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Manual wheelchair training programs: a scoping review of educational approaches and intended learning outcomes

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Abstract

Background Training programs grounded in educational theory offer a systematic framework to facilitate learning and outcomes. This scoping review aims to map the educational approaches documented for manual wheelchair training and to record intended learning outcomes and any relationships between learning theories, instructional design and outcomes.

Methods Eight databases; Cochrane's Library, EMBASE, CINAHL, PubMed, Scopus, EmCare, Medline, ProQuest Nursing and Allied Health Database and grey literature were searched in September 2023, with citation chaining for relevant papers. Included papers related to manual wheelchair training programs/protocols describing intended wheelchair training outcomes for adults and/or caregivers. Data extracted included study characteristics, type of intervention, explicit learning theories, instructional design principles and intended learning outcomes. The International Classification of Functioning and Kirkpatrick's evaluation framework were used to organise intended outcomes.

Results Of the forty-four articles included in this review, only fourteen explicitly used a learning theory in the instructional design of training. Training outcomes most commonly related to changes in knowledge/skills of manual wheelchair users (Level 2b of Kirkpatrick's evaluation ($n=43$), with less emphasis on participatory outcomes. Training designs incorporating Social Cognitive Theory ($n=8$) were more likely to explore long term training outcomes, compared with other training designs.

Conclusion Wheelchair training programs that are designed using learning theory are more likely to produce learning outcomes that are retained and meaningfully applied. Such longer terms outcomes could have systemic cost and efficiency implications, such as reduction in wheelchair falls and readmissions to hospital. Deliberate integration of learning theory into manual wheelchair training design is recommended to support broad outcomes and long-term learning. This design could synergise different learning theories.

Keywords Manual Wheelchair Training, Patient education, International Classification of Functioning, Kirkpatrick's Evaluation Framework

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Background

Mobility, that is, the ability to move around in the environment, is a foundation skill, enabling engagement in essential daily activities and participation in multiple aspects of community, social, and civic life. Mobility can be more challenging for wheelchair users who may experience lower levels of community participation compared to ambulatory individuals [1]. Multiple factors influence mobility outcomes for wheelchair users, including personal factors such as the cognitive, emotional, and functional abilities of the user, as well as the physical built environment and the social environment, including availability and ability/willingness of professional or informal supports [2–4]. Low community participation is associated with loneliness, depression, increased morbidity and mortality, and increased health service burden [5–7]. An estimated 1% of the population relies on a wheelchair to assist with their mobility [8]. Due to the global ageing population, increasing prevalence of chronic and progressive conditions, increased rates of road traffic injuries, occupational injury, violence and humanitarian crisis, it is anticipated that there will be a proportionate rise in the number of people requiring a wheelchair [8, 9] and requiring training in wheelchair use.

Wheelchair training is well positioned to support community wheelchair use through targeted development of wheelchair skills, education on efficient biomechanical propulsion techniques and development of self-efficacy and confidence in wheelchair use, which in turn supports independence and occupational engagement [2, 5, 10]. A range of manual wheelchair (MWC) training approaches exist and some of these entail formalised protocols and training programs. Wheelchair training education may be delivered through individual [11–15] or group training [16–22] that is facilitated by either clinicians [23–28], or peer wheelchair users [16, 17, 21, 22, 29–31]. The training may use technology including virtual reality [32] and biofeedback methods [33–37]. Learning can occur within laboratory [33, 36, 38, 39], inpatient [23, 26, 27], or community settings [11, 16, 40] and is also offered online [14, 41]. The intensities for the training differ ranging from 10 min [33] to three to four hours [21] and can be offered over differing time periods, from one day [42] to two years [18]. Many wheelchair training programs focus on short term outcomes related to individual wheelchair skill acquisition and confidence (i.e. going forwards, going up slight incline, wheelie) or principles of biomechanical propulsion (i.e. contact angle, force, stroke frequency) and a recent meta-analysis has demonstrated the effectiveness of many of these manual wheelchair training programs [43, 44]. However, limited empirical studies consider the long-term translation of these skills and knowledge and whether this learning has been applied beyond the context of training delivery, to participants' everyday activities. Additionally, the large volume and diversity of training programs makes it difficult for service providers to ascertain whether a training program supports the learning and contextual needs of the recipients of their training.

Wheelchair training has traditionally been situated in theories of social models of disability, medical models of disability and biomechanical theory, which direct the design of programs through influencing outcomes such as access and participation outcomes (eg. social model of disability), skill acquisition (medical model of disability) or upper limb strength (eg biomechanics). These theories are critical, as they inform how the training enables the intended outcomes. However, these theories do not intentionally direct the educational approach that underpins training design to inform "how" and "why" the learning occurs. Educational approaches include the design of training programs, including learning theories which inform approach and instructional design used to support the learning experience to achieve intended learning outcomes of wheelchair training programs. What is known, is that training programs that are underpinned by learning theory provide a framework to develop effective, appealing and reliable training that is systematic in its approach to support instructional efficiency and facilitation of learning [45]. Personal factors influencing an individuals' capacity to engage in training and the differing motivations and goals of individuals are important considerations in developing training objectives that align with the aspirations of the individual [46, 47]. Objectives that are clearly articulated, realistic and offer flexibility create a foundation for effective communication, engagement and evaluation, contributing to a positive learning experience [46]. Some known learning theories adopted in the design of manual wheelchair training include social cognitive theory, motor learning, situated learning and behavioral learning theory. Each of these theories offer perspectives and assumptions that contribute to the effectiveness of training methodologies. These theories and assumptions are highlighted in Table 1.

Instructional design encompassing progressive introduction of knowledge, with opportunity for knowledge application within familiar settings is additionally important for retention and transferability of knowledge and skills across different contexts, enhancing motivation to learn and encouraging problem solving and adaptability [52]. Learning which includes peers can also support learning and enable the opportunity for feedback, which is important in supporting progress and growth [53].

The evidence for including educational design in training underpins the proposition that wheelchair training that incorporates a theoretically derived educational

Table 1 Learning theories and Descriptors

Name	Author	Year	Descriptor
Social Cognitive Theory	Bandura	1986	Emphasizes the role of observing others, cognitive processes and social experiences in determining behaviour and learning [48]
Motor Learning Theory	Schmidt	1975	repeated practice and timely feedback is important for developing specific skill acquisition, improving biomechanics and generalizing these skills across different contexts [49]
Situated Learning	Lave	1991	Posits that training is more effective when it is context specific ie., it involves tasks and environments that a wheelchair user will encounter [50]
Behavioural Learning Theory	Skinner	1965	grounded in principles of behaviorism, where skills are demonstrated and practiced and observable behaviors are reinforced through feedback [51]

approach will be more efficacious in facilitating long term meaningful wheelchair training outcomes than comparatively undertheorized or pragmatic approaches to training. Further clarity about educational design underpinning existing training programs will also support informed decisions about the appropriateness of different training programs for individuals, situations and contexts. This knowledge can be used to inform future education and training design.

Using a scoping review methodology, this paper seeks to clarify educational design used in existing wheelchair training programs, and uses Kirkpatrick's evaluation framework to address the research question;

> *"What are the educational design principles and intended outcomes of MWC training programs and is there a relationship between learning theory and instructional design and outcomes?"*

Methods

Aim

This research will specifically focus on the following aims;

- To identify MWC training programs that report explicit learning theory and instructional design and intended learning outcomes.
- To determine evaluation levels of MWC training programs, using Kirkpatrick's evaluation framework.
- To determine if there is a relationship between learning theory and instructional design within training programs and the value/impact of the program on stakeholders including wheelchair users and their caregivers, health care providers and policy makers.

Approach to review

A scoping review [54] served as the basis for an exploratory analysis of learning design and the intended training outcomes within MWC training programs that are reported in the literature. A review protocol is available via Open Science Framework osf.io/h6yru. Kirkpatrick's Evaluation levels [55] and the International Classification of Functioning (ICF) [56] were used as frameworks to systematically map training outcomes. The outcomes mapped to the different Kirkpatrick levels included; participant reactions, changes in attitudes/perceptions or knowledge/skills, behaviour changes and changes in health and wellbeing. This framework has been used across medical and allied health education and enables a multi-dimensional approach to the evaluation of training programs that delivers a nuanced perspective on their learning outcomes. The ICF is an established and internationally recognised framework that acted as a means to map/classify the types of outcomes across personal factors, environmental factors, activities and participation and environmental factors. This allowed for further insights into intended outcomes of the MWC training programs.

Inclusion/Exclusion criteria

The search used the PCC framework (Participants, Concept, Context) [57] to focus on MWC users and/or their caregivers and education/training on using a MWC across all contexts. Papers about wheelchair training programs or protocols describing an intended wheelchair training outcome were included. This excluded any reviews of literature ie., scoping reviews, systematic reviews, literature reviews; summary/position papers, surveys that were not specific to one wheelchair training program/protocol and any training programs where outcomes were not measured or intending to be measured. Training pertaining to powered wheelchairs were deliberately excluded due to observed variations in upper limb exertion and propulsion mechanisms between manual and powered wheelchair users. Training that included solely paediatric wheelchair users or abled bodies users simulating as wheelchair users were also excluded to enable the capturing of literature nuanced to wheelchair training for adults/older adults. Table 2 outlines the inclusion and exclusion criteria for this research question.

Table 2 Inclusion and exclusion criteria using participants, concept, context framework

Participants	
Inclusion	Exclusion
• MWC users and/or their caregivers who were commencing wheelchair use as adults • Papers where only some participants meet the inclusion criteria (on the basis that they may have applicability to those commencing wheelchair use as adults)	• Able-bodied persons simulating wheelchair users including clinicians and students • Paediatric wheelchair users
Concept	
Inclusion	Exclusion
• Wheelchair training intervention or protocol describing an intended wheelchair training outcome • Papers which had a mix of powered and manual wheelchair users	• Focus solely on exercise prescription to support wheelchair use • Exclusive training of powered wheelchair use • Any reviews of literature ie., scoping reviews, systematic reviews, literature reviews; • Summary/position papers • Surveys that were not specific to one wheelchair training program/protocol • Any training programs where outcomes have not been measured or intended to be measured
Context	
Inclusion	Exclusion
• Any setting including but not limited to; inpatient, community, virtual settings, homes of wheelchair users, residential care facilities, sports training centres/labs and schools/universities	

Search strategy

A broad systematic search strategy, was conducted with support from a medical librarian. Eight databases; Cochrane's Library, EMBASE, CINAHL, PubMed, Scopus, EmCare, Medline, ProQuest Nursing and Allied Health Database were searched in July 2022 and updated in September 2023. Each database was searched by using MeSH headings (if applicable), synonyms, wildcards and truncations where appropriate and all terms are included in additional file 1. A search for grey literature was completed in October 2022 and repeated in September 2023 using Google scholar, TROVE, Open Grey NICE, SIGN, ECRI guidelines Trust, TRIP and focused websites including Australian Association of Gerontology, the ISWP and a Google advanced search, including the top 300 results [58]. To reflect contemporary training approaches, only studies published after 1995 were included. Papers that were not available in English were excluded. Reference lists from literature reviews, scoping reviews, systematic reviews were screened for further relevant studies before being excluded. Final search results were uploaded and duplicates removed in EndNote and then exported into Covidence Systematic Review software for further deduplication.

Study screening and selection

Abstract and full text screening were conducted by two independent reviewers on 4212 articles using the developed inclusion and exclusion criteria. Reviewers discussed conflicts, until consensus was achieved. Following screening, 44 articles were included in the review, as shown in the PRISMA-ScR diagram in Fig. 1 [59].

