

THE EFFECT OF ADAPTIVE SPORTS ON INDIVIDUALS WITH ACQUIRED NEUROLOGICAL DISABILITIES AND ITS ROLE IN REHABILITATION A SYSTEMATIC REVIEW

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ABSTRACT

The aims of this systematic review were to report on the feasibility of adaptive sports for individuals with acquired central neurological lesion; to analyze the effects of this approach according to the domains of the International Classification of Functioning, Health and Disability (ICF); and to emit guiding points for future research. Two authors searched PubMed, Scopus, Cochrane, Pedro, and SPORTdiscus for eligible trials. Data concerning demographics, outcome measures, results, and conclusions were extracted, and a qualitative synthesis was performed. Adaptive sports seem to be a feasible, efficient, and cost-effective complement to conventional rehabilitation. Significant effects were found on all domains of the ICF, except “environmental factors.” Key factors, such as intervention volume, intensity, and type, play a determining role. This review is the first to expose the beneficial effects of adaptive sports practice among individuals with neurological lesions by relying on prospective evidence.

Introduction

Sedentary behaviors are high among individuals with an acquired central neurological lesion (1). Less than 20% of this population manage to achieve the 2010 World Health Organization recommendations, namely to engage in minimum 150 min of moderately intense physical activity per week (2). Inactivity further increases with age and degree of mobility impairment (3). However, regular engagement in physical activity decreases morbidity and mortality rates following motor disability, and even induces disease-modifying effects (4,5). By improving the individuals' physical conditions, activities of daily living, social participation, and quality of life improve (6). Engaging in physical activity therefore has the ability to decrease disability, as defined by the International

Classification of Functioning, Health and Disability (ICF) (7). However, long-term adherence to physical activity remains low (8). Overcoming this challenge is crucial to sustain improvements (9).

Physical activity programs require engagement in energy expenditure through bodily movements (10). Such programs, which have become essential components of neurological rehabilitation, lack motivational stimuli, and patients often stop engaging in these activities after discharge from rehabilitation (11). Sport practice, however, focuses on performance and involves rules, competition, and team work. These factors increase sense of enjoyment and adherence (12).

Although the literature on the benefits of sports among the physically abled has been extensive, little has focused on sports adapted for populations with physical disabilities. Nevertheless, authors believe that by requiring task-specific, repetitive, and intense training, sport practice stimulates motor recovery and improves motor function following neurological lesion (13). Adaptive sports could, therefore, be used as a tool to improve rehabilitation. As populations of individuals with central neurological impairments will substantially expand in the coming years (14), it is crucial to research efficient and cost-effective treatments to integrate in rehabilitation. However, to date, no clinical reviews have explored the topic at hand.

The aims of this systematic review are to: 1) report on the feasibility of adaptive sports as a rehabilitative tool; 2) investigate its effects according to the on motor disability following acquired neurological lesion ICF framework (7); and 3) analyze the available literature in order to emit guiding points for future research.

Methods

RESEARCH STRATEGY

This systematic review was registered in PROSPERO (CRD42019125534). The research process was carried out in accordance to the 2009 PRISMA guidelines (15). The population, namely, adults with acquired central neurological disability, was specified into three subgroups: spinal cord injury (SCI), stroke, and multiple sclerosis (MS) as these are among the costliest neurological disorders (16).

LITERARY SEARCH

Keywords were identified using the Populations, Intervention, Comparison, Outcome (PICO) method. Combining keywords in relation to the populations (stroke, multiple sclerosis OR MS, spinal cord injury OR SCI, wheelchair users, physical disability, neurological disability) and the intervention (adaptive sport, wheelchair sports, swimming, basketball, rugby, handbike, dance, horse-riding, golf, etc.) using boolean operators, allowed to construct different research equations, introduced into PubMed, Scopus, Cochrane, Pedro, and SPORTdiscus. All references were exported from the databases to Endnote. Reference lists of relevant trials and reviews were examined.

