91–94] developed a motivational interviewing-based program for physical activity and sports in a nationwide network of rehabilitation centers and departments in the Netherlands. Martin Ginis et al. approached it from a different angle in spinal cord injury (SCI)-Canada considering geographic and cultural differences [95]. The research project Rehabilitation, Sports & Active Lifestyle (ReSpAct 2.0; www.respact.nl) [92,94,96] employed a rehabilitation center-based approach of motivational interviewing strategy among a diverse cohort of persons with a physical disability and/or chronic disease. This observational longitudinal study will continue to follow these persons with impairment limitations on their physical activity behavior and sports involvement up to 6 years after the conclusion of their rehabilitation and evaluate whether they meet today's guidelines for health-related physical activity. This will help to further our understanding of the important constructs of physical activity, fatigue, and pacing among individuals with a disability.

Ambulant monitoring of the physiology and biomechanics of activities, exercise, and training has become more and more common practice in adapted sports, as stated above. Today simple activity monitoring at the individual level has become highly feasible with the current generations of smartwatches and smartphones. There is a continued trend to application among people with a disability or chronic disease. Even in wheelchair mobility, these commercial devices generate potentially logical information on daily activity. Recently, activity monitoring in daily wheelchair propulsion was employed with the Active8 [15], a novel activity monitor evolved from the much more complex research set-up that was designed initially by Bussmann and colleagues [97].

On another note, physical activity measurement in groups of persons with a disability is often still questionnaire-based [92,98], while objective measurements are indeed feasible, available, and often seen as the better way to go. However, this is not necessarily true, as stressed by Kopcakocva et al. [99]. Accelerometry-based devices are becoming more and more available for activity monitoring as do smartwatch or smartphone-based technologies for health surveillance. The underlying algorithms and calculus are, however, not yet tuned to special populations and those with lower speeds, asymmetry, or other movement irregularities in gait. There is a great need for a better understanding of physical activity as an energy burner both in the use of valid and reliable subjective and objective monitoring measures. The Dutch WHEELS/D-ACT-WHEEL projects have sparked research on activity monitoring and coaching of lifestyle challenges among populations that are wheelchair users. A challenge that uses different sensor and smart technologies for monitoring and feedback.

Handbikebattle

An active lifestyle in users of handrim-wheelchairs would always be in a fragile balance to upper extremity loading. Here the handcycle is the preferred alternative mode of locomotion [100–102], being more energy-efficient and less mechanically loading for the shoulders due to the 360° fully active cycle with both flexors and extensors being involved. As a consequence higher speeds and/or distances can be travelled [103,104]. With the work of Valent et al., and handcycling became a recognized alternative fitness modality in rehabilitation practice and beyond [105–107]. In the aftermath of the Dutch multicenter Umbrella cohort study and

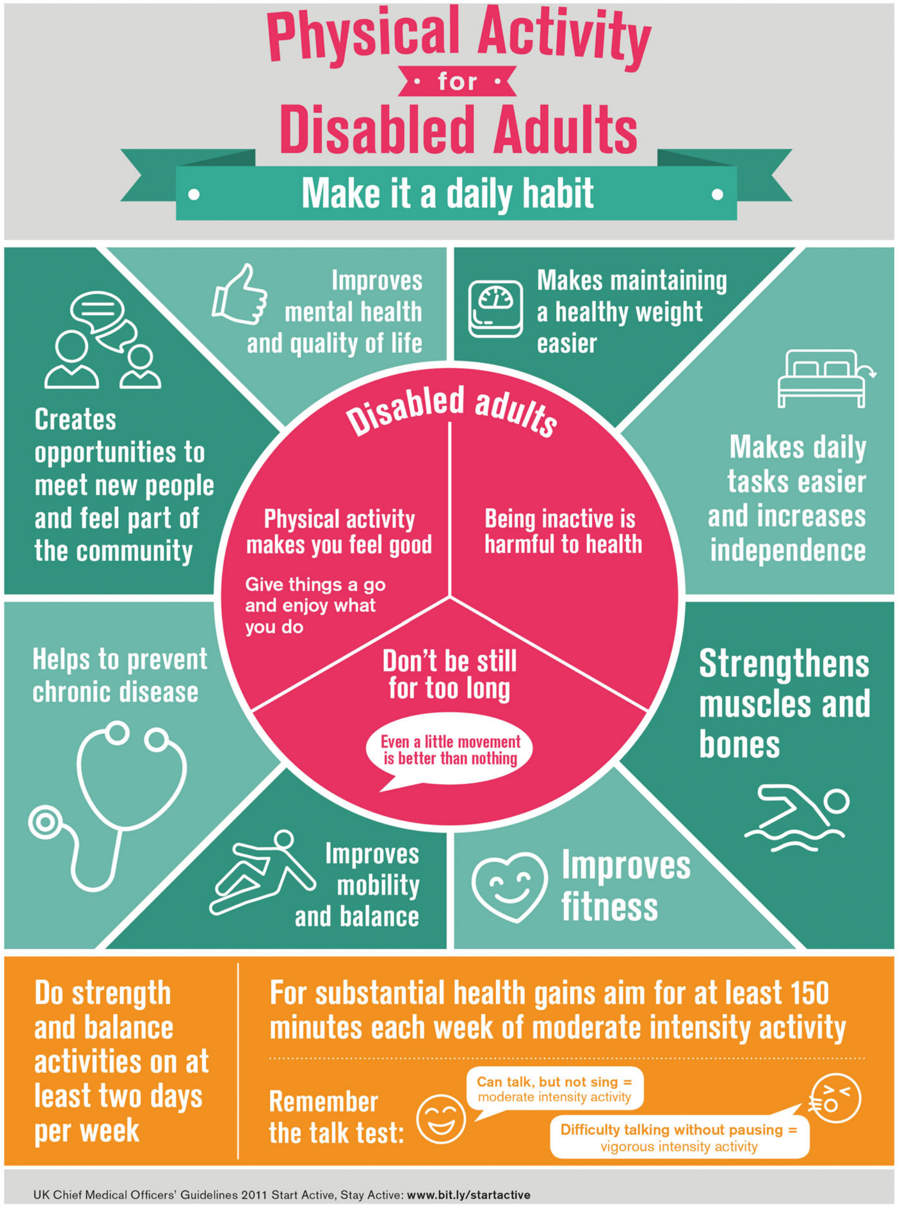

Figure 7. Infographic on Physical Activity for disabled adults. Published in: UK Chief Medical Officers' physical activity guidelines, 7 September 2019, Department of Health and Social Care; ©Crown copyright 2019, this publication is licensed under the terms of the Open Government Licence v3.0, except where otherwise stated (nationalarchives.gov.uk/doc/open-government-licence/version/3).