Data extraction and synthesis

Data for extraction was guided by the research question and agreed on by members of the research team. The data charting table was iteratively updated as charting progressed. Data were charted pertaining to author, year of publication, country of publication, paper type, type of intervention, any explicit learning theory/ies identified. Other charting included; the facilitator of learning and the presence of instructional design principles including modelling, problem solving, peer/group learning, scaffolding and feedback. Intended learning outcomes were examined and mapped using Kirkpatrick's evaluation framework (Fig. 2) by two reviewers who discussed and agreed to apply the Kirkpatrick's levels according to the nature of the length and outcomes of the included programs [55]. Wheelchair skills and performance outcomes measured immediately post-program (classified

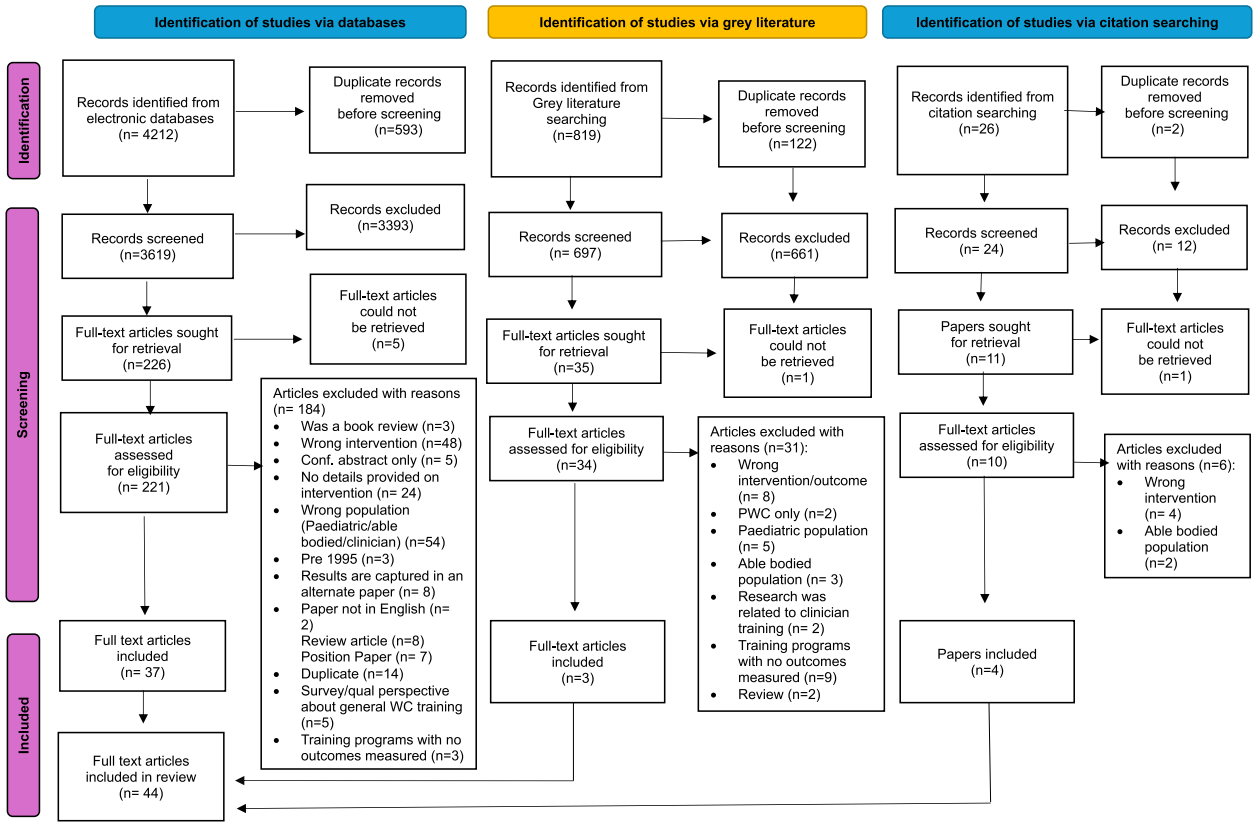

Fig. 1 PRISMA-ScR

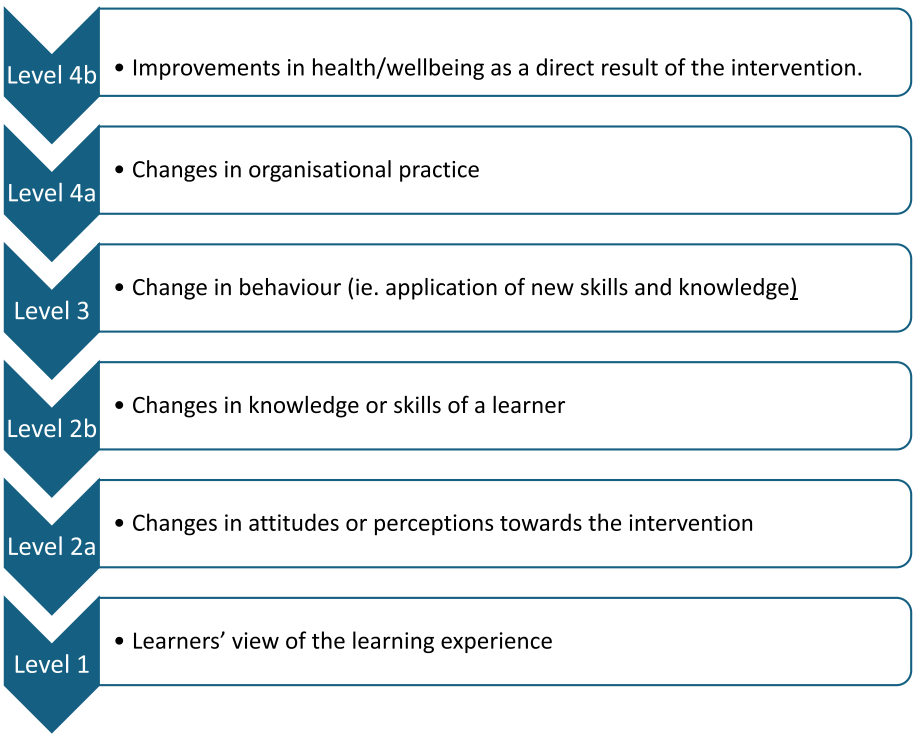

Fig. 2 Kirkpatrick's hierarchy

as up to 4 weeks) were interpreted as Kirkpatrick's Level 2b (modified skills and behaviour) while skills and performance outcomes measured > 4 weeks post program were interpreted as Kirkpatrick's Level 3 (behavioural change), as this suggested transfer of skills. When behaviour change had a direct benefit to the wheelchair user/caregiver it was interpreted to be Kirkpatrick's Level 4b (improvements in health and wellbeing directly associated with training). Any conflicts between reviewers were discussed until consensus was reached. The WHO ICF was also used to map intended training outcomes to biopsychosocial outcomes including personal factors, environmental factors, activities and participation and body structures and functions. Results from the Kirkpatrick's analysis were cross referenced with the mapping of the ICF to explore any relationships between the intended learning outcomes extracted using the different frameworks.

Results

Study characteristics

All 44 papers were published between 2004 and 2023, most frequently in 2015 ($n=5$), 2021 ($n=4$) and 2016 ($n=4$). Papers were published across 11 countries (1 unknown), most commonly within North America (Canada = 16, USA = 15, Mexico = 1), followed by Asia (Korea = 3, India = 1, Turkey = 1), Europe (Netherlands = 2, Norway = 1, Poland = 1), Africa (Morocco = 1) and Australia ($n=1$). Papers were most commonly randomized control trials (RCT)($n=24$) and Pre and Post Design ($n=8$) but also included cohort studies ($n=3$), mixed methods ($n=2$), case studies ($n=2$), qualitative designs ($n=2$), protocols ($n=2$) and cross sectional design ($n=1$). Various training programs and outcome tools were used across the papers, most commonly the wheelchair skills training program or adapted versions of this program ($n=12$) and the wheelchair skills test or questionnaire ($n=22$) Table 3 provides detail on included papers.

Learning theory and instructional design

An explicit learning theory was described as part of the background or study design in fourteen of the 44 included papers. The most common learning theory identified was *Social Cognitive Theory* ($n=8$) [76], where the instructional design included scaffolded learning ($n=7$) live or video modelling ($n=8$) via peer trainers ($n=4$) or clinicians ($n=4$) and verbal feedback on performance ($n=6$). The majority of these studies supported problem solving around wheelchair use ($n=7$) and some incorporated peer or group learning ($n=3$). Five papers reported using *Motor Learning Theory* [77] to conceptualise the study design, with educational procedures supported by clinicians ($n=4$) or biofeedback technology ($n=1$) [13]. Two papers [12, 26] reported the use of modelling to support learning and four provided visual or verbal feedback. The others did not provide this, or it was not clearly stated. Problem solving and peer learning were not incorporated into the learning design of these papers. *Situated learning theory* [50] was described in one training program [21], where the learning process was shaped by participation amongst peer wheelchair users and peer trainers responsible for modelling skills [21]. Other than modelling of skills, this paper did not clearly describe other mechanisms utilized to facilitate wheelchair use.

Despite only 14 papers providing an explicit theoretical foundation for learning, the instructional design of the remaining 30 papers appeared to use insights from learning theories for their training design, but did not explicitly report this in the study design. The majority of training programs facilitated learning through instruction and feedback provided by wheelchair trainers (typically health professionals) ($n=21$), peer wheelchair users ($n=2$) or technology including wheelchair simulators that provide biofeedback ($n=7$). While methodology was not always clear, in training programs that relied on technology to facilitate learning ($n=2$), the instructional design principles used were reflective of a *Behaviourist* approach to learning [78]. This approach included a structured focus on instruction, practice and feedback ($n=5$), yet limited consideration of broader instructional design principles, including social (peer learning) and experiential learning (problem solving) and limited modelling ($n=2$) [35, 79]. Training facilitated by a wheelchair trainer where there was no explicit learning theory ($n=21$) often demonstrated explicit instructional design principles including; demonstration of specific wheelchair skills or propulsion style, live ($n=6$) or via video modelling ($n=7$); feedback provision ($n=7$), social learning (group training) ($n=5$) and a scaffolded approach to learning ($n=6$). One study that did not explicitly identify a learning theory used problem solving to support wheelchair use [19]. Table 4 provides an overview of learning theories and instructional designs seen across the paper.

Kirkpatrick's evaluation of outcomes

Training outcomes were mapped to Kirkpatrick's evaluation framework, as outlined in Fig. 2 [55]. Training aligned to outcomes related to changed knowledge and skills of MWC users (Level 2b) was most commonly mapped across the papers ($n=43$), followed by changes in MWC users/caregivers' attitudes/perceptions (Level 2a) ($n=17$) and MWC users/caregivers perspectives of the learning experience (Level 1) ($n=17$). There were a smaller amount of papers evaluating MWC users'

Table 3 Study characteristics table

Author	Publication Date	Country of Publication	Type of Paper	Training Program used	Outcome Tools Used/Intended measures
Beaudoin et al., [16]	2021	Canada	Mixed Methods	Roulez avec confiance (RAC) OR Wheeling with Confidence	WheelCon- MWC Self efficacy WST-Q- Perceived wheelchair skill capacity, performance SWLS- Quality of Life
Best et al., [11]	2005	Canada	RCT	Wheelchair skills training program	Questionnaire- Qualitative perspectives WST- wheelchair skill capacity and performance
Best et al., [17]	2016	Canada	RCT	Self-Efficacy Enhanced Wheelchair Training Intervention (WheelSee)	WheelCon- MWC Self efficacy WST-Q- Perceived wheelchair skill capacity, performance WhOM- Satisfaction with social participation Life Space Mobility- community mobility
Blouin et al., [34]	2015	Canada	Cohort Study	Wheelchair Simulator with Haptic feedback	Instrumented wheel- mechanical efficiency force
Bonaparte et al., [60]	2004	Canada	RCT	Wheelie training using the proactive balance strategy (PBS) and conventional reactive balance strategy (RBS)	Success Rate of performing wheelie Time taken to complete a wheelie Questions- qualitative perspectives
Charlton et al., [23]	2021	Australia	Mixed Methods	Modified version of the wheelchair skills training program	WST-Q- Perceived wheelchair skill capacity, performance FIM mobility- wheelchair mobility GAS- Attainment of wheelchair goals
Chen [12]	2019	USA	RCT	Clinical Practice Guidelines for preserving shoulder function	Instrumented wheel- push cadence, hand-axel position, push angle Questionnaire- Qualitative perspectives
Choi et al., [24]	2020	Korea	Pre and Post	Training across six skills; ascending/descending low and high curbs and ascending and descending stairs	Korean-Quebec User Evaluation of Satisfaction with Assistive Technology Wheelchair skills Questionnaire
Ctri [61]	2023	Unclear	Protocol	Training Program 1: Virtual self learning for wheelchair skills Training program 2: Virtual wheelchair skills training with a trained instructor Training program 3: In person wheelchair skills training	Self-Reported Feedback (tool not specified) Ability to complete wheelchair skills (tool not specified)
DeGroot et al., [35]	2009	USA	Cohort Study	Biomechanical efficiency training on a wheelchair treadmill, carpeted surface, ramp and cross slope	Instrumented wheel- push length, push frequency, force
Desai et al., [62]	2013	India	Pre and Post design	Wheelchair skills training program	Questionnaire- qualitative perspectives WST- wheelchair skill capacity and performance FIM- locomotion and transfer ability
Furmaniuk et al., [18]	2010	Poland	Pre and Post design	Rugby skills group including muscle strength and endurance training and wheelchair skills	WST- wheelchair skill capacity and performance
Garrett et al., [63]	2011	USA	Case Study	Adapted wheelchair skills training program	WST- wheelchair skill capacity and performance