STUDY SELECTION

Articles were included when 1) the reported language was English or French; 2) the trial followed a longitudinal and prospective design; 3) the investigated populations were adults with stroke, SCI, or MS; 4) the intervention was an adaptive sports program; and 5) the primary outcome measured physical and/or psychological variables. Sample groups referred to as “wheelchair users” were included when the three investigated disabilities made up more than 50% of the sample. Articles were excluded if 1) the article was a review or case-report; 2) the investigated population included cognitive, mental, and sensorial disabilities, or was specific to veterans; 3) the intervention was a physical activity program (could not lead to competition) or required the use of any type of technology; and 4) the primary outcome focused on immediate physiological effects.

Two researchers (L.D. and G.S.) independently screened titles and abstracts of the retrieved studies to assess for eligibility, after removal of duplicates. Articles free from exclusion criteria were selected for full-text lecture, and corresponding authors were contacted when full-text was not available. Articles containing all inclusion criteria were included for qualitative synthesis. Disagreements were resolved through consensus.

DATA EXTRACTION AND SYNTHESIS

Results were extracted into a piloted table (Table 1) by a single author (L.D.), with verification from a second author (G.S.). Articles were divided according to study design and ranked in a descending order according to quality. Sample demographics, including size, motor disorder, age, sex ratio, and phase of rehabilitation were extracted. Early phase referred to participants within the first 6 months of rehabilitation. The outcome measures, interventions (type, duration, frequency, and intensity if available), results (difference in means within or between groups in points or percentage when $P < 0.05$, effect size if available), and conclusions were extracted. Results were synthesized in a qualitative and narrative format, according to the ICF domains and components, with their corresponding code.

LEVEL OF EVIDENCE AND QUALITY APPRAISAL

Level of evidence was attributed according to study design. Randomized controlled trials (RCT) represented the highest level of evidence (level I), followed by controlled trials (level II) and single-cohort studies (level III). Study quality was appraised by a single author (LD) using items of the Downs and Black scale, which has high internal consistency, reliability, and accuracy (47). Items assessing external validity, internal validity, and power were used, whereas reporting items were excluded as these did not differ according to study-design. Moreover, as the modality of the intervention prevented the masking of subjects to attribution, item 14: “attempt to blind subjects to the intervention” was removed. Sixteen items were, thus, checked. Studies scoring above 10 were of good quality (or excellent if above 14), whereas studies scoring less were of mediocre quality (or poor if below 5).

RESULTS

The search was conducted from October 2018 to March 2019. From the 4101 articles screened, 30 were selected (Fig. 1). Among the included studies, 16%, or $n = 5$ trials, followed an RCT design (level I), 31% ($n = 9$) had a control group which did not receive adaptive sports, without random allocation (level II), and 53% ($n = 16$) followed a single cohort (level III). Average methodological quality was mediocre (8/16) and ranged from 3 to 16 on the modified Downs and Black scale (Table 2). Item 27, concerning power to detect clinically important effects, was the most absent, deteriorating internal validity.

Outcome measures concerned all domains of the ICF, except “environmental factors,” commonly studied through cross-sectional designs. “Bodily functions and structures” was the most studied domain, with $n = 24$ trials investigating this domain, followed by “activity and participation” ($n = 9$), grouped due to close interaction between both domains, and finally “personal factors” ($n = 6$). Five trials investigated quality of life, and six studied feasibility. A wide range of components of the ICF domains were studied through heterogeneous tests and scales. Lack of RCT, together with the variety of scales used to measure a range of outcomes, limited the analysis of the literature to a qualitative synthesis.

A total of 741 participants were recruited, ranging from samples of 4 to 123. More than 65% were male participants. Average age was 42 years, with stroke patients being the oldest group (averaging 58.6 years) and SCI subjects, the youngest one (averaging 32.6 years). The latter population also was the most researched, with 44% of the included studies having samples solely made up of individuals with SCI. Studies enrolling only participants with stroke or MS made up 23% and 20% of the studies, respectively. The remaining 13% were referred to as “wheelchair users” and had heterogeneous groups in terms of neurological causes of motor disabilities (spina bifida, lower-limb amputations, etc.). Finally, 16% of the included studies were performed during the early phase, whereas 84% evaluated late phases.

Eleven different types of adaptive sports were investigated (Fig. 2). The most researched adaptive sport was handbiking.

Table 1.
Summary of included trials characteristics — demographics, protocol, outcome measures, and results.