the ALLRISC project on restoration of mobility and health among persons with spinal cord injury, the Handbikebattle (www.handbikebattle.nl) was born in 2012. This is an annual 6-month handbike training (in 12 Dutch rehabilitation centers), which precedes the 20 km uphill handbike mountain challenge in June in the Austrian Kaunertall. The event is organized by the HandbikeBattle Foundation and the centers involved and meant for (inactive) people with a lower-limb disability, after inpatient rehabilitation [108,109]. The event is accompanied by a longitudinal cohort study that involves all participants each year and follows them in a pre-post rhythm of measurements prior to training, just before the mountain race and up to a year after the event. The measurements are focused on physical and mental capacity, and well-being outcomes [110–113]. Handcycling is assumed to benefit both the shoulder health and the cardio-metabolic condition and beyond that is fun as a sport or recreation outdoor. Attach-unit bikes provide an alternative model for commuting, but neither of them could enter shops, housing, or other public buildings [100]. The HandbikeBattle may be seen as a first stepping stone towards a model for life-long rehabilitation care for persons with a spinal cord injury, as suggested by Stuart et al. for stroke patients [114].

Health care 2030: prevention and lifestyle medicine?

All in all, assistive technologies and their daily use in the public environment may indeed reduce health risks - in the musculoskeletal system as well as in the cardiometabolic system -in those with a disability or functional limitation [115]. This is evident for individuals with mobility impairments such as lower limb impaired individuals (e.g., stroke, amputation, cerebral palsy, spinal cord injury) or those with capacity limitations (e.g., those with cardiac or lung disease, cancer). This will impact daily functioning,

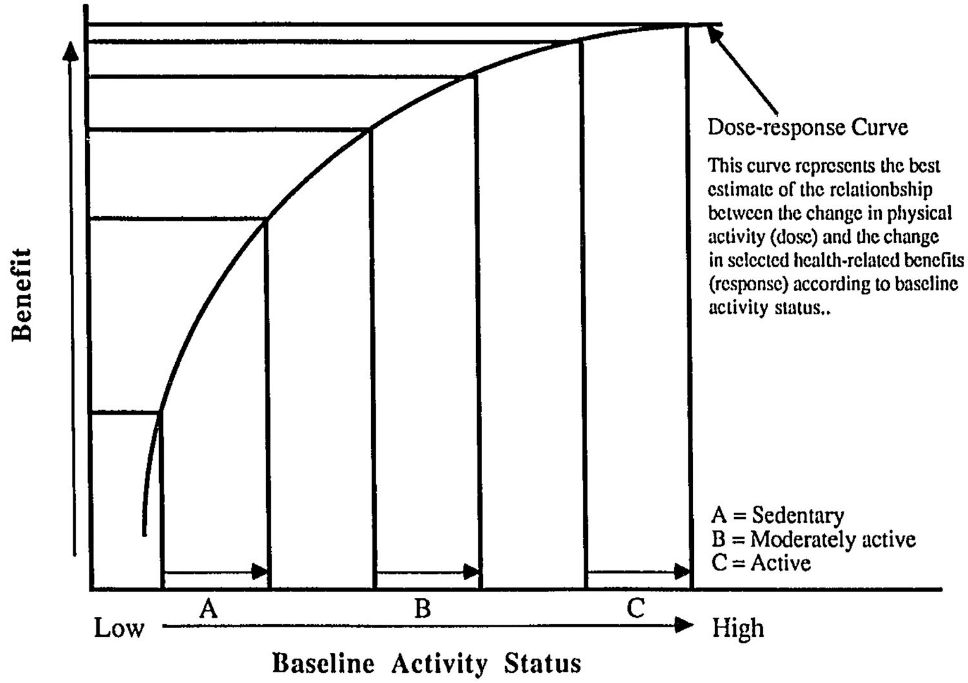

Figure 8. The benefits of physical activity as postulated in this theoretical dose-response association presented by William Haskell in his 1994 Wolffe Memorial Lecture at the American College of Sports Medicine annual meeting [118]; the lower the fitness, the greater the benefits of a more physically active lifestyle. This figure was reproduced with permission from Haskell and Wolfe [118].

participation, and independence and quality of life [116]. Physical inactivity and sedentariness are a growing problem in a changing world of automation and mechanization. The recent "Special Eurobarometer 472" reports on sport and physical activity in all member states of the EU and signals a downward trend in most countries on "regular exercise or play sports" category and the inverse on the category "never" [86]. The Dutch guideline for a healthy active lifestyle (2017) prescribes 150 min/week (30 min/day) of moderate to vigorous physical activity (e.g., walking, cycling) in adults and older people [117]. "The more the better," and "something is better than nothing," which notions were already stressed by Haskell in 1994 and expressed in his diagram on physical activity, intensity and health benefits as indicated in Figure 8. [118]. Demographic developments drive a changing health care system with different changing medical disciplines, including rehabilitation medicine and the evolution of preventive and lifestyle medicine. Inactivity and sedentariness drive health care industry and the societal public health agenda, creating among others waves of accessible smart and sensor technologies (Supporting Health by Technology, 8th International Conference, Center for eHealth & Wellbeing Research University of Twente, UMCG, University of Groningen; Enschede, The Netherlands [119]).