Table 3 (continued)

Author	Publication Date	Country of Publication	Type of Paper	Training Program used	Outcome Tools Used/Intended measures
Giesbrecht et al., [29]	2021	Canada	Protocol	TEAM Wheels (e-health wheelchair training program)	WST-Q- Perceived wheelchair skill capacity, performance WheelConSF- MWC Self efficacy Actigraph datalogger- MWC mobility Short Form 36 Health Survey- health related quality of life
Giesbrecht & Miller [64]	2017	Canada	RCT	Enhancing Participation in the Community (EPIC Wheels)- monitored wheelchair training via a computer tablet	WST- wheelchair skill capacity, performance WheelConM- MWC Self efficacy WhOM- Wheelchair outcomes Health Utilities Index- Quality of Life Life Space Mobility- community mobility
Giesbrecht & Miller [41]	2019	Canada	RCT	Enhancing Participation in the Community (EPIC Wheels)- monitored wheelchair training via a computer tablet	Questionnaire- qualitative perspectives WheelConM- MWC Self efficacy Life Space Mobility- community mobility WST- wheelchair skill capacity, performance WhOM- Wheelchair outcomes Health Utilities Index- Quality of Life
Giesbrecht et al., [65]	2015	Canada	Pre and Post design	Enhancing Participation in the Community (EPIC Wheels)- monitored wheelchair training via a computer tablet	Questionnaire- qualitative perspectives WST- wheelchair skill capacity, performance WheelConM- MWC Self efficacy
Kirby et al., [13]	2008	Canada	RCT	Wheelchair skills training program	Questionnaire- qualitative perspectives Time to achieve skill acquisition- timer
Kirby et al., [66]	2001	Canada	RCT	Training in wheelie related skills	Questionnaire- qualitative perspectives Likert Scales- difficulty of wheelchair skills Time to achieve skill acquisition- timer
Kirby et al., [42]	2004	Canada	Pre and Post design	Wheelchair skills training program adapted for caregivers	Questionnaire- qualitative perspectives WST-Q- Perceived wheelchair skill capacity, performance
Kirby et al., [25]	2016	USA	RCT	Wheelchair Skills Training Program	Questionnaire- qualitative perspectives WST- wheelchair skill capacity, performance
Kotajarvi et al., [33]	2006	USA	Cohort Study	Biomechanical efficiency training with visual feedback	Instrumented wheel- Fraction of Effective Force, stroke frequency, stroke angle
Limroongreungrat et al., [67]	2009	USA	RCT	Wheelchair propulsion training with video feedback	
MacPhee, [26]	2004	Canada	RCT	Wheelchair skills training program	Questionnaire- qualitative perspectives WST- wheelchair skill capacity, performance PIADS- competence, adaptability, self esteem regarding assistive devices
McClure et al., [27]	2010	USA	RCT	Implementation of clinical practice guidelines "Preservation of Upper Limb Function Following Spinal Cord Injury"	Instrumented wheel- push length and frequency WUSPI- Shoulder Pain

Table 3 (continued)

Author	Publication Date	Country of Publication	Type of Paper	Training Program used	Outcome Tools Used/Intended measures
Miller et al., [19]	2019	Canada	RCT	Wheelchair Self-Efficacy Enhanced for Use (WheelSeeU) training program	WheelConM- MWC Self efficacy Life Space Mobility- community mobility WST-Q- Perceived wheelchair skill capacity, performance WhOM- Wheelchair goal outcomes Late Life Function and disability index- Quality of Life
Morgan et al., [28]	2017	USA	Pre and Post design	Wheelchair Propulsion biomechanical training	Video motion capture- push frequency, hand axel relationship, force WST- wheelchair skill capacity, performance
Ozturk et al., [68]	2011	Turkey	RCT	Wheelchair Skills Training Program	Questionnaire- qualitative perspectives WST- wheelchair skill capacity, performance
Park & Jung [20]	2022	Korea	RCT	Modified Wheelchair skills training program	Questionnaire- qualitative perspectives WST- wheelchair skill capacity, performance COPM- ADL engagement Korean Modified Barthels Index- ADL engagement
Pellichero [30]	2020	Canada	Qualitative Research	Wheelchair Self-Efficacy Enhanced for Use (WheelSeeU) training program	Interviews- Qualitative perspectives
Quinones-Uriostegui et al., [69]	2017	Mexico	Pre and Post design	WHO 8 step guidelines on the provision of manual wheelchairs in less resourced settings	QUEST- Satisfaction with wheelchair services WST-Q- Perceived wheelchair skill capacity, performance WHOQoL-BREF- health and quality of life
Rice et al., [37]	2010	USA	Case Study	Manual wheelchair propulsion training program using visual feedback	Instrumented Wheel- stroke cadence, force, contact angle
Rice et al., [38]	2013	USA	RCT	Manual wheelchair propulsion training program using visual feedback	Instrumented Wheel- stroke cadence, force, contact angle
Rice et al., [70]	2015	USA	RCT	Manual wheelchair propulsion training	Instrumented Wheel- stroke cadence, force, contact angle
Rice et al., [71]	2014	USA	RCT	Implementation of the Paralysed Veterans of America's Clinical Practice Guidelines for Preservation of Upper Limb Function	Instrumented Wheel- stroke cadence, force, contact angle WUSPI- Shoulder Pain Craig Handicap Assessment-Satisfaction with Life
Richter et al., [36]	2011	USA	Pre and Post design	Biomechanical wheelchair propulsion training using biofeedback	Instrumented Wheel- stroke cadence, force, contact angle, breaking moment
Routhier et al., [15]	2012	Canada	RCT	French-Canadian version of the Wheelchair Skills Training Program	WST/WST-Q actual and perceived wheelchair skill capacity, performance
Standal et al., [21]	2008	Norway	Qualitative Research	Wheels in Motion training program	Interviews- Qualitative perspectives
Tasiemski, et al., [22]	2021	Morocco	Pre and Post design	Wheelchair Skills and Empowerment Camp	QUEST- Satisfaction with manual wheelchair Queensland Evaluation Wheelchair Skills- ability to complete a range of wheelchair skills

Table 3 (continued)

Author	Publication Date	Country of Publication	Type of Paper	Training Program used	Outcome Tools Used/Intended measures
Van Der Scheer et al., [72]	2015	Netherlands	RCT	Low-intensity wheelchair propulsion training	Instrumented Wheel- stroke cadence, force, contact angle
Van Der Scheer et al., [73]	2016	Netherlands	RCT	Low-intensity wheelchair propulsion training	Instrumented Wheel- stroke cadence, force, contact angle Power output over 15m- wheelchair specific fitness Exercise Tests- aerobic capacity, submaximal fitness, isometric strength, anaerobic work capacity
Worobey et al., [74]	2016	USA	RCT	Wheelchair skills training program	WST- wheelchair skill capacity, performance
Yeo & Kwon [75]	2018	Korea	RCT	Wheelchair skills training program	WST- wheelchair skill capacity, performance
Yong Tai et al., [31]	2015	USA	RCT	Learning three wheelchair skills; ramps, wheelie and kerbs using video feedback	Time to complete wheelchair skills

Abbreviations: COPM Canadian occupational performance measure, *FIM* Functional independence measure, *GAS* Goal attainment scale, *MMT* Manual muscle testing, *METS* Metabolic equivalent of task, *PIADS* Psychosocial Impact of Assistive devices Scale, *QUEST* Quebec User Evaluation of Satisfaction with Assistive Technology, *VAS* Visual analogue scale, *WheelConM* Wheelchair use confidence scale, *WST* Wheelchair skills test, *WST-Q* Wheelchair skills test questionnaire, *WhOM* The wheelchair outcome measure, *WHOQoL-BREF* World Health Organisation Quality of Life- BREF, *WUSPI* Wheelchair use shoulder pain index

Table 4 Learning theories and Instructional design

Authors Name	Learning Theory Explicitly Mentioned	Learning theory	Instructional design					
			Facilitated by who/what	Modelling Used	Problem Solving	Peer /group Learning Used	Scaffolding used	Feedback Provided
Beaudoin et al., [16]	Yes	Social Cognitive Theory	Peer wheelchair trainer	yes- peer trainer and group members	yes	yes	yes	Yes- verbal
Best et al., [11]	No	atheoretical	Experienced WC trainer	no	no	no	yes	not specified
Best et al., [17]	Yes	Social Cognitive Theory	Peer WC Trainer	yes	yes	yes	yes	verbal feedback
Blouin et al., [34]	No	atheoretical	Technology—WC Simulator	no	no	no	no	yes- visual and haptic feedback
Bonaparte et al., [60]	No	atheoretical	WC Trainers	yes- video	no	no	no	verbal feedback
Charlton et al., [23]	No	atheoretical	WC Trainers	yes	no	yes	yes	verbal feedback
Chen [12]	Yes	Motor Learning Theory	WC Trainers	yes- video	no	no	no	Verbal and proprioceptive feedback
Choi et al., [24]	No	atheoretical	WC Trainers (PT)	no	no	no	no	not specified
Ctri [61]	No	insufficient detail	wheelchair trainer and Technology	unclear	unclear	unclear	unclear	unclear
DeGroot et al., [35]	No	atheoretical	WC Trainer and technology (Treadmill with biofeedback)	yes- via video	no	no	no	visual feedback (through technology) and verbal (trainer)
Desai et al., [62]	No	atheoretical	unclear	unclear	unclear	unclear	unclear	unclear
Furmaniuk et al., 18]	No	atheoretical	unclear	unclear	unclear	unclear	unclear	unclear
Garrett et al., [63]	No	atheoretical	unclear	unclear	unclear	unclear	unclear	unclear
Giesbrecht et al., [29]	Yes	Social Cognitive Theory	Peer WC Trainers	yes- via videos	yes	no	yes	no
Giesbrecht & Miller [64]	Yes	Social Cognitive Theory	WC Trainer	yes- live and via video	yes	no	yes	yes- verbal
Giesbrecht & Miller [41]	Yes	Social Cognitive Theory	WC Trainer	yes- live and via video	yes	no	yes	yes- verbal
Giesbrecht et al., [65]	Yes	Social Cognitive Theory & Andragogy theory	WC Trainer	yes- live and via video	yes	no	yes	yes- verbal
Kirby et al., [13]	Yes	Motor Learning Theory	WC Trainer	unclear	no	no	no	unclear
Kirby et al., [66]	No	Contained elements of Vygotsky's sociocultural learning	WC Trainer	yes- via video and live (if requested)	no	no	no	yes- verbal

Table 4 (continued)