Author (Ref) Level of Evidence (Quality)	Outcome Measures	Participants: <i>n</i> , Diagnosis Groups: <i>n</i> , Mean Age Men: Women Phase of Rehabilitation	Measure Points	Intervention Measures	Results	Conclusion
Bunketorp-Kall et al. (17) Level I (16/16)	<ul style="list-style-type: none"> - Perception of stroke recovery (Stroke Impact Scale (SIS)) - Gait measured (Timed Up and Go (TUG)) - Balance (Berg balance scale (BBS) and the Bäckstrand, Dahlberg, and Lijénäs balance scale (BDL-BS)) - Grip strength (Gripitt) - Cognition (Barrow Neurological Institute Screen for Higher Cerebral Functions (BNIS)) - Working memory (subtest of Letter-Number Sequencing (LNS)) 	<ul style="list-style-type: none"> <i>n</i> = 123 stroke EG1: <i>n</i> = 41 EG2: <i>n</i> = 41 CG: <i>n</i> = 41 	<ul style="list-style-type: none"> T0: prior to intervention T1: 12 wk later T2: 3-month follow-up T3: 6-month follow-up 	<ul style="list-style-type: none"> EG1: Horse-riding 2 h 2 × per week 12 wk EG2: rhythm-and-music 1.5 h 2 × per week 12 wk CG: standard care 	<ul style="list-style-type: none"> - EG1 (+12.14%) and EG2 (+23.8%) improved SIS scores significantly more than the CG at T1, T2, and T3. EG1 improved more than EG2. - TUG, BBS, and BDL-BS improved significantly in the EG1, but not in the EG2, at T1, T2, and T3. - Grip strength significantly improved in the EG2 at T1, T2, and T3. - Cognition and memory significantly improved in the EG2 at T3. 	<ul style="list-style-type: none"> Multimodal interventions, such as horse-riding and rhythm-and-music therapy, can induce improvements that are maintained among stroke survivors with moderate disability.
Najadabadi et al. (18) Level I (16/16)	<ul style="list-style-type: none"> - Motor control (reaching and grasping kinematic analysis) - Functional performance (motor activity log, Wolf Motor Function Test (WMFT), Box and Block Test (BBT), and Wrist Position Test (WPT)) 	<ul style="list-style-type: none"> <i>n</i> = 48 stroke EG1: <i>n</i> = 16 EG2: <i>n</i> = 16 CG: <i>n</i> = 16 	<ul style="list-style-type: none"> T0: prior to intervention T1: 7 wk later T2: 7-wk follow-up 	<ul style="list-style-type: none"> EG1: competitive volleyball 1 h 3 × per week 7 wk EG2: volleyball 60 min 3 × per week 7 wk + traditional rehabilitation 30 min 3 × per week (both EG1 and EG2) 30 min CG: traditional rehabilitation 30 min 3 × per week 	<ul style="list-style-type: none"> - Reaching and grasping significantly improved in EG1 and EG2, but not in CG, at T1 and T2. EG1 improved significantly more than EG2. - WMFT significantly increase at T1 and T2 for all groups. BBT and WPT significantly improved in EG1 and EG2. EG1 demonstrated greater improvements than EG2 in all functional measures at T1 and T2. 	<ul style="list-style-type: none"> Volleyball exercises enhance upper-limb motor control following stroke, which improves global functional performance. Performing these exercises in a competitive setting further optimizes the results.