Society is changing, so is health care, and with that the field of rehabilitation practice. This societal change follows trends in technological innovation for diagnostics and treatment, the demographic changes with growing numbers of elderly and fewer younger individuals being born in western societies, and the individual wish for a long and healthy life leading to consequently complex personal and political choices.

This drives the costs of healthcare and the need for cost-effective choices. With a participative society, individual responsibilities towards health increase, physical fitness and activity and other healthy lifestyle dimensions are key to health. Recently, the Dutch Health Care Board made a plea for preventive health care. The new University Medical Center of Groningen (UMCG) research mission and vision embraced – next to mechanisms of disease and innovative strategies and techniques – prevention as one of the three central themes of research. In 2018 the University of Groningen and UMCG founded the Aletta Jacobs School for Public Health (https://www.rug.nl/research/healthy-ageing/aletta-jacobs-school-of-public-health/). The "Beweegziekenhuis" ("a hospital that expresses healthy aging, active lifestyle and "exercise = medicine' in its essentials" [120]) has started to become more visible in the academic hospital organization [27] not only in research but also in patient care. Just recently at "the International Society for Physical Activity and Health Congress (ISPAH)" (15 to 17 October 2018), the new digital Moving Medicine tool was launched, intended to help healthcare professionals advise patients on how physical activity can help to manage their conditions, prevent disease and aid recovery" (https://www.gov.uk/government/news/new-physical-activity-resource-for-health-professionals). "Prevention" as one of three central research themes emphasizes this evolution in a very visible way. With different experiments on pre and post-rehabilitation [8,121–125], the "Lifestyle Navigator" [126] and "Physicians Implement *Exercise = medicine*" (PIE = M) [127], a collaborative project between VU Medical Center in Amsterdam and UMCG to provide an understanding of the potential and role of the doctor in the implementation of exercise, active lifestyle and sports (and later lifestyle) as medicine in direct patient treatment, exercise as a recipe; this should lead to a new e-based tool that supports the doctor in deriving an individualized advice or recipe. A similar approach is seen in the United Kingdom, where the Department of Health and Social care pronounced its ambition in "Prevention is better than cure; our vision to help you live well for longer" (https://www.gov.uk/government/publications/prevention-is-better-than-cure-our-vision-to-help-you-live-well-for-longer).
Prevention is indeed the way to go in an ever-aging society and where health care costs keep growing beyond our reach. Following the worldwide movement of "exercise = medicine," the paradigm of "lifestyle = medicine" is the next step to take in health care, professional training, and medical research. This will

be even more so for rehabilitation medicine and care [128]. With those ambitions well aligned, the future could turn out to create a healthy aging population as part of a man-made "Blue Zone" in which health care, healthy living, durable living environment, and societal organization synchronize with one another (1st Healthwise Lustrum Conference Man Made Blue Zones: Healthy Ageing Together, Center for Expertise Healthwise, University of Groningen, 3 April 2018).

Rehabilitation 2030

In February 2017, the World Health Organization organized a call for action to meet the ever-increasing worldwide need for rehabilitation with a policy agenda [129–133]. This evolved into a report "Scaling-up rehabilitation as the world-wide Health Strategy of the twenty-first century" by Gutenbrunner et al. in a special issue of the Journal of Rehabilitation Medicine [134]. With an aging population and the increasing prevalence of non-communicable diseases, limitations in functioning and disability are increasing [135]. The specific team-oriented approach aimed at human functioning and the reduction of consequences of (permanent) disease or trauma can arguably benefit the general health care system and the emerging needs for people with functional limitations [135,136]. Following Gutenbrunner et al., the implementation of the strategies and character of rehabilitation medicine and care into a broader health care system would potentially generate an array of different types of health-related rehabilitation services, from acute to post-acute and long-term care services, including community-based rehabilitation service [137]. The latter development would evidently link to the development of more in-depth specializations such as for instance geriatric rehabilitation.

In short, rehabilitation medicine and practice will evidently change, potentially with more specialization and concentration, leading to fewer centers and more patients per center, with different diagnoses, having to be treated at the same or even lower costs and in less time. Just as an example serves the recent study on targeted neurotechnology in SCI that restores walking in some humans with incomplete SCI [138]. If the cure for paralysis will indeed be successful, such new technologies lead to (slightly) different patient groups with different rehabilitation treatment and training requirements. Self-management for the patient will be actively pursued, following the "Position stand Dutch Rehabilitation Medicine" in 2015 (https://revalidatiegeneeskunde.nl/sites/default/files/attachments/Beleid/position_paper_revalidatiegeneeskunde_2015.pdf) [139], but also with the currently decreasing rehabilitation time. With that, there will remain "lessons to be learned" beyond the actual process of rehabilitation, where fewer clinical rehabilitation doses or sessions (time) will boost the societal need for recently evolved "private-party" modules as the "Wheelchair skill training," "Handbikebattle," or "Rehabilitation is learning" [140].

Other than the integration of lifestyle or preventive medicine into the rehabilitation practice and discipline, secondary and tertiary prevention would require a form of "human and assistive technology asset management" [37], where patients (and personnel), as well as technological infrastructure, are viewed as essential assets to be taken care of in view of optimal healthy behavior and life, now and on the short and long-term and in the context of sustainability and durability. Technological innovations will play crucial roles in the evolution of rehabilitation care, diagnostics, and critical treatment with, for example, eHealth [119], smart and sensor technology [70,71], emerging gaming for health. Such technologies require careful research to understand and optimize user interactions and outcomes. In multidisciplinary collaboration with industries, research must be conducted in an early stage of development and innovation to secure rehabilitation technology with evidence-based effectiveness, to prevent too early investments in such technologies, simply because it is an appealing gadget. The future also asks for a self-aware patient, not being the consumer only, self-effective, and able to manage the complex environment of health care and the process of recovery and health maintenance. This potential must be stimulated and improved in a context driven by patients and professionals alike and employing the knowledge and theory of behavioral and (bio)-medical sciences.