Authors Name	Learning Theory Explicitly Mentioned	Learning theory	Instructional design					
			Facilitated by who/what	Modelling Used	Problem Solving	Peer /group Learning Used	Scaffolding used	Feedback Provided
Kirby et al., [42]	No	atheoretical	WC Trainer	yes- live and via video	no	no	no	yes- verbal
Kirby et al., [25]	No	atheoretical	WC Trainer	not specified	no	no	yes	not specified
Kotajarvi et al., [33]	No	atheoretical	Technology-instrumented WC	not specified	no	no	no	visual feedback (via video)
Limroongreungrat et al., [67]	No	atheoretical	WC trainer-not specified but assumed	unclear	no	no	no	yes video and verbal feedback
MacPhee, [26]	Yes	Motor Learning Theory	WC Trainers	via video	no	no	yes	yes- verbal
McClure et al., [27]	No	atheoretical	WC Trainer	via video	no	no	no	no
Miller et al., [19]	No	atheoretical	Peer trainer	not specified	yes	yes	yes	no
Morgan et al., [28]	Yes	Motor Learning Theory	WC Trainer	not specified	no	no	no	yes visual feedback (mirrors) and verbal
Ozturk et al., [68]	No	atheoretical	WC Trainer	not specified	no	no	yes	not specified
Park & Jung [20]	No	atheoretical	WC Trainer	not specified	no	no	yes	not specified
Pellichero [30]	Yes	Social Cognitive Theory	Peer WC User	yes- live	yes	yes	yes	yes- verbal
Quinones-Uriostegui et al., [69]	No	insufficient detail	wheelchair trainer and technology	unclear	unclear	unclear	unclear	unclear
Rice et al., [37]	Yes	Motor Learning Theory with elements of integrated cognitive load theory	Technology-biofeedback	no	no	no	no	yes- visual provided on a screen
Rice et al., [38]	No	atheoretical	Technology-biofeedback	via video	no	no	no	visual feedback on screen
Rice et al., [70]	Yes	Social Cognitive Theory	WC Trainer	live instruction	no	no	no	no
Rice et al., [71]	No	atheoretical	WC Trainer	via video	no	no	no	no
Richter et al., [36]	No	atheoretical	Technology-biofeedback	no	no	no	no	yes- visual via screen in front of them
Routhier et al., [15]	No	atheoretical	WC Trainers	no	no	no	no	no
Standal et al., [21]	Yes	Situated learning	Peer WC User	yes	no	yes	no	no
Tasiemski, et al., [22]	No	atheoretical	Peer WC user	yes	no	Yes	no	no
Van Der Scheer et al., [72]	No	atheoretical	Wheelchair Trainer	no	no	no	no	no

Table 4 (continued)

Authors Name	Learning Theory Explicitly Mentioned	Learning theory	Instructional design					
			Facilitated by who/what	Modelling Used	Problem Solving	Peer /group Learning Used	Scaffolding used	Feedback Provided
Van Der Scheer et al., [73]	No	atheoretical	Wheelchair Trainer	no	no	no	no	no
Worobey et al., [74]	No	atheoretical	wheelchair trainer	yes- live	no	yes	no	no
Yeo & Kwon [75]	No	atheoretical	wheelchair trainer	no	no	yes	no	no
Yong Tai et al., [31]	No	atheoretical	wheelchair trainer	yes- live and video	no	no	no	yes- verbal and visual feedback

application of trained skills and behaviour (Level 3) ($n=14$) and outcomes related to the health and well-being of MWC users (Level 4b)($n=12$). There were no papers that reported on evaluating change to organisational practice (Level 4a) ($n=0$). Mapping of papers to Kirkpatrick's Evaluation levels are detailed further below and summarised in Table 5.

Level 1: Learners' view of the learning experience (n = 17)

Papers evaluating the learners' view of the learning experience included those underpinned by the social cognitive theory ($n=3$), motor learning theory ($n=3$), situated learning ($n=1$) and those that did not report a learning theory ($n=10$). There was agreeance across papers that wheelchair users reported training as a beneficial [13, 25, 41, 68, 73] fun, and engaging experience [11, 26, 30, 32, 65] that supports independence [13, 62]. Some users reported enjoying having a peer wheelchair user provide- training and identified having skills modelled by peers as beneficial [21, 30]. This opportunity was reported to contribute to higher levels of motivation for learning [21]. Some users also saw merit in having a professional instructor [30] and enjoyed 1:1 training that could be personalised to a wheelchair users' goals and be completed in the home environment [25]. Wheelchair users liked training to include both instruction and physical demonstration of wheelchair skills, opportunity to practice [20, 30, 64, 66] and provision of truthful and positive verbal feedback [30]. Situational learning opportunities, enhanced feedback [20], delivery of training as soon as possible after the onset of a condition, and longer duration of training provision were also suggested [20].

Level 2a: Changes in attitudes or perceptions (n = 21)

Twenty-one papers included outcomes related to attitudes, including those underpinned by the social cognitive theory ($n=7$), motor learning theory ($n=2$), situated learning ($n=1$) and those that did not report on learning theory ($n=11$). Outcomes measured included wheelchair use self-efficacy [16, 17, 30, 41, 64, 65] confidence in completing skills [13, 19, 23, 42] and perceived ease of wheelchair propulsion/performance of wheelchair skills [12, 13, 22]. Wheelchair training was linked with perceptions of increased skill acquisition, empowerment/sense of control [30], independence [13, 62], relief for caregivers [25, 62] and conquering fears surrounding wheelchair use [25]. Wheelchair users did not always want to engage in wheelchair training [23]. While many did not find wheelchair training to be emotionally or physically stressful [13, 42] others perceived advanced skills, level transfers and pressure relief as being difficult skills to learn [20, 68], and some felt learning to do a "wheelie" was fatiguing and dangerous [60].

Level 2b: Outcomes related to changes in knowledge or skills of a learner (n = 43)

Across the papers, the most commonly reported outcome for wheelchair training programs related to changes in wheelchair skills and knowledge, with this being included across forty-three studies. Of these studies, most were measured/were intended to be measured immediately or up to a week after the program ($n=40$) and the remainder ($n=3$) between two- and four-weeks post completion [12, 74, 75] or the time period was not clearly specified ($n=1$) [30]. Acquisition of wheelchair skill capacity was most frequently captured through a version of the Wheelchair Skills Test (WST) or Wheelchair Skills Test

Table 5 Mapping of outcomes to Kirkpatrick's evaluation

Authors Name	Kirkpatrick's Levels of learning evidence					
	Level 1 Participation	**Level 2a) Modification Attitudes/Perceptions**	**Level 2b) Modification Knowledge/Skills**	**Level 3) Behaviour Change**	**Level 4a) change to organisational practice**	**Level 4b) Benefits to patients/Clients**
Beaudoin et al., [16]	Not Reported	Statistically significant increase in MWC Self-efficacy	Statistically significant increase in perceived MWC skills capacity and performance	Statistically significant increase in perceived MWC skills capacity and performance > 4 weeks	Not Reported	Statistically significant increase in satisfaction with social participation. No change in Quality of life
Best et al., [11]	The WSTP was enjoyable and improved wheelchair skills and confidence	Not Reported	Statistically significant improvement in wheelchair skills < 4 weeks post intervention	Not Reported	Not Reported	Not Reported
Best et al., [17]	Not Reported	Statistically significant higher MWC self-efficacy < 4 weeks post intervention	Statistically significant improvements in wheelchair skill capacity and performance < 4 weeks post intervention No statistically significant difference in life-space mobility scores < 4 weeks post intervention	Not Reported	Not Reported	Moderate effect on satisfaction with participation (not statistically significant)
Blouin et al., [34]	Not Reported	Not Reported	Some improved mechanical efficiency force during haptic feedback 2 min post intervention	Not Reported	Not Reported	Not Reported
Bonaparte et al., [60]	Not Reported	Wheelie is too dangerous for older people- reluctant to try. Training is fatiguing	All participants were able to perform a wheelie < 4 weeks post intervention	Not Reported	Not Reported	Not Reported
Charlton et al., [23]	Conflicting opinions about the best way to learn to use a wheelchair	Perceived increased confidence in completing MWC skills	Increased wheelchair skill capacity and mobility 91% of participants achieved their goals	Not Reported	Not Reported	Not Reported
Chen [12]	All participants felt safe and that they had learnt something through the training	87.5% felt that they found pushing a wheelchair easier	Significant improvements in push, push cadence, hand-axle distance. No improvements in push angle	Not Reported	Not Reported	Not Reported
Choi et al., [24]	Not Reported	Not Reported	Improved capacity and confidence in 6 wheelchair skills trialled	Not Reported	Not Reported	Not Reported
Ctri [61]	Protocol only* Feedback on teaching methods	Not Reported	Protocol only* Wheelchair usage and skills to be assessed	Not Reported	Not Reported	Not Reported

Table 5 (continued)

Authors Name	Kirkpatrick's Levels of learning evidence					
	Level 1 Participation	**Level 2a) Modification Attitudes/Perceptions**	**Level 2b) Modification Knowledge/Skills**	**Level 3) Behaviour Change**	**Level 4a) change to organisational practice**	**Level 4b) Benefits to patients/Clients**
DeGroot et al., [35]	Not Reported	Not Reported	Push length, average and peak force increased, push frequency decreased	Not Reported	Not Reported	Not Reported
Desai et al., [62]	Not Reported	Increased independence, improvement of wheelchair skills and relief for caregiver	A significant improvement (26.82%) in Wheelchair capacity and performance Transfer and Locomotion increased significantly (transfers 34%, mobility 20.88%)	A significant improvement (40.3%) in Wheelchair capacity and performance Transfer and Locomotion increased significantly (transfers 55.31%, mobility 31.87%)	Not Reported	Not Reported
Furmaniuk et al., [18]	Not Reported	Not Reported	Significant increase (24.0%,) in wheelchair skills	Not Reported	Not Reported	Not Reported
Garrett et al., [63]	Not Reported	Not Reported	Significant improvement in wheelchair skills	Not Reported	Not Reported	Not Reported
Giesbrecht et al., [29]	Not Reported	Protocol only* Wheelchair self-efficacy to be assessed	Protocol only* Wheelchair skills to be assessed	Protocol only* Wheelchair skills and MWC Mobility to be assessed	Not Reported	Protocol only* Satisfaction with Participation using and health related quality of life to be assessed
Giesbrecht & Miller [64]	Not Reported	*feasibility study only Plans to assess self-efficacy	Non-significant improvement in wheelchair skills capacity and safety	Not Reported	Not Reported	*feasibility study only Plans to look at participation and health related quality of life
Giesbrecht & Miller [41]	98% of responses were agree/strongly agree to the effectiveness of the training program	Statistically significant improvement in self-efficacy	Non statistically significant improvement in MWC skill capacity and mobility	Not Reported	Not Reported	Statistically significant improvement in participation in life activities and improved health related quality of life
Giesbrecht et al., [65]	The program was excellent and would be beneficial for transition to wheelchair use. Activities were fun and engaging	Self-efficacy increased in both participants	Participant 1 demonstrated no change in wheelchair skill and safety. Participant 2 had improved skill capacity and safety	Not Reported	Not Reported	Not Reported
Kirby et al., [13]	93% of participants found the training sessions useful	93% participants perceived improved abilities and confidence. Training equipped users for getting around in their wheelchair at home and outside	For 14 (61%) of the skills, there was increased success in skill acquisition	Not Reported	Not Reported	Not Reported

Table 5 (continued)

Authors Name	Kirkpatrick's Levels of learning evidence					
	Level 1 Participation	**Level 2a) Modification Attitudes/Perceptions**	**Level 2b) Modification Knowledge/Skills**	**Level 3) Behaviour Change**	**Level 4a) change to organisational practice**	**Level 4b) Benefits to patients/Clients**
Kirby et al., [66]	Training was easier to comprehend when instructions were verbalised and a demonstration of the skill given	Individuals with a self-deploying wheelie aid found 6 skills (stationery wheelie, turns in place, moves forward, turn corner, curb descent, move backwards) less difficult to perform, and 1 skill (Gravel) more difficult	On individual skills, participants using the self-deploying wheelie aid learned 2 of the skills (stationery wheelie and turns in place) in significantly less time	Not Reported	Not Reported	Not Reported
Kirby et al., [42]	Training was beneficial	Learning was helpful and facilitated confidence Training was not stressful or uncomfortable	Statistically significant improvements in wheelchair skill with the greatest improvements seen in the advanced intervention	No significant differences in the retention of wheelchair skills < 4 weeks post intervention	Not Reported	Not Reported
Kirby et al., [25]	Training was beneficial and participants appreciated the personalisation of goals and 1:1 training in their own environments	Participants felt empowered, perceived greater independence/ decreased reliance on others. Transfer from floor to MWC was indicated as an important skill to learn	Non statistically significant improvement in community MWC skills. Improved advanced MWC skills were significantly higher	No significant decline in MWC skills performance at 1 year follow up	Not Reported	Not Reported
Kotajarvi et al., [33]	Not Reported	Not Reported	Propulsion velocity was higher with visual feedback, Fraction of Effective Force was unchanged, stroke frequency decreased, stroke angle increased	Not Reported	Not Reported	Not Reported
Limroongreungrat et al., [67]	Not Reported	Not Reported	Improved stroke cadence, and push angle	Not Reported	Not Reported	Not Reported
MacPhee, [26]	Participants learnt a lot and enjoyed training. It helped them understand what they were capable of Participants expressed learn how to use the MWC right and having time to do this	Not Reported	Significant improvement in wheelchair skills	Not Reported	Not Reported	Competence, adaptability and self-esteem (related to QOL) all increased but there were no statistically significant differences between control/ intervention