<p>Beinotti et al. (19) Level I (14/16)</p>	<p>-Quality of life (Outcomes Study 36-item Short-Form health survey (SF-36)) n = 24 stroke EG: n = 12 59 8:2 late CG: n = 12 52 6:4 late</p>	<p>T0: prior to intervention T1: 16 wk later</p>	<p>EG: Horse riding 30 min 1 × per week 16 wk + physiotherapy 50 min 3 × per week 16 wk CG: physiotherapy 50 min 3 × per week 16 wk</p>	<p>-EG at T2: + 16.6 points -CG at T2: - 6.1 points Difference is statistically significant. This global increase was due to significantly more improvements in three subdomains: functional capacity, physical aspects, and mental health.</p>	<p>Supplementing horseback riding therapy to conventional therapy enhances its effect on quality of life of stroke patients.</p>
<p>Velikonja et al. (20) Level I (21/26)</p>	<p>-Spasticity (EDSS pyramidal functions (pyr) and modified Ashworth scale (MAS)) -Cognitive functions (mazes subtests of the Executive Function Module from the Neuropsychological assessment battery (NAB), Tower of London and Brickenkamp d2 test) -Mood (Center for Epidemiological Studies-Depression scale (CES-D)) -Fatigue measured by the Modified Fatigue Impact scale (MFIS).</p> <p>n = 20 relapsing-remitting, primary progressive and secondary progressive MS EG1: n = 10, median age: 42 n/A late EG2: n = 10, median age: 41 n/A late</p>	<p>T0: prior to intervention T1: 10 wk later</p>	<p>EG1: climbing, 1 h, 1 × per week, 10 wk EG2: hatha yoga, 1 h, 1 × per week 10 wk</p>	<p>-MAS scores did not alter at T2, in neither groups. EG1 had significantly improved EDSSpyr by 25% at T1. -Executive function did not alter, but selective attention significantly improved in the EG2 by 17% at T1. -MFIS significantly improved by 32.5% at T1 in the EG1. -Neither interventions had a significant impact on CES-D scores.</p>	<p>Both climbing and yoga are effective at improving specific MS symptoms and can be used as complementary therapies to conventional treatment.</p>
<p>Park et al. (21) Level I (14/16)</p>	<p>-Upper-limb function (Manual function test (MFT), and a hand dynamometer) -Balance (Berg balance scale (BBS), good balance system for static balance and 10 m walk test (10MWT)) -Quality of life (Stroke Specific Quality of Life questionnaire (SS-QOL))</p> <p>n = 26 stroke EG: n = 13 n/A n/A early CG: n = 13 n/A n/A early</p>	<p>T0: prior to intervention T1: 6 wk later</p>	<p>EG: boxing (sitting or standing) 30 min 3 × per week 6 wk + physical therapy 3 × per week 6 wk CG: physical therapy 3 × per week 6 wk</p>	<p>-MFT scores (+ 3.62 points), dynamic balance (+ 6.08 points) and SS-QOL scores (+ 17.31 points) improved significantly in the EG, which was significantly more than in the CG. -Both groups significantly increased hand grip strength (+ > 0.85 kg) and static balance at T1. -Gait significantly improved in the EG (5.78 s) but not in the CG at T1.</p>	<p>A 6-wk sitting boxing program has beneficial effects on upper-limb function, balance, gait, and quality of life of stroke inpatients.</p>

Author (Ref) Level of Evidence (Quality)	Outcome Measures	Participants: <i>n</i> , Diagnosis Groups: <i>n</i> , Mean Age Men: Women Phase of Rehabilitation	Measure Points	Intervention Measures	Results	Conclusion
Ng et al. (22) Level II (12/16)	-Quality of life (Patient-reported Outcomes Measurement Information System-Global Health (PROMIS-GH)) -Fatigue (Fatigue Impact Scale (FIS)) -Depression (Beck Depression Inventory) -Cognitive function (MS functional Composite Measure) -Balance and mobility (Berg Balance Scale (BBS), the Dynamic Gait Index (DGI) and the Timed-Up and Go (TUG))	<i>n</i> = 12 relapsing-remitting MS <i>n</i> = 1 primary progressive MS EG: <i>n</i> = 7, 49 1:6 late CG: <i>n</i> = 6, 55 0:6 late	T0: prior to intervention T1: 6 wk later	EG: Dance 1 h 2 × per week 6 wk CG: not specified	-The EG underwent significant improvements in PROMIS-GH scores (+42 points) and MS functional composite measure (-0.9 points). -No improvements were noted in the CG.	Ballroom dancing is a feasible leisure physical activity which induces light to moderate physical exercising. It induces improvements in quality of life and cognition among individuals with MS.
Munoz-Lasa et al. (23) Level II (12/16)	-Activity (Barthel Index (BI)) -Balance (Tinetti Performance-Oriented Mobility Assessment (POMA)) -Gait (gait analysis)	<i>n</i> = 27 relapsing-remitting, primary progressive and secondary progressive MS EG: <i>n</i> = 12, 44.8 5:7 late CG: <i>n</i> = 15, 46.2 6:9 late	T0: prior to intervention T1: 6 months later	EG: Horse riding 30-40 min 1 × per week 10 wk → 4-wk break → second round of 10 wk CG: Physiotherapy 30-40 min 1 × per week 10 wk → 4-wk break → second round of 10 wk	-EG group significantly improved balance. -Gait stride-time and ground-reaction forces significantly improved. -No significant change in BI. -No change in CG.	Horseback riding is more efficient than physiotherapy at improving balance and gait of ambulatory individuals with MS.
Schachten et al. (24) Level II (11/16)	-Cognitive performance (go/no task and visual-spatial memory through the block-tapping test and Mental Rotation Test (MRT)) -Physical performance (BBS) -Emotional performance (CES-D)	<i>n</i> = 14 stroke EG1: <i>n</i> = 7 55.14 n/A late CG: <i>n</i> = 7 53.14 (±13.54) n/A late	T0: prior to intervention T1: 10 wk later	EG1: golf 1 h 2 × per week 10 wk CG: social communication 1 h 2 × per week 10 wk	-CES-D scale, go-no go task and BBS scores significantly increased at T1 for both groups. -MRT scores increased significantly more in the EG1 than in the CG at T1, with a high effect size (<i>d</i> = 1.49)	Golf training improves emotional and cognitive symptoms, as well as visual imagery ability in stroke patients.