To secure current and future patient-oriented rehabilitation care quality, there is a continued need for process-anchored longitudinal observational research in multicenter and multidisciplinary networks and teams. Using the best quality – evidence-based – knowledge in practice, requires academic knowledge brokers and embedded scientists that can manage the cyclic measurement process, analyze and interpret such data in a systematic coherent and accessible manner, leading to the fruitful implementation of our best understanding, as well as broadly supported policy decisions on innovations in strategy and or technology. Again, multidisciplinary collaboration is key, with the self-aware patient in a responsible role in the patient-oriented research process.

Conclusions

Multidisciplinary clinical-rehabilitation research is providing answers, while it simultaneously helps to generate new questions. It deepens our understanding of (impaired) human movement and functioning, and it stresses the importance of continued multidisciplinary (inter)national collaboration. The take-home messages of the current introduction are a plea for continued multidisciplinary research in rehabilitation, human movement, technology, and allied disciplines. This should be aimed at improved functioning and optimal individualized supportive technology, encompassing more precise notions for human and technology "asset management" at individual and organization levels. This will lead to further evolution of rehabilitation care as a model in health care in general, and ensuring a stronger embodiment of preventive and lifestyle medicine for a self-aware and responsible patient. In 2020 and beyond, it is expected that health care developments will continue to emphasize the importance of (secondary) prevention with (active) lifestyle interventions becoming a crucial part of rehabilitation practice, while rehabilitation medicine and care more and more evolve into the center of general health care [134]. In short, that is the positive message that brings together this 6th edition of RehabMove.

Disclosure statement

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References

[1] Van der Woude LHV, Meijs PJM, Van der Grinten BA, et al. eds. Ergonomics of manual wheelchair propulsion, state of the art. 1993. Amsterdam (The Netherlands): IOS press.

[2] JRRD. 3rd International Congress Restoration on (wheeled) mobility in SCI rehabilitation. J Reh Res & Dev. 2004;41(2): 1–85.

[3] JRRD. Background on the 3rd International Congress. J Reh Res Dev. 2005;42(3):1–110.

[4] Van der Woude LHV. Rehabilitation: mobility, exercise & sports'. Assistive technology research series. Amsterdam (The Netherlands): IOS Press; 2010.

[5] Van der Woude LHV, Hopman MTE, Van Kemenade CH, eds. Biomedical aspects of manual wheelchair propulsion: state of the art II. Amsterdam (the Netherlands): IOS press; 1999.

[6] de Groot S, Bevers G, Post MWM, et al. Effect and process evaluation of implementing standardized tests to monitor patients in spinal cord injury rehabilitation. Disabil Rehab. 2010;32(7):588–597.

[7] van der Woude LHV, de Groot S, Bijker KE, et al. 4th International State-of-the-art-congress 'Rehabilitation: mobility, exercise & sports'. Disabil Rehab. 2010;32(26): 2149–2154.

[8] T&D. 3rd International Congress 'Restoration of (wheeled) mobility in SCI rehabilitation, State of the art II'I: its background. Technol Disability. 2005;17:55–123.

[9] Houdijk H, Janssen TW. Disability and rehabilitation on the move: mobility, exercise and sports for people with physical disabilities. Disabil Rehab. 2017;39(2):113–114.

[10] Sparrow WA, Newell KM. The coordination and control of human creeping with increases in speed. Behav Brain Res. 1994;63(2):151–158.

[11] Sparrow WA, Newell KM. Energy expenditure and motor performance relationships in humans learning a motor task. Psychophysiology. 1994;31(4):338–346.

[12] Sparrow WA. Energetics of human activity. Champaign (IL): Human Kinetics; 2000.

[13] de Klerk R, Lutjeboer T, Vegter RJK, et al. Practice-based skill acquisition of pushrim-activated power-assisted wheelchair propulsion versus regular handrim propulsion in novices. J Neuroeng Rehab. 2018;15(1):56.

[14] Goosey-Tolfrey VL, Vegter RJK, Mason BS, et al. Sprint performance and propulsion asymmetries on an ergometer in trained high- and low-point wheelchair rugby players. Scand J Med Sci Sports. 2018;28(5):1586–1593.

[15] Leving MT, Horemans HLD, Vegter RJK, et al. Validity of consumer-grade activity monitor to identify manual wheelchair propulsion in standardized activities of daily living. PLoS One. 2018;13(4):e0194864.

[16] van der Scheer JW, de Groot S, Vegter RJK, et al. Low-intensity wheelchair training in inactive people with long-term spinal cord injury. Am J Phys Med Rehab. 2015; 94(11):975–986.

[17] Vegter RJK, Hartog J, de Groot S, et al. Early motor learning changes in upper-limb dynamics and shoulder complex loading during handrim wheelchair propulsion. J Neuroeng Rehab. 2015;12:26.

[18] Buurke TJW, Lamoth CJC, Vervoort D, et al. Adaptive control of dynamic balance in human gait on a split-belt treadmill. J Exp Biol. 2018;221(13):jeb174896.

[19] Weiland S, Smit IH, Reinders-Messelink H, et al. The effect of asymmetric movement support on muscle activity during Lokomat guided gait in able-bodied individuals. PLoS One. 2018;13(6):e0198473.

[20] Ijmker T, Houdijk H, Lamoth CJC, et al. Energy cost of balance control during walking decreases with external stabilizer stiffness independent of walking speed. J Biomech. 2013;46(13):2109–2114.

[21] Wezenberg D, van der Woude LH, Faber WX, et al. Relation between aerobic capacity and walking ability in older adults with a lower-limb amputation. Arch Phys Med Rehab. 2013;94(9):1714–1720.

[22] Samuelsson KA, Tropp H, Gerdle B. Shoulder pain and its consequences in paraplegic spinal cord-injured, wheelchair users. Spinal Cord. 2004;42(1):41–46.