Table 5 (continued)

Authors Name	Kirkpatrick's Levels of learning evidence					
	Level 1 Participation	**Level 2a) Modification Attitudes/Perceptions**	**Level 2b) Modification Knowledge/Skills**	**Level 3) Behaviour Change**	**Level 4a) change to organisational practice**	**Level 4b) Benefits to patients/Clients**
McClure et al., [27]	Not Reported	Not Reported	Trend for greater push length and lower frequency in intervention group	Significantly lower peak force and faster propulsion	Not Reported	Increased shoulder pain and satisfaction with life and non significant improvements in ADL/Community participation
Miller et al., [19]	Not Reported	Improvement in confidence in wheelchair use noted	A non-significant small improvement in wheelchair skill capacity	A non-significant improvement in MWC skills and mobility	Not Reported	Acquisition of ADL/social goals and participation in physical activities No changes to disability index scores
Morgan et al., [28]	Not Reported	Not Reported	Improved push loop and hand axel relationship and peak force. Improved wheelchair skills scores	Not Reported	Not Reported	Not Reported
Ozturk et al., [68]	Participants experiences were positive and encouraging and they learnt a lot	Advanced skills were more difficult to perform safely	Significant increase in wheelchair skill capacity	Not Reported	Not Reported	Not Reported
Park & Jung [20]	Areas for improvement include additional training methods (ie., videos), consideration of additional situations, improved feedback, longer/more responsive training period	Relieving pressure from the buttocks and completing a level transfer were perceived to be the most difficult skills	Statistically significant improvement in wheelchair skills and engagement in ADLs immediately post intervention	Not Reported	Not Reported	Not Reported
Pellichero [30]	Participants enjoyed the combination of practice, instruction and demonstration when learning Group work created a sense of belonging. Peer trainers were credible and motivated them but professionals and family also played an important role. Valued truthful and positive verbal encouragement was important	Participants reported increased sense of control. Training helped participants feel capable of pushing themselves to achieve more	All study participants reported perceived improvements in MWC skills	Improved skills and self-efficacy positively impacted on autonomy and independence. Increased self-efficacy towards MWC use and increased confidence impacted on participation in other meaningful activities/ social activities	Not Reported	Increased self-efficacy towards MWC use and increased confidence impacted on participation in other meaningful activities/ social activities. The training created a sense of belonginess and connectedness

Table 5 (continued)

Authors Name	Kirkpatrick's Levels of learning evidence					
	Level 1 Participation	**Level 2a) Modification Attitudes/Perceptions**	**Level 2b) Modification Knowledge/Skills**	**Level 3) Behaviour Change**	**Level 4a) change to organisational practice**	**Level 4b) Benefits to patients/Clients**
Quinones-Uriostegui et al., [69]	Users were satisfied with services provided	Participants satisfaction with wheelchair provision were significantly higher		Significant increase wheelchair skills and how well participants used their skills in everyday life	Not Reported	No significant differences in physical, psychological, social, environmental and overall health and quality of life perception
Rice et al., [37]	Not Reported	Not Reported	Decreased stroke cadence decreased peak force and increased contact angle	Not Reported	Not Reported	Not Reported
Rice et al., [38]	Not Reported	Not Reported	Increased contact angle and decrease in stroke frequency immediately post intervention	Increased contact angle and decrease in stroke frequency 3 months post intervention	Not Reported	Not Reported
Rice et al., [70]	Not Reported	Not Reported	Non statistically significant improvements in stroke frequency contact angle and peak force. Statistically significant changes in pectoralis major strength	Not Reported	Not Reported	Not Reported
Rice et al., [71]	Not Reported	Not Reported	Significantly lower push frequency, greater push length on tiles and ramp. No significant differences in peak force across ramp, tile or carpeted surfaces	Significantly greater push length on ramp. No significant differences in force across tiles, ramp and carpet at 6 and 12 months post intervention	Not Reported	No differences in shoulder pain Trend of increased satisfaction with life
Richter et al., [36]	Not Reported	Not Reported	Improvement in peak force (11%), contact angle (31%) braking moment (44%), cadence (64%) and push distance (225%)	Not Reported	Not Reported	Not Reported
Routhier et al., [15]	Not Reported	Not Reported	Statistically significant improvement in overall MWC skills. No statistically significant changes for the indoor/advanced level skills	Improved skills identified post intervention were maintained 3 months post intervention	Not Reported	Not Reported

Table 5 (continued)

Authors Name	Kirkpatrick's Levels of learning evidence					
	Level 1 Participation	**Level 2a) Modification Attitudes/Perceptions**	**Level 2b) Modification Knowledge/Skills**	**Level 3) Behaviour Change**	**Level 4a) change to organisational practice**	**Level 4b) Benefits to patients/Clients**
Standal et al., [21]	Participants liked peer learning framework- it supported learning	Learning with others provided motivation	MWC users acquired knowledge from other MWC users in regards to wheelchair use	Not Reported	Not Reported	Peer learning extended beyond skills and techniques, to include ways for the participants to make sense of their situations as MWC users
Tasiemski, et al., [22]	Not Reported	Camp participants were overall satisfied with adjusting, safety and security, durability, ease to use, and comfort measures of MWC	Improvement in ascending/ descending a ramp, negotiating an indoor circuit, maintaining balance on back wheels, ascending and descending a gutter and distance covered in MWC	Not Reported	Not Reported	Not Reported
Van Der Scheer et al., [72]	Not Reported	Not Reported	No significant difference between groups on propulsion techniques including push frequency, push force, contact angle or push time	No significant differences between groups on propulsion techniques including push frequency, push force, contact angle or push time at > 4 weeks post intervention	Not Reported	Not Reported
Van Der Scheer et al., [73]	Perceived improved fitness attributed to training	Not Reported	No significant differences between the exercise and control groups on wheelchair specific fitness, wheelchair skill performance or physical activity levels	Not Reported	Not Reported	Not Reported
Worobey et al., [74]	Not Reported	Not Reported	No significant differences in wheelchair skills for intervention and control group	Not Reported	Not Reported	Not Reported
Yeo & Kwon [75]	Not Reported	Not Reported	Wheelchair skills were significantly greater than those in the control group	Wheelchair skills were significantly greater than those in the control group at > 4 weeks post intervention	Not Reported	Not Reported

Table 5 (continued)

Authors Name	Kirkpatrick's Levels of learning evidence					
	Level 1 Participation	**Level 2a) Modification Attitudes/Perceptions**	**Level 2b) Modification Knowledge/Skills**	**Level 3) Behaviour Change**	**Level 4a) change to organisational practice**	**Level 4b) Benefits to patients/Clients**
Yong Tai et al., [31]	Not Reported	Not Reported	No significant difference between experimental/control groups in time required to do a wheelchair ramp and curb skill. A significant reduction in time to complete a wheelie	Not Reported	Not Reported	Not Reported
TOTAL	*N* = 17	*N* = 21	*N* = 44	*N* = 14	*N* = 0	*N* = 12

or Questionnaire (WST-Q) [60] ($n=28$). Many papers reported improvements ($n=15$) in capacity up to 4 weeks post program. Biomechanical efficiency was explored across thirteen papers, with most ($n=10$) reporting improved mechanical efficiency for one or more variables, including push frequency, force, contact angle, push length, braking torque. Knowledge was also acquired from peers sharing their experiences [21].

Level 3: Change in behaviour (ie. application of new skills and knowledge) (n = 14)

Fourteen papers intended to/did evaluate the application of wheelchair knowledge and skills at least 4 weeks post program, most commonly between 30–90 days ($n=6$) [15, 16, 62, 72, 75, 79], six months ($n=4$) [19, 27, 29, 42] and between 9- 12 months ($n=4$) [25, 30, 69, 71], with seven suggesting an improvement or maintenance of skills after the provision of training. Of these papers three were underpinned by the social cognitive theory [48], the rest reported no explicit learning theory ($n=11$). Outcomes/intended outcomes centered around wheelchair skill performance ($n=8$), indoor and community mobility ($n=4$) and wheelchair propulsion variables measuring mechanical efficiency ($n=3$). Qualitative outcomes also reflected behaviour change including wheelchair users "no longer having to leave their MWC in the closet anymore" [30] (p.195).

Level 4b. Reported improvements in health/wellbeing as a direct result of the program (n = 12)

Outcomes related to improvements in health and wellbeing as a direct result of wheelchair training ($n=12$), were more common in papers incorporating Social Cognitive Theory ($n=6$, than those underpinned by motor learning theory ($n=1$), situational learning ($n=1$) and atheoretical/other papers ($n=4$). Outcomes/intended outcomes centered around participant satisfaction with social participation/engagement ($n=8$), quality of life/changes to disability index ($n=4$) and shoulder pain ($n=2$). Papers reported mostly an increased satisfaction with social or activities of daily living participation ($n=7$), positive ($n=2$) [26, 41] or no significant change ($n=2$) [16, 69] for quality-of-life outcomes. Shoulder pain did not significantly change [71] or was reported to increase [27].

Intended outcomes mapped to ICF

Typically, the intended outcomes of MWC training designs were aligned most strongly to the activities and participation component of the ICF ($n=32$), with a predominant focus on the attainment of single or multiple wheelchair skills ($n=26$) and less emphasis on participatory outcomes such as improving functional mobility ($n=7$) and functional goal/ADL achievement outcomes ($n=4$). There was also intent to improve outcomes related to body structures and functions ($n=16$) across papers. These outcomes included multiple variables relating to wheelchair propulsion technique ($n=13$), upper limb strength/performance ($n=3$) [70, 73, 75], pain scores ($n=2$) [27, 71] and ability to divide one's attention when using the wheelchair ($n=1$) [29]. Twenty-one papers included outcomes mapped to personal factors, which included psychological, emotional or social aspects that were unique to individuals. This most frequently included self-efficacy in wheelchair use ($n=8$), confidence ($n=8$) and Quality of Life ($n=8$) [21]. There were four training programs that reported outcomes related to environmental factors [16, 21, 30, 69], that were most prominently related to social environments and relationships formed during wheelchair training ($n=4$). Figure 3 visually maps the outcomes of papers across the ICF components.

Relationships between educational design and ICF findings

Programs that were designed using principles of Social Cognitive Theory had proportionately more intended outcomes related to personal factors within the ICF ($n=8$, 100%) than papers using motor learning theory ($n=2$,40%) or atheoretical/other papers ($n=11$, 31%). Programs including Social Cognitive Theory in their training design were also proportionately more likely to have outcomes charted to the activities and participation component of the ICF ($n=7$, 87.5%), compared to motor learning theory ($n=3$, 60%) or those with an atheoretical or other design ($n=22$, 70%).

There were similarly higher proportions of outcomes related to environmental factors with programs using Social Cognitive Theory within their training design ($n=2$, 25%) [16, 30] compared to atheoretical study designs ($n=1$, 3%) [69]. One training design underpinned by situated learning explored environmental outcomes ($n=1$, 100%) [21]. Those study designs that were based on motor learning theory tended to have proportionately higher outcomes related to body structures and functions ($n=3$, 60%), than those using atheoretical/other design ($n=11$, 35%) or Social Cognitive Theory ($n=2$, 25%). Table 6 details the learning theories and outcomes mapped to the ICF.

Discussion

Using learning theories to underpin and develop educational programs is important in creating and delivering learning experiences that are meaningful with outcomes that are sustained over time. As there are many published studies that describe protocols and approaches to MWC training, this study examined how these training approaches were informed by educational theory,

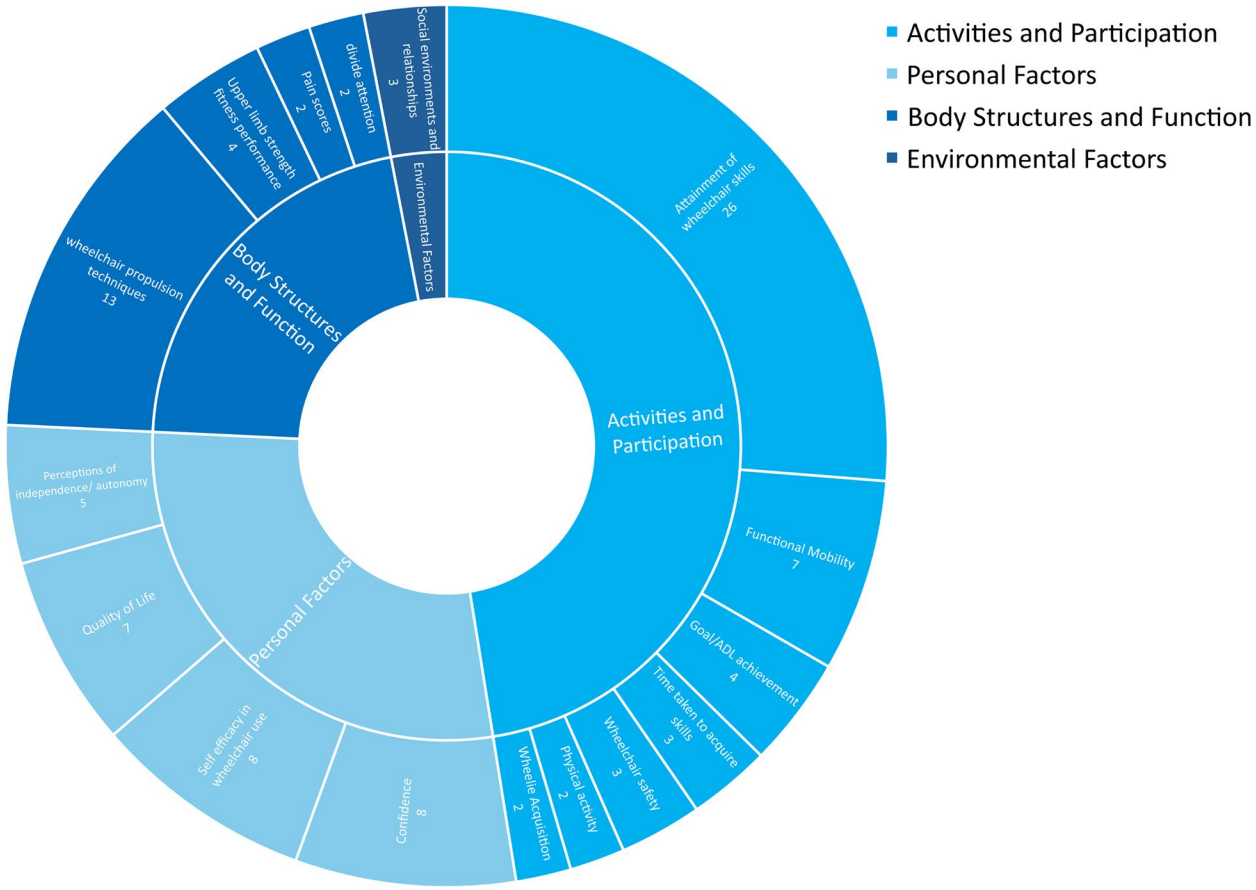

Fig. 3 Outcomes mapped to the ICF

the learning approaches that were reported as part of the instructional design of the included studies, and the range of intended outcomes of these studies.

Overall, only a small proportion of papers included in this review explicitly used theories of teaching and learning to guide MWC training. The inconsistent integration of learning theory into MWC training programs appears to be similar in other areas of healthcare practice education, including falls prevention programs [80], where only a small amount of educational programs have been recognised to be grounded in an educationally robust theoretical approach [81]. Within tertiary institutions learning theories act to conceptually inform educational instructions, with the aim to foster the development of skill, knowledge and change in behaviour, performance or potential [82]. This derives from knowledge that training programs underpinned by learning theory provide structure to support a tailored approach to education that enables learners to engage and be empowered [82]. Training approaches that are not underpinned by a learning theory do not always address the complex nature of training, including the preferences and cognitive processes that influence peoples' responses to training programs [83]. In the context of wheelchair training, this suggests that if wheelchair service providers are to realise the long-term benefit of wheelchair training programs, then the integration of best-practice educational approaches is required.

This claim is supported by findings of the review which saw differences in outcomes of training designs that incorporated an explicit learning theory to those that did not. Studies that included a behaviourist approach to learning, often included a step-by-step approach to training, which was premised on shaping skill acquisition through demonstration, skill practice and feedback provision. These training designs gave limited consideration to the broader context of the individual MWC users' goals, motivations, cognitive and physical strengths/weaknesses, and their participatory and contextual training needs. As such, outcomes of these programs mostly related to the acquisition of specific wheelchair skills, such as wheelies (captured under the activities and participation component of the ICF) or improvement of a specific principle of propulsion biomechanics, such as push angle (captured under the body structures and

Table 6 Mapping of outcomes to the ICF

Authors Name	Learning Theory	Outcomes of Training in relation to the ICF			
		Environmental Factors	**Activities and Participation**	**Body Structures and Function**	**Personal Factors**
Beaudoin et al., [16]	Social Cognitive Theory-	"A positive social experience", "Influence of the physical environment", "Learning more than skills"	Wheelchair skills	Not reported	Wheelchair self-efficacy Quality of Life
Best et al., [11]	atheoretical	Not reported	wheelchair skills	Not reported	Confidence in wheelchair use
Best et al., [17]	Social Cognitive Theory	Not reported	wheelchair skills Functional Mobility	Not reported	wheelchair self-efficacy and confidence
Blouin et al., [34]	atheoretical	Not reported	Not reported	Mechanical force efficiency	Not reported
Bonaparte et al., [60]	atheoretical	Not reported	Performance of a wheelie	Not reported	Confidence in completing skill
Charlton et al., [23]	atheoretical	Not reported	Functional goal achievement Wheelchair skills Wheelchair Mobility	Not reported	Experience of wheelchair training- Increased confidence to use wheelchair
Chen [12]	Motor Learning Theory	Not reported	Not reported	Push effectiveness Hand axel distance Push cadence Push angle Adherence to clinical practice guidelines	Perceived efficiency in using wheelchair
Choi et al., [24]	atheoretical	Not reported	Wheelchair skill capacity	Not reported	Confidence
Ctri [61]	Insufficient detail	Not reported	wheelchair skills	Not reported	Not reported
DeGroot et al., [35]	atheoretical	Not reported	Not reported	Peak and Average push forces Push length Push frequency Average speed	Not reported
Desai et al., [62]	atheoretical	Not reported	Wheelchair skills Transfers and Mobility	Not reported	Perceptions of independence
Furmaniuk et al., [18]	atheoretical	Not reported	Wheelchair skills	Not reported	Not reported
Garrett et al., [63]	atheoretical	Not reported	Wheelchair Skills	Not reported	Not reported
Giesbrecht et al., [29]	Social Cognitive Theory	Not reported	Wheelchair skills capacity	Not reported	Wheelchair self-efficacy Satisfaction with wheelchair performance
Giesbrecht & Miller [64]	Social Cognitive Theory	Not reported	Wheelchair skills Wheelchair Safety Wheelchair mobility	Not reported	Wheelchair self-efficacy Health Related Quality of Life
Giesbrecht & Miller [41]	Social Cognitive Theory	Not reported	Wheelchair skills Community Mobility	Divided attention when using wheelchair (wheeling while talking)	Satisfaction with wheelchair performance Self efficacy in WC use Health Related Quality of Life

Table 6 (continued)

Authors Name	Learning Theory	Outcomes of Training in relation to the ICF			
		Environmental Factors	**Activities and Participation**	**Body Structures and Function**	**Personal Factors**
Giesbrecht et al., [65]	Social Cognitive Theory & Andragogy theory	Not reported	Wheelchair skills Wheelchair Safety Wheelchair mobility	Not reported	Wheelchair self-efficacy Health Related Quality of Life
Kirby et al., [13]	Motor Learning Theory	Not reported	Skill acquisition and time taken to acquire skill	Not reported	Not reported
Kirby et al., [66]	Contained elements of Vygotsky's sociocultural learning	Not reported	Time taken and ability to complete a wheelie	Not reported	Confidence Satisfaction with wheelchair performance
Kirby et al., [42]	atheoretical	Not reported	Safety when completing wheelies	Not reported	User and trainer perspectives of intervention
Kirby et al., [25]	atheoretical	Not reported	Wheelchair skills	Not reported	Not reported
Kotajarvi et al., [33]	atheoretical	Not reported	Not reported	Peak velocity Fraction of Effective Force Stroke Frequency Stroke Angle	Not reported
Limroongreungrat et al., [67]	atheoretical	Not reported	Not reported	Push kinematics Number of push strokes and push angle	Not reported
MacPhee, [26]	Motor Learning Theory	Not reported	Wheelchair skills	Not reported	Quality of Life
McClure et al., [27]	atheoretical	Not reported	Not reported	Manual Wheelchair Propulsion: Push frequency (cadence) push angle peak and average force velocity Pain	Quality of Life
Miller et al., [19]	atheoretical	Not reported	Wheelchair skills Wheelchair mobility (use) Engagement in activities of daily living	Not reported	Confidence in wheelchair use
Morgan et al., [28]	Motor Learning Theory	Not reported	Wheelchair skills	Push Loop hand axel relationship push angle Push frequency Push efficient peak force	Not reported
Ozturk et al., [68]	atheoretical	Not reported	Wheelchair skills	Not reported	Not reported

Table 6 (continued)

Authors Name	Learning Theory	Outcomes of Training in relation to the ICF			
		Environmental Factors	**Activities and Participation**	**Body Structures and Function**	**Personal Factors**
Park & Jung [20]	atheoretical	Not reported	Wheelchair skills Activities of daily living Participation Activity Goals	Not reported	Participants perspectives
Pellichero [30]	Social Cognitive Theory	Improved social life and feeling of belonging	Increased independence and autonomy	Not reported	Increased confidence and Self efficacy "Got spirit back"
Quinones-Uriostegui et al., [69]	insufficient detail	social relationships and environmental domains	ability to complete wheelchair skill and how well they use the skill in everyday life	Not reported	Not reported
Rice et al., [37]	Motor Learning Theory with integrated elements of cognitive load theory	Not reported	Not reported	contact angle stroke cadence Propulsion Force	Not reported
Rice et al., [38]	atheoretical	Not reported	Not reported	contact angle stroke frequency stroke force	Not reported
Rice et al., [70]	Social Cognitive Theory	Not reported	Not reported	Push Frequency Push length Peak and Average force and velocity Pain	Satisfaction with Life and Participation
Rice et al., [71]	atheoretical	Not reported	Physical activity	stroke force contact angle stroke frequency braking torque Upper limb strength	Not reported
Richter et al., [36]	atheoretical	Not reported	Not reported	Peak Force contact angle braking moment cadence push distance	Not reported
Routhier et al., [15]	atheoretical	Not reported	Wheelchair skills	Not reported	Not reported
Standal et al., [21]	Situated learning	Social relationships and a supportive environment	Not reported	Not reported	Users' perceptions of the program
Tasiemski, et al., [22]	atheoretical	Not reported	Wheelchair skills	Not reported	Not reported
Van Der Scheer et al., [72]	atheoretical	Not reported	Not reported	Push frequency Peak Force contact angle push time	Not reported

Table 6 (continued)

Authors Name	Learning Theory	Outcomes of Training in relation to the ICF			
		Environmental Factors	**Activities and Participation**	**Body Structures and Function**	**Personal Factors**
Van Der Scheer et al., [73]	atheoretical	Not reported	Wheelchair skill performance physical activity levels	peak aerobic work capacity, submaximal fitness, anaerobic work capacity and isometric strength	Not reported
Worobey et al., [74]	atheoretical	Not reported	Wheelchair Skills	Not reported	Not reported
Yeo & Kwon [75]	atheoretical	Not reported	Wheelchair skills	Upper limb skill performance	Not reported
Yong Tai et al., [31]	atheoretical	Not reported	Time to acquire wheelchair skills	Not reported	Not reported

functions component of the ICF). While the prescriptive nature of these training designs supports the easy translation of instruction across contexts, the one size fits all approach means that training may not be tailored to the needs/preferences/values of MWC users and does not situate training within the contexts that MWC users will need to apply their newly learned skills. The studies that focussed on biomechanical change or skill acquisition were in line with Kirkpatrick's Level 2b outcomes, and generally excluded outcomes related to the personal and participatory outcomes of the users. Given this focus, it is uncertain whether these training designs provide outcomes that will translate long-term to support community integration/participation and quality of life across diverse contexts—including lower- and middle-income countries (Level 4b of Kirkpatrick's evaluation levels).