[23] van Drongelen S, de Groot S, Veeger HEJ, et al. Upper extremity musculoskeletal pain during and after rehabilitation in wheelchair-using persons with a spinal cord injury. Spinal Cord. 2006;44(3):152–159.

[24] van Drongelen S, van der Woude LH, Janssen TW, et al. Glenohumeral contact forces and muscle forces evaluated in wheelchair-related activities of daily living in able-bodied subjects versus subjects with paraplegia and tetraplegia. Arch Phys Med Rehab. 2005;86(7):1434–1440.

[25] Veeger HE, Rozendaal LA, van der Helm FC. Load on the shoulder in low intensity wheelchair propulsion. Clin Biomech. 2002;17(3):211–218.

[26] Veeger HE, van der Woude LH, Rozendal RH. Load on the upper extremity in manual wheelchair propulsion. J Electromyogr Kinesiol. 1991;1(4):270–280.

[27] Ginis KAM, van der Scheer JW, Latimer-Cheung AE, et al. Correction: evidence-based scientific exercise guidelines for adults with spinal cord injury: an update and a new guideline. Spinal Cord. 2018;56(11):1114.

[28] Cook A, Hussey S. Assistive technologies: principles and practice. St Louis (MO): Mosby Year Book, Inc.; 2002.

[29] Cooper RA. Rehabilitation engineering applied to mobility and manipulation. London (UK): CRC Press; 1995.

[30] Van Dijk F, van Dormolen M, Kompier MAJ, et al. Herwaardering model arbeidsbelastbaarheid. TSG. 1990; 68:3–10.

[31] WHO. International classification of functioning, disability and health. Geneva (Switzerland): World Health Organisation; 2001.

[32] Salvendy G. Handbook of human factors. New York (NY): Wiley & Sons; 1987.

[33] Magasi S, Wong A, Miskovic A, et al. Mobility device quality affects participation outcomes for people with disabilities: a structural equation modeling analysis. Arch Phys Med Rehab. 2018;99(1):1–8.

[34] Simmons SF, Schnelle JF, MacRae PG, et al. Wheelchairs as mobility constraints: predictors of wheelchair activity in nonambulatory nursing home residents. J Am Geriatr Soc. 1995;43:383–388.

[35] Van Nimwegen KJ. Feasibility of the headroom analysis in early economic evaluation of innovative diagnostic technologies with no immediate treatment implications. Value Health. 2014;17(7):A550.

[36] Markiewicz K, van TJA, Steuten LMG, et al. Combining headroom and return on investment analysis to rank potential commercial value of six medical devices in development. Value Health. 2014;17(7):A443.

[37] Management IoHA. The anatomy of asset management. Bristol (UK): The Institute of Asset Management; 2015.