Many of the included programs situated in atheoretical approaches to wheelchair training may benefit from a holistic approach to wheelchair training, including the inclusion of alternate learning theories to strengthen robustness of the educational outcomes and consideration of how the intended participatory context of the wheelchair user could be integrated into the study design. Experiential learning opportunities, where learning is developed through doing and engaging in problem solving in real life situations, is one suggestion [84]. Using such an approach allows MWC users to reflect on the outcomes of their actions to further support and reinforce their learning leading to behavioural outcomes that enhance community participation and social and vocational engagement. Additionally, design could include social-constructivist approaches to learning [85], where knowledge of wheelchair-use is co-constructed through interacting and collaborating with others, including peer wheelchair users or peer trainers. Wheelchair training approaches integrating constructivist training strategies could encourage collaborative problem solving and allow for the opportunity to share experiences, discuss challenges and collaboratively find solutions [86, 87].

Manual wheelchair training is underpinned by multiple modelss depending on the outcomes it is striving to achieve. Social models of disability address societal barriers and foster inclusion to support users to navigate their environments effectively, while medical models of disability and biomechanical models will more strongly emphasise an individual's physical health and capacity to engage in training through optimising technical aspects of wheelchair use including propulsion biomechanics. While these models are main principles of manual wheelchair training, this review highlights the need for the complementary integration of appropriate learning theory to create a holistic, theoretically informed approach to wheelchair training. Training designs incorporating Social Cognitive Theory [88] had a stronger focus on outcomes that were long term and broad. This was because they focused on application of wheelchair skills and knowledge (Level 3 Kirkpatrick's framework) to support community participation and quality of life (Level 4b Kirkpatrick's framework). A Social Cognitive Theory approach to learning encompasses observational and social learning, hands on practice and privileges authentic feedback and hence integrates elements of behaviourism, experiential learning and social constructivism in addition to emphasizing building self-efficacy in wheelchair use. This learning theory therefore aligns with the social and practical aspects of wheelchair use, making it an effective theory for use in MWC training designs that are targeting broader outcomes of training (Level 4b Kirkpatrick's framework). This is not the only learning theory that could be embedded into wheelchair training designs, however it does provide a lens through which to consider how the learning process will unfold for the MWC user and what their outcomes will likely be. Alternatively, there is also opportunity for the synergistic combining of learning theories. Motor learning theory, which was also a prominent learning theory in this review had a strong focus on the acquisition of skills (Kirkpatrick's Level 2b) and attended less to behavioural and participatory outcomes. The integration of this learning theory with another, such as situational learning may offer an increasingly holistic approach to training that recognizes the multifaceted nature of wheelchair use.

Further attention to the educational design of MWC training will contribute to a framework that enables stakeholders of wheelchair training (wheelchair users, clinicians, and peer wheelchair trainers) to access programs that are grounded in learning theory, which could emphasise what learning is important at any given time point for a MWC user, including both individual skill and participatory outcomes. Overall, it is noted that further investigation into ancillary wheelchair training outcomes such as hospital length of stay, hospital avoidance, long term service provision requirements and staff resourcing is required. Understanding the influence of MWC training on healthcare costs is critical for organisational decision making and the translation of these training designs into practice (Level 4a Kirkpatrick's framework).

Implications for practice

The relative absence of learning theory embedded within the reporting of MWC training programs suggests that present training programs are not always designed and developed through an educational lens. This appears to be consistent with broader assistive technology education and training, potentially due to lack of tradition to do so within this field. When working with clients to

teach them how to use assistive technology, clinicians are well placed to deliberately integrate learning theory into their training programs, so that the learning is relevant to the needs and stage of competence of the MWC user. This can include focus on short and long term outcomes and can be readily applied by MWC users to the different contexts in which they live. By not leveraging learning theories, training programs may miss opportunity to enhance learning experiences. There is now a call to redesign the MWC training programs that exist to ensure they align with educational approaches that are appropriate for the context of the MWC user. Existing programs must move beyond approaches that exclusively target the acquisition of wheelchair skills or propulsion techniques. Doing so will potentially result in improved engagement/participation in the community, quality of life, and health care costs as well as reducing carer reliance and hospital admissions related to tips/falls and upper limb related overuse injuries.

Limitations

This review did not include papers with able bodied persons simulating wheelchair users, or clinicians/students being trained or those under the age of 18; therefore some training approaches and potential learning theories may not have been captured in this review. Additionally, there are a number of limitations of using the Kirkpatrick's model to evaluate the impact of training [89]. The model is intended as outcome focused and does not attend to the contextual factors that can influence training and the underlying mechanisms that may influence outcomes [89]. To ameliorate this, we applied the ICF as an additional organisational framework, in particular, to further contextualise context and outcomes. However, we acknowledge that the use of Kirkpatrick's evaluation framework to measure behaviour change outcomes may have introduced subjectivity, particularly around categorising behavioural change outcomes based on the timing of the outcome measures. Outcomes measured at four weeks post intervention may not be reflective of behaviour change. To support further understanding of contextual factors that may influence manual wheelchair training outcomes it is suggested that a realist evaluation approach is used to identify specific aspects of manual wheelchair training programs that may influence outcomes.

Conclusion

Mirroring a broader trend in the area of patient education, existing MWC training programs do not consistently integrate learning theories into their instructional design. This review demonstrates that the delivery of training programs which lack an explicit educational underpinning are more likely to result in short term outcomes that may not have community application for the people they intend to service. To support outcomes related to community participation and vocational and leisure pursuits for manual wheelchair users, the educational approach needs to incorporate holistic learning theories and instructional design to further understanding of the organisational impact of broad outcomes and long-term learning.

Abbreviations

ICF	International Classification of Functioning
MWC	Manual Wheelchair
PCC	Participants, Concept, Context
WST	Wheelchair Skills Test
WST-Q	Wheelchair Skills Test Questionnaire

Supplementary Information

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Supplementary Material 1.

Authors' contributions

All authors were responsible for Conceptualization; Methodology; Writing—review & editing, KC was responsible for Writing the original manuscript, KC and SA were reposnsible for formal analysis and SA, NL and CM were responsible for supervision.

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Data availability

The data sets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

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Competing interests

The authors declare no competing interests.

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References

1. Best KL, Miller WC. Physical and leisure activity in older community-dwelling canadians who use wheelchairs: a population study. J Aging Res. 2011;2011:147929.

2. Pritchard E, Barker A, Day L, Clemson L, Brown T, Haines T. Factors impacting the household and recreation participation of older adults living in the community. Disabil Rehabil. 2015;37(1):56–63.
3. De Coninck L, Declercq A, Bouckaert L, Vermandere M, Graff MJL, Aertgeert B. Perspectives of older adults with a chronic condition on functioning, social participation and health: a qualitative study. BMC Geriatr. 2021;21(1):418.
4. Giesbrecht EM, Miller WC, Woodgate RL. Navigating uncharted territory: a qualitative study of the experience of transitioning to wheelchair use among older adults and their care providers. BMC Geriatr. 2015;15:91.
5. Huebner RA, Johnson K, Bennett CM, Schneck C. Community participation and quality of life outcomes after adult traumatic brain injury. Am J Occup Ther. 2003;57(2):177–85.
6. Mayo NE, Wood-Dauphinee S, Côté R, Durcan L, Carlton J. Activity, participation, and quality of life 6 months poststroke. Arch Phys Med Rehabil. 2002;83(8):1035–42.
7. Gill TM, Kurland B. The burden and paterns of disability in activities of daily living among community-living older persons. The Journals of Gerontology. 2003;58A(1):70.
8. WHO. Wheelchair Provision Guidelines. Geneva; 2023. Report No.: Licence: CC BY-NC-SA 3.0 IGO.
9. AIHW. Older Australia at a glance (fourth edition). Canberra: AIHW; 2007.
10. Gowran RJ, Clifford A, Gallagher A, McKee J, O'Regan B, McKay EA. Wheelchair and seating assistive technology provision: a gateway to freedom. Disabil Rehabil. 2022;44(3):370–81.
11. Best KL, Kirby RL, Smith C, MacLeod DA. Wheelchair skills training for community-based manual wheelchair users: a randomized controlled trial. Arch Phys Med Rehabil. 2005;86(12):2316–23.
12. Chen P. Wheelchair Propulsion for Everyday Manual Wheelchair Users: Repetition Training and Machine Learning-based Monitoring. Arts & Sciences Electronic Theses and Dissertations. 2019.
13. Kirby RL, Corkum CG, Smith C, Rushton P, MacLeod DA, Webber A. Comparing performance of manual wheelchair skills using new and conventional rear anti-tip devices: randomized controlled trial. Arch Phys Med Rehabil. 2008;89(3):480–5.
14. Liu HYT, Chia RM, Setiawan IMA, Crytzer TM, Ding D. Development of "My Wheelchair Guide" app: a qualitative study. Disabil Rehabil Assist Technol. 2019;14(8):839–48.
15. Routhier F, Kirby RL, Demers L, Depa M, Thompson K. Efficacy and retention of the French-Canadian version of the wheelchair skills training program for manual wheelchair users: a randomized controlled trial. Arch Phys Med Rehabil. 2012;93(6):940–8.
16. Beaudoin M, Best KL, Raymond E, Routhier F. Influence of Roulez avec confiance, a peer-led community-based wheelchair skills training program, on manual wheelchair users. Disabil Rehabil Assist Technol. 2021;18(7):1093–100.
17. Best KL, Miller WC, Huston G, Routhier F, Eng JJ. Pilot Study of a Peer-Led Wheelchair Training Program to Improve Self-Efficacy Using a Manual Wheelchair: A Randomized Controlled Trial. Arch Phys Med Rehabil. 2016;97(1):37–44.
18. Furmaniuk L, Cywinska-Wasilewska G, Kaczmarek D. Influence of long-term wheelchair rugby training on the functional abilities of persons with tetraplegia over a two-year period post-spinal cord injury. Journal of Rehabilitation Medicine (Stiftelsen Rehabiliteringsinformation). 2010;42(7):688–90.
19. Miller WC, Best KL, Eng JJ, Routhier F. Influence of Peer-led Wheelchair Training on Wheelchair Skills and Participation in Older Adults: Clinical Outcomes of a Randomized Controlled Feasibility Trial. Arch Phys Med Rehabil. 2019;100(6):1023–31.
20. Park JM, Jung HS. A study on the effects of modified wheelchair skills program (WSP) for hemiplegic clients. Assist Technol. 2022;34(1):26–33.
21. Standal OF, Jespersen E. Peers as resources for learning: a situated learning approach to adapted physical activity in rehabilitation. Adapt Phys Activ Q. 2008;25(3):208–27.
22. Tasiemski T, Wilski M, Urbanski P. One world project's wheelchair skills training camp in Morocco - effects of a community peer-based programme. Disabil Rehabil Assist Technol. 2021;18(6):736–42.
23. Charlton K, Murray C, Boucaut R, Berndt A. Facilitating manual wheelchair skills following lower limb amputation using a group process: A nested mixed methods pilot study. Aust Occup Ther J. 2021;68(6):490–503.
24. Choi WS, Lee JM, Kim TY, Kim JH, Lee JA, Choi H. Development of adjustable wheelchair training structure and validation of usefulness for evaluation and training of manual wheelchair skill. J Mechan Med Biol. 2020;20(10):2040032.
25. Kirby RL, Mitchell D, Sabharwal S, McCranie M, Nelson AL. Manual Wheelchair Skills Training for Community-Dwelling Veterans with Spinal Cord Injury: A Randomized Controlled Trial. PLoS ONE [Electronic Resource]. 2016;11(12):e0168330.
26. MacPhee AH, Kirby RL, Coolen AL, Smith C, MacLeod DA, Dupuis DJ. Wheelchair skills training program: A randomized clinical trial of wheelchair users undergoing initial rehabilitation. Arch Phys Med Rehabil. 2004;85(1):41–50.
27. McClure LA. Implementation of clinical practice guidelines following acute spinal cord injury: University of Pittsburgh; 2010.
28. Morgan KA, Tucker SM, Klaesner JW, Engsberg JR. A motor learning approach to training wheelchair propulsion biomechanics for new manual wheelchair users: A pilot study. J Spinal Cord Med. 2017;40(3):304–15.
29. Giesbrecht E, Faieta J, Best K, Routhier F, Miller WC, Laberge M. Impact of the TEAM Wheels eHealth manual wheelchair training program: Study protocol for a randomized controlled trial. PLoS ONE [Electronic Resource]. 2021;16(10):e0258509.
30. Pellichero A, Best KL, Routhier F, Miller WC. Exploring Older Adults' Experiences and Perceptions with a Peer-Led Wheelchair Training Program. Canadian Journal of Occupational Therapy - Revue Canadienne d Ergotherapie. 2020;87(3):192–9.
31. Yong Tai W, Limroongreungrat W, Li-Shan C, Xiang K, Liang-Ching T, Yu-Ping C, et al. Immediate video feedback on ramp, wheelie, and curb wheelchair skill training for persons with spinal cord injury. J Rehabil Res Dev. 2015;52(4):421–30.
32. Chaar F, Archambault PS. Usability of a virtual reality manual wheelchair simulator. Disabil Rehabil Assist Technol. 2022;18(8):1489–99.
33. Kotajarvi BR, Basford JR, An KN, Morrow DA, Kaufman KR. The effect of visual biofeedback on the propulsion effectiveness of experienced wheelchair users. Arch Phys Med Rehabil. 2006;87(4):510–5.
34. Blouin M, Lalumière M, Gagnon DH, Chénier F, Aissaoui R. Characterization of the immediate effect of a training session on a manual wheelchair simulator with haptic biofeedback: towards more effective propulsion. IEEE Trans Neural Syst Rehabil Eng. 2015;23(1):104–15.
35. DeGroot KK, Hollingsworth HH, Morgan KA, Morris CL, Gray DB. The influence of verbal training and visual feedback on manual wheelchair propulsion. Disabil Rehabil Assist Technol. 2009;4(2):86–94.
36. Richter WM, Kwarciak AM, Guo L, Turner JT. Effects of single-variable biofeedback on wheelchair handrim biomechanics. Arch Phys Med Rehabil. 2011;92(4):572–7.
37. Rice I, Gagnon D, Gallagher J, Boninger M, Rice I, Gagnon D, et al. Hand rim wheelchair propulsion training using biomechanical real-time visual feedback based on motor learning theory principles. J Spinal Cord Med. 2010;33(1):33–42.
38. Rice LA, Smith I, Kelleher AR, Greenwald K, Hoelmer C, Boninger ML. Impact of the clinical practice guideline for preservation of upper limb function on transfer skills of persons with acute spinal cord injury. Arch Phys Med Rehabil. 2013;94(7):1230–46.
39. Rodgers MM, Keyser RE, Rasch EK, Gorman PH, Russell PJ. Influence of training on biomechanics of wheelchair propulsion. J Rehabil Res Dev. 2001;38(5):505–11.
40. Worobey L, Kirby RL. Clinician wheelchair skills training using self-study and remote asynchronous feedback. J Spinal Cord Med. 2017;40(5):584.
41. Giesbrecht EM, Miller WC. Effect of an mHealth Wheelchair Skills Training Program for Older Adults: A Feasibility Randomized Controlled Trial. Arch Phys Med Rehabil. 2019;100(11):2159–66.
42. Kirby RL, Mifflen NJ, Thibault DL, Smith C, Best KL, Thompson KJ, et al. The manual wheelchair-handling skills of caregivers and the effect of training. Arch Phys Med Rehabil. 2004;85(12):2011–9.
43. Keeler L, Kirby RL, Parker K, McLean KD, Hayden JA. Effectiveness of the Wheelchair Skills Training Program: a systematic review and meta-analysis. Disabil Rehabil Assist Technol. 2019;14(4):391–409.
44. Tu CJ, Liu L, Wang W, Du HP, Wang YM, Xu YB, et al. Effectiveness and safety of wheelchair skills training program in improving the wheelchair skills capacity: a systematic review. Clin Rehabil. 2017;31(12):1573–82.