[38] Mital A, Karwowkski W. Ergonomics in rehabilitation. London (UK): Taylor & Francis; 1988.
[39] Kumar S. Perspectives in rehabilitation ergonomics. London (UK): Taylor & Francis; 1997.
[40] Kumar S. Ergonomics for rehabilitation professionals. London (UK): CRC Press; 2009.
[41] Kilkens OJ, Dallmeijer AJ, Nene AV, et al. The longitudinal relation between physical capacity and wheelchair skill performance during inpatient rehabilitation of people with spinal cord injury. Arch Phys Med Rehab. 2005;86(8): 1575–1581.
[42] Kilkens OJE, Post MWM, Dallmeijer AJ, et al. Relationship between manual wheelchair skill performance and participation of persons with spinal cord injuries 1 year after discharge from inpatient rehabilitation. J Rehab Res Dev. 2005;42(3):65–73.
[43] Haisma JA, Bussmann JB, Stam HJ, et al. Changes in physical capacity during and after inpatient rehabilitation in subjects with a spinal cord injury. Arch Phys Med Rehab. 2006;87(6):741–748.
[44] van Koppenhagen CF, de Groot S, Post MWM, et al. Wheelchair exercise capacity in spinal cord injury up to five years after discharge from inpatient rehabilitation. J Rehab Med. 2013;45(7):646–652.
[45] Bertocci G, Smalley C, Page A, et al. Manual wheelchair propulsion on ramp slopes encountered when boarding public transit buses. Disabil Rehab Assist Technol. 2019; 14(6):561–566.
[46] Welage N, Liu KP. Wheelchair accessibility of public buildings: a review of the literature. Disabil Rehab Assist Technol. 2011;6(1):1–9.
[47] Vegter RJK, de Groot S, Lamoth CJ, et al. Initial skill acquisition of handrim wheelchair propulsion: a new perspective. IEEE Trans Neural Syst Rehab Eng. 2014;22(1): 104–113.
[48] Vegter RJK, Lamoth CJ, de Groot S, et al. Inter-individual differences in the initial 80 minutes of motor learning of handrim wheelchair propulsion. PLoS One. 2014;9(2): e89729.
[49] Scheer J, Groot S, Tepper M, et al. Wheelchair-specific fitness of inactive people with long-term spinal cord injury. J Rehab Med. 2015;47(4):330–337.
[50] Sauret C, Siyou Fotso V, Bascou J, et al. Cluster analysis to investigate biomechanical changes during learning of manual wheelchair locomotion: a preliminary study. Comput Methods Biomech Biomed Engin. 2015;18(1): 2058–2059.
[51] Fliess-Douer O, Vanlandewijck YC, Van der Woude LHV. Most essential wheeled mobility skills for daily life: an international survey among paralympic wheelchair athletes with spinal cord injury. Arch Phys Med Rehab. 2012; 93(4):629–635.
[52] Almasbakk B, Whiting HT, Helgerud J. The efficient learner. Biol Cybern. 2001;84(2):75–83.
[53] Ijmker T, Houdijk H, Lamoth CJ, et al. Effect of balance support on the energy cost of walking after stroke. Arch Phys Med Rehab. 2013;94(11):2255–2261.
[54] IJmker T, Noten S, Lamoth CJ, et al. Can external lateral stabilization reduce the energy cost of walking in persons with a lower limb amputation? Gait Posture. 2014;40(4): 616–621.
[55] Wezenberg D, de Haan A, Faber WX, et al. Peak oxygen consumption in older adults with a lower limb amputation. Arch Phys Med Rehab. 2012;93(11):1924–1929.
[56] Fliess-Douer O, Vanlandewijck YC, van der Woude LHV. Reliability and validity of perceived self-efficacy in wheeled mobility scale among elite wheelchair-dependent athletes with a spinal cord injury. Disabil Rehab. 2013; 35(10):851–859.
[57] Fliess-Douer O, Van der Woude LH, Vanlandewijck YC. Test of Wheeled Mobility (TOWM) and a short wheelie test: a feasibility and validity study. Clin Rehab. 2013; 27(6):527–537.
[58] de Groot S, Vegter R, Vuijk C, et al. WHEEL-I: development of a wheelchair propulsion laboratory for rehabilitation. J Rehab Med. 2014;46(6):493–503.
[59] van Velzen JM, de Groot S, Post M, et al. RE: return to work after spinal cord injury: is it related to wheelchair capacity at discharge from clinical rehabilitation? Response. Am J Phys Med Rehabil. 2009;88(12):1036–1036.
[60] van Velzen JM, van Leeuwen CMC, de Groot S, et al. Return to work five years after spinal cord injury inpatient rehabilitation: is it related to wheelchair capacity at discharge? J Rehab Med. 2012;44(1):73–79.
[61] Osterthun R, Tjalma TA, Spijkerman DCM, et al. Functional independence of persons with long-standing motor complete spinal cord injury in the Netherlands. J Spinal Cord Med. 2020;43(3):380–387.
[62] Osthertun R. Outcomes after Spinal Cord Injury. Thesis. Groningen (The Netherlands): University of Groningen; 2018.
[63] Van Drongelen S, Van der Woude LH, Janssen TW, et al. Mechanical load on the upper extremity during wheelchair activities. Arch Phys Med Rehabil. 2005;86(6): 1214–1220.
[64] Kloosterman MGM, Buurke JH, de Vries W, et al. Effect of power-assisted hand-rim wheelchair propulsion on shoulder load in experienced wheelchair users: a pilot study with an instrumented wheelchair. Med Eng Phys. 2015; 37(10):961–968.
[65] Kloosterman MGM, Buurke JH, Schaake L, et al. Exploration of shoulder load during hand-rim wheelchair start-up with and without power-assisted propulsion in experienced wheelchair users. Clin Biomech. 2016;34:1–6.
[66] de Vries WHK, Veeger HEJ, Baten CTM, et al. Can shoulder joint reaction forces be estimated by neural networks? J Biomech. 2016;49(1):73–79.
[67] de Vries WHK, Veeger HEJ, Baten CTM, et al. Determining a long term ambulatory load profile of the shoulder joint: neural networks predicting input for a musculoskeletal model. Hum Mov Sci. 2012;31(2):419–428.
[68] WHO. World report on disability 2011. Geneva (Switzerland): WHO Press; 2011.
[69] van Gemert-Pijnen L, Kelders SM, Kip H, et al. eHealth research, theory and development: a multidisciplinary approach. London (UK): Routledge, Taylor & Francis; 2018.
[70] Karatsidis A, Bellusci G, Schepers H, et al. Estimation of ground reaction forces and moments during gait using only inertial motion capture. Sensors. 2016;17(12):75.
[71] Karatsidis A, et al. Validation of wearable visual feedback for retraining foot progression angle using inertial sensors and an augmented reality headset. J Neuroeng Rehab. 2018;15(1):78.

[72] de Witte AMH, Hoozemans MJM, Berger MAM, et al. Development, construct validity and test-retest reliability of a field-based wheelchair mobility performance test for wheelchair basketball. J Sports Sci. 2018;36(1):23–32.
[73] van der Slikke RMA, Berger MAM, Bregman DJJ, et al. From big data to rich data: the key features of athlete wheelchair mobility performance. J Biomech. 2016;49(14): 3340–3346.
[74] van der Slikke RMA, de Witte AMH, Berger MAM, et al. Wheelchair mobility performance enhancement by changing wheelchair properties: what is the effect of grip, seat height, and mass? Int J Sports Physiol Perform. 2018;13(8): 1050–1058.
[75] van der Slikke RMA, Bregman DJJ, Berger MAM, et al. The future of classification in wheelchair sports: can data science and technological advancement offer an alternative point of view? Int J Sports Physiol Perform. 2018;13(6): 742–749.
[76] Stoter IK, Hettinga FJ, Altmann V, et al. Initial steps towards an evidence-based classification system for golfers with a physical impairment. Disabil Rehabil. 2017; 39(2):152–163.
[77] Muchaxo RA, de Groot S, Van der Woude LHV, et al. Handcycling classification: a first look into the current classification system. Paper presented at: 6th Rehabmove Congress. Rehabilitation: mobility, exercise & sports. 2018 December 12–14, Groningen, The Netherlands.
[78] Altman VC, Catharina V. Impact of trunk impairment on activity limitation with a focus on wheelchair rugby [dissertation]. Leuven (Belgium): KULeuven.
[79] van der Scheer JW, Hutchinson MJ, Paulson T, et al. Reliability and validity of subjective measures of aerobic intensity in adults with spinal cord injury: a systematic review. PM & R. 2018;10(2):194–207.
[80] Krops LA, Albada T, van der Woude LHV, et al. Anaerobic exercise testing in rehabilitation: a systematic review of available tests and protocols. J Rehab Med. 2017;49(4): 289–303.
[81] Nash MS, van de Ven I, van Elk N, et al. Effects of circuit resistance training on fitness attributes and upper-extremity pain in middle-aged men with paraplegia. Arch Phys Med Rehabil. 2007;88(1):70–75.
[82] Leving MT, Vegter RJK, de Groot S, et al. Effects of variable practice on the motor learning outcomes in manual wheelchair propulsion. J NeuroEngineering Rehabil. 2016; 13(1):2–15.
[83] Leving MT, Vegter RJK, Hartog J, et al. Effects of visual feedback-induced variability on motor learning of handrim wheelchair propulsion. PLoS One. 2015;10(5): e0127311.
[84] van der Slikke RMA, Mason BS, Berger MAM, et al. Speed profiles in wheelchair court sports; comparison of two methods for measuring wheelchair mobility performance. J Biomech. 2017;65:221–225.
[85] Veeger TTJ, et al. Improving mobility performance in wheelchair basketball. J Sport Rehabil. 2019;28(1):59–66.
[86] European Union. Special Eurobarometer 472 – Wave EB88.4 – TNS opinion & social. 2017.
[87] Verschuren O, Peterson MD, Balemans ACJ, et al. Exercise and physical activity recommendations for people with cerebral palsy. Dev Med Child Neurol. 2016;58(8):798–808.
[88] Martin Ginis KA, van der Scheer JW, Latimer-Cheung AE, et al. Evidence-based scientific exercise guidelines for adults with spinal cord injury: an update and a new guideline. Spinal Cord. 2018;56(4):308–321.
[89] Smith R, Reid H, Matthews A, et al. Infographic. Physical activity for disabled adults. Br J Sports Med. 2018;52(8): 532–533.
[90] Krops LA. Physical activity in hard-to-reach physically disabled people; development, implementation and effectiveness of a community-based intervention, in Rehabilitation Medicine, UMCG. Groningen (The Netherlands): University of Groningen; 2018. p. 197.
[91] van der Ploeg HP, van der Beek AJ, van der Woude LHV, et al. Physical activity for people with a disability: a conceptual model. Sports Med. 2004;34(10):639–649.
[92] Alingh RA, Hoekstra F, van der Schans CP, et al. Protocol of a longitudinal cohort study on physical activity behaviour in physically disabled patients participating in a rehabilitation counselling programme: ReSpAct. BMJ Open. 2015;5(1):e007591.
[93] Hoekstra F, Alingh RA, van der Schans CP, et al. Design of a process evaluation of the implementation of a physical activity and sports stimulation programme in Dutch rehabilitation setting: ReSpAct. Implement Sci. 2014;9:127.
[94] Hoekstra F, Hettinga FJ, Alingh RA, et al. The current implementation status of the integration of sports and physical activity into Dutch rehabilitation care. Disabil Rehabil. 2017;39(2):181–186.
[95] Hoekstra F, et al. National approaches to promote sports and physical activity in adults with disabilities: examples from the Netherlands and Canada. Disabil Rehabil. 2019; 41(10):1217–1226.
[96] Hoekstra F, van Offenbeek MAG, Dekker R, et al. Implementation fidelity trajectories of a health promotion program in multidisciplinary settings: managing tensions in rehabilitation care. Implementation Sci. 2017;12:143.
[97] Bussmann JB, Hartgerink I, van der Woude LH, et al. Measuring physical strain during ambulation with accelerometry. Med Sci Sports Exerc. 2000;32(8):1462–1471.
[98] van der Ploeg HP, Streppel KRM, van der Beek AJ, et al. Successfully improving physical activity behavior after rehabilitation. Am J Health Promot. 2007;21(3):153–159.
[99] Kopcakova J, Veselska ZD, Geckova AM, et al. Is being a boy and feeling fat a barrier for physical activity? The association between body image, gender and physical activity among adolescents. Int J Environ Res Public Health. 2014;11(11):11167–11176.
[100] van der Woude LH, Dallmeijer AJ, Janssen TW, et al. Alternative modes of manual wheelchair ambulation: an overview. Am J Phys Med Rehabil. 2001;80(10):765–777.
[101] van der Woude LH, Veeger HE, Dallmeijer AJ, et al. Biomechanics and physiology in active manual wheelchair propulsion. Med Eng Phys. 2001;23(10):713–733.
[102] Arnet U, van Drongelen S, Veeger DJan, et al. Force application during handcycling and handrim wheelchair propulsion: an initial comparison. J Appl Biomech. 2013;29(6): 687–695.
[103] Arnet U, et al. Determinants of handbike use in persons with spinal cord injury: results of a community survey in Switzerland. Disabil Rehabil. 2015;38(1):1–6.
[104] Arnet U, Drongelen S, Scheel-Sailer A, et al. Shoulder load during synchronous handcycling and handrim wheelchair propulsion in persons with paraplegia. J Rehab Med. 2012;44(3):222–228.