45. Khalil MK, Elkhider IA. Applying learning theories and instructional design models for effective instruction. Adv Physiol Educ. 2016;40(2):147–56.
46. Littooij E, Doodeman S, Holla J, Ouwerkerk M, Post L, Satink T, et al. Setting meaningful goals in rehabilitation: A qualitative study on the experiences of clients and clinicians in working with a practical tool. Clin Rehabil. 2022;36(3):415–28.
47. Mutchnick MG. The Role of Motivation in Rehabilitation. In: Williams JM, Long CJ, editors. Cognitive Approaches to Neuropsychology. Boston, MA: Springer, US; 1988. p. 169–87.
48. Bandura A. Social foundations of thought and action : a social cognitive theory. Englewood Cliffs, N.J: Prentice-Hall; 1986.
49. Schmidt RA. A schema theory of discrete motor skill learning. Psychol Rev. 1975;82(4):225–60.
50. Laver JW, E. Situated Learning: Legitimate Peripheral Participation (Learning in Doing: Social, Cognitive and Computational Perspectives). Cambridge. 1991.
51. Skinner BF. Science and human behavior: Simon and Schuster; 1965.
52. Choi J-I, Hannafin M. Situated Cognition and Learning Environments: Roles, Structures, and Implications for Design. Education Tech Research Dev. 1995;43(2):53–69.
53. Horsburgh J, Ippolito K. A skill to be worked at: using social learning theory to explore the process of learning from role models in clinical settings. BMC Med Educ. 2018;18(1):156.
54. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. Int J Soc Res Methodol. 2005;8(1):19–32.
55. Yardley S, Dornan T. Kirkpatrick's levels and education "evidence." Med Educ. 2012;46(1):97–106.
56. Bickenbach JE, Chatterji S, Badley EM, Ustün TB. Models of disablement, universalism and the international classification of impairments, disabilities and handicaps. Soc Sci Med. 1999;48(9):1173–87.
57. Pollock D, Davies EL, Peters MDJ, Tricco AC, Alexander L, McInerney P, et al. Undertaking a scoping review: A practical guide for nursing and midwifery students, clinicians, researchers, and academics. J Adv Nurs. 2021;77(4):2102–13.
58. Haddaway NR, Collins AM, Coughlin D, Kirk S. The Role of Google Scholar in Evidence Reviews and Its Applicability to Grey Literature Searching. PLoS ONE. 2015;10(9):e0138237.
59. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. Ann Intern Med. 2018;169(7):467–73.
60. Bonaparte JP, Kirby RL, Macleod DA. Learning to perform wheelchair wheelies: comparison of 2 training strategies. Arch Phys Med Rehabil. 2004;85(5):785–93.
61. Ctri. Comparing the effectiveness of 3 types of wheelchair skills training. 2023.
62. Desai R, Jayavant S, Varshneya H. To investigate the immediate and short term effects of wheelchair skill training program (WSTP) on participation in patients with spinal cord involvement. Indian Journal of Occupational Therapy (Indian Journal of Occupational Therapy). 2013;45(2):9–14.
63. Garrett B, Snowdon L, McCarthy S. Clinical application of the wheelchair skills program: Objective testing and training methods. Topics in Spinal Cord Injury Rehabilitation. 2011;16:59.
64. Giesbrecht EM, Miller WC. A randomized control trial feasibility evaluation of an mHealth intervention for wheelchair skill training among middle-aged and older adults. PeerJ. 2017;5:e3879.
65. Giesbrecht EM, Miller WC, Jin BT, Mitchell IM, Eng JJ. Rehab on Wheels: A Pilot Study of Tablet-Based Wheelchair Training for Older Adults. JMIR Rehabilitation And Assistive Technologies. 2015;2(1):e3.
66. Kirby RL, Lugar JA, Breckenridge C. New wheelie aid for wheelchairs: controlled trial of safety and efficacy. Arch Phys Med Rehabil. 2001;82(3):380–90.
67. Limroongreungrat W, Chang L-S, Wang YT, Acker C, Maurer C, Sprigle S. Effectiveness Of Immediate Video Feedback On Wheelchair Propulsion Training For Patients With Spinal Cord Injuries: 2693 Board #87 May 29 3:30 PM - 5:00 PM. Med Sci Sports Exerc. 2009;41(5):430.
68. Ozturk A, Ucsular FD. Effectiveness of a wheelchair skills training programme for community-living users of manual wheelchairs in Turkey: a randomized controlled trial. Clin Rehabil. 2011;25(5):416–24.
69. Quiñones-Uriostegui I, Alessi-Montero A, Bueyes-Roiz V, Nuñez-Carrera L, Moreno-Hernández A, Quinzaños-Fresnedo J, et al. Wheelchair users' satisfaction after provision using the WHO 8-step guidelines: A pilot study. J Spinal Cord Med. 2023;47(5):640–8.
70. Rice IM, Rice LA, Motl RW. Promoting Physical Activity Through a Manual Wheelchair Propulsion Intervention in Persons With Multiple Sclerosis. Arch Phys Med Rehabil. 2015;96(10):1850–8.
71. Rice LA, Smith I, Kelleher AR, Greenwald K, Boninger ML. Impact of a wheelchair education protocol based on practice guidelines for preservation of upper-limb function: a randomized trial. Arch Phys Med Rehabil. 2014;95(1):10-9.e1.
72. van der Scheer JW, de Groot S, Vegter RJ, Hartog J, Tepper M, Slootman H, et al. Low-Intensity Wheelchair Training in Inactive People with Long-Term Spinal Cord Injury: A Randomized Controlled Trial on Propulsion Technique. Am J Phys Med Rehabil. 2015;94(11):975–86.
73. van der Scheer JW, de Groot S, Tepper M, Faber W, group A, Veeger DH, et al. Low-intensity wheelchair training in inactive people with long-term spinal cord injury: A randomized controlled trial on fitness, wheelchair skill performance and physical activity levels. J Rehabil Med. 2016;48(1):33–42.
74. Worobey LA, Kirby RL, Heinemann AW, Krobot EA, Dyson-Hudson TA, Cowan RE, et al. Effectiveness of Group Wheelchair Skills Training for People With Spinal Cord Injury: A Randomized Controlled Trial. Arch Phys Med Rehabil. 2016;97(10):1777-84.e3.
75. Yeo SS, Kwon JW. Wheelchair Skills Training for Functional Activity in Adults with Cervical Spinal Cord Injury. Int J Sports Med. 2018;39(12):924–8.
76. Bandura A. Human agency in social cognitive theory. American Psychological Association. 1989;44:1175–84.
77. Kafri M, Atun-Einy O. From Motor Learning Theory to Practice: A Scoping Review of Conceptual Frameworks for Applying Knowledge in Motor Learning to Physical Therapist Practice. Phys Ther. 2019;99(12):1628–43.
78. Ng'andu K, Hambulo F, Haambokoma N, Milingo T. The Contribution of Behavioral Theories of Learning to Education. 2013:1.
79. Rice IM, Pohlig RT, Gallagher JD, Boninger ML. Handrim wheelchair propulsion training effect on overground propulsion using biomechanical real-time visual feedback. Arch Phys Med Rehabil. 2013;94(2):256–63.
80. Lee DCA, Pritchard E, McDermott F, Haines TP. Falls prevention education for older adults during and after hospitalization: A systematic review and meta-analysis. Health Educ J. 2013;73(5):530–44.
81. Mukhalalati BA, Taylor A. Adult learning theories in context: a quick guide for healthcare professional educators. J Med Educ Curric Dev. 2019;6:2382120519840332.
82. Chowdhury MS. Human behavior in the context of training: An overview of the role of learning theories as applied to training and development. Journal of Knowledge management practice. 2006;7(2):1–11.
83. Knecht-Sabres LJ. Experiential Learning in Occupational Therapy: Can It Enhance Readiness for Clinical Practice? Journal of Experiential Education. 2013;36(1):22–36.
84. Amineh RJ, Asl HD. Review of constructivism and social constructivism. Journal of social sciences, literature and languages. 2015;1(1):9–16.
85. Savery JR, Duffy TM. Problem based learning: An instructional model and its constructivist framework. Educ Technol. 1995;35(5):31–8.
86. Steffe L, Gale J. A constructivist approach to teaching. Constructivism in education. 1995:489–523.
87. Islam KF, Awal A, Mazumder H, Munni UR, Majumder K, Afroz K, et al. Social cognitive theory-based health promotion in primary care practice: A scoping review. Heliyon. 2023;9(4):e14889.
88. Best KL, Miller WC, Eng JJ, Routhier F, Goldsmith C. Randomized controlled trial protocol feasibility: The Wheelchair Self-Efficacy Enhanced for Use (WheelSeeU). Canadian Journal of Occupational Therapy - Revue Canadienne d Ergotherapie. 2014;81(5):308–19.
89. Allen LM, Hay M, Palermo C. Evaluation in health professions education—Is measuring outcomes enough? Med Educ. 2022;56(1):127–36.

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