[105] Valent LJ, Dallmeijer AJ, Houdijk H, et al. Influence of hand cycling on physical capacity in the rehabilitation of persons with a spinal cord injury: a longitudinal cohort study. Arch Phys Med Rehabil. 2008;89(6):1016–1022.
[106] Valent LJM. The effects of hand cycling on physical capacity in persons with spinal cord injury, in Human Movement Sciences. Amsterdam (The Netherlands): Vrije Universiteit; 2009.
[107] Valent LJM, Dallmeijer AJ, Houdijk H, et al. Effects of hand cycle training on physical capacity in individuals with tetraplegia: a clinical trial. Phys Ther. 2009;89(10):1051–1060.
[108] Valent LJM, Gobets D, Holst L, et al. Trainen voor de HandbikeBattle: effecten op fitheid en herstel; De eerste resultaten van de HandbikeBattle (Dutch). Ned Tijdschr Revalidatiegeneeskunde. 2014;36(3):99–104.
[109] van Leeuwen CMC, Verwer J, van Koppenhagen CF, et al. Trainen voor de HandbikeBattle: mentale effecten; De eerste resultaten van de HandbikeBattle (Dutch). Ned Tijdschr Revalidatiegeneeskunde. 2014;36(3):104–107.
[110] de Groot S, Kouwijzer I, Baauw M, et al. Effect of self-guided training for the HandbikeBattle on body composition in people with spinal cord injury. Spinal Cord Ser Cases. 2018;4:79.
[111] Kouwijzer I, Nooijen C, Breukelen K, et al. Effects of push-off ability and handcycle type on handcycling performance in able-bodied participants. J Rehab Med. 2018;50(6):563–568.
[112] de Groot S, Hoekstra SP, Grandjean Perrenod Comtesse P, et al. Relationships between internal and external handcycle training load in people with spinal cord injury training for the handbikebattle. J Rehab Med. 2018;50(3):261–268.
[113] Hoekstra S, Valent L, Gobets D, et al. Effects of four-month handbike training under free-living conditions on physical fitness and health in wheelchair users. Disabil Rehabil. 2017;39(16):1581–1588.
[114] Stuart M, Chard S, Roettger S. Exercise for chronic stroke survivors: a policy perspective. J Rehab Res Dev. 2008;45(2):329–336.
[115] Jaarsma EA, Dekker R, Geertzen JHB, et al. Sports participation after rehabilitation: barriers and facilitators. J Rehab Med. 2016;48(1):72–79.
[116] Krops LA, Jaarsma EA, Dijkstra PU, et al. Health related quality of life in a Dutch rehabilitation population: reference values and the effect of physical activity. PLoS One. 2017;12(1):e0169169.
[117] Gezondheidsraad *Beweegrichtlijnen (Dutch)*. Advice to Minister Health Care, Well-being and Sport Nr. 2017/08; Aug 22; The Hague (The Netherlands); 2017.
[118] Haskell WL, Wolffe JB. Memorial lecture. Health consequences of physical activity: understanding and challenges regarding dose-response. Med Sci Sports Exerc. 1994;26(6):649–660.
[119] Van Gemert-Pijnen L, , Kelders SM, Kip H, et al. eHealth research, theory and development, a multidisciplinary approach. London (UK): Routledge; 2018. p. 355.
[120] de Groot S, Houdijk H, Hettinga F, et al. Fifth international state-of-the-art congress "Rehabilitation: mobility, exercise & sports": an overview. Disabil Rehabil. 2017;39(2):115–120.
[121] Wijnen A, Bouma SE, Seeber GH, et al. The therapeutic validity and effectiveness of physiotherapeutic exercise following total hip arthroplasty for osteoarthritis: a systematic review. PLoS One. 2018;13(3):e0194517.
[122] Coppen A, Bailey J. 20 most-cited countries in clinical medicine ranked by population size. Lancet. 2004;363(9404):250.
[123] Rimmer JH, Braddock D. Health promotion for people with physical, cognitive and sensory disabilities: an emerging national priority. Am J Health Promot. 2002;16(4):220–224.
[124] Ter Hoeve N, Sunamura M, Stam HJ, et al. Effects of two behavioral cardiac rehabilitation interventions on physical activity: a randomized controlled trial. Int J Cardiol. 2018;255:221–228.
[125] ter Hoeve N, Sunamura M, van Geffen ME, et al. Changes in physical activity and sedentary behavior during cardiac rehabilitation. Arch Phys Med Rehabil. 2017;98(12):2378–2384.
[126] De Roos RA, Dekker R, Stevens M, et al. Moving towards an exercise & movement-friendly academic hospital: the UMCG Lifestyle navigator. Paper presented at: 6th State-Of-The-Art Congress. Rehabilitation: mobility, exercise & sports. 2018 December 12–14, Groningen, The Netherlands.
[127] Bouma A. The PIE = M PROJECT; Development of a tool to stimulate exercise is medicine in hospital care. Paper presented at: 6th State-Of-The-Art-Congress. Rehabilitation: mobility, exercise & sports. 2018 December 12–14, Groningen, The Netherlands.
[128] Cowan RE. Exercise is medicine initiative: physical activity as a vital sign and prescription in adult rehabilitation practice. Arch Phys Med Rehabil. 2016;97(9):S232–S237.
[129] Arienti C, et al. Cochrane and World Health Organization "Rehabilitation 2030: a call for action." Recenti Prog Med. 2018;109(2):149–150.
[130] Negrini S. The possibilities and challenges of "Rehabilitation 2030: a call for action" by the World Health Organization: a unique opportunity not to be missed. Eur J Phys Rehab Med. 2017;53(2):169–172.
[131] Negrini S. Introduction to the special section "Rehabilitation 2030: a call for action" by the World Health Organization (WHO). Eur J Phys Rehab Med. 2017;53(2):151–152.
[132] Briggs AM, Dreinhofer KE. Rehabilitation 2030: a call to action relevant to improving musculoskeletal health care globally. J Orthop Sports Phys Ther. 2017;47(5):297–300.
[133] Gimigliano F, Negrini S. The World Health Organization "Rehabilitation 2030: a call for action." Eur J Phys Rehab Med. 2017;53(2):155–168.
[134] Stucki G, Bickenbach J, Gutenbrunner C, et al. Scaling-up rehabilitation as the worldwide health strategy of the 21st century. J Rehab Med. 2018;50(4):309–385.
[135] Stucki G, Bickenbach J, Gutenbrunner C, et al. Rehabilitation: the health strategy of the 21st century. J Rehab Med. 2018;50(4):309–316.
[136] Gutenbrunner C, Bickenbach J, Borg K, et al. Scaling up rehabilitation – towards an international policy agenda. J Rehab Med. 2018;50(4):307–308.
[137] Gutenbrunner C, Bickenbach J, Melvin J, et al. Strengthening health-related rehabilitation services at national levels. J Rehab Med. 2018;50(4):317–325.
[138] Wagner FB, Mignardot J-B, Le Goff-Mignardot CG, et al. Targeted neurotechnology restores walking in humans with spinal cord injury. Nature. 2018;563(7729):65–71.
[139] VRA. Actief naar zelfredzaamheid en eigen regie; position paper revalidatiegeneeskunde. Utrecht (The Netherlands): VRA; 2015.
[140] Vuijk I. Rehabilitation is learning, inspiration for rehabilitation professionals. Amsterdam: Studio HB; 2014.