<p>Dallmeijer et al. (25) Level II (10/16)</p>	<p>-Physical strain and physical capacity (wheelchair ergometer testing)</p>	<p>$n = 24$ SCI ASIA A-D EG1: $n = 9$ trained quad rugby players 30:6 9:0 late EG2: $n = 6$ untrained quad rugby players 26:0 5:1 late CG: $n = 9$ inactive tetraplegics 39:6 7:2 late</p>	<p>T0: prior to moment group EG2 started intervention T1: 3 months later T2: 6 months later</p>	<p>EGs: quad rugby 1.5-2 h 1 × per week 6 months + 2 competitive matches CG: not specified</p>	<p>-No significant improvements in PO_{2peak}, VO_{2peak} and physical strain at T2 for neither groups. -Group EG2 had significantly increased maximal isometric strength scores at T1 (+24N) and T2 (+15N).</p>	<p>Wheelchair rugby training once a week for 6 months did not measurably improve physical strain and capacity, except for maximal isometric strength. Higher training frequency and/or intensity may be needed.</p>
<p>Moreno et al. (26) Level III (10/16)</p>	<p>-Pulmonary function (spirometry testing)</p>	<p>$n = 15$ tetraplegics ASIA A EG: $n = 8$ 25:8 8:0 late CG: $n = 7$ 33:0 7:0 late</p>	<p>T0: prior to intervention T1: 1 yr later</p>	<p>EG: wheelchair rugby 2 h 3-4 × per week 1 yr + 1 competitive season CG: $n = 3$ traditional physical therapy, 2 × per week $n = 4$ no rehabilitation</p>	<p>-EG's forced vital capacity (FVC), forced expired volume after 1 s (FEV1), and maximal voluntary ventilation (MVV) significantly improved at T1 by 9.12%, 9.05%, and 6.5% respectively. -Correlation between total training time and pulmonary function ($r^2 > 0.058$).</p>	<p>Regular participation in wheelchair rugby improves pulmonary function of tetraplegic men.</p>
<p>Furmaniuk et al. (27) Level II (10/16)</p>	<p>-Functional status (Wheelchair Skills Test (WST)) -Muscle strength (ASIA motor score)</p>	<p>$n = 40$ incomplete tetraplegics, ASIA B or C EG: $n = 20$ 30:0 20:0 late CG: $n = 20$ 28:8 20:0 late</p>	<p>T0: prior to intervention T1: 2 yr later</p>	<p>Both groups: 8-d sports camp with 3 sport sessions daily lasting 1.5 h + EG: wheelchair rugby 2 h 1 × per week 2 yr CG: not specified</p>	<p>-Significantly larger (difference of 28%) improvements in WST scores among the EG than the CG. -No ASIA score change in neither groups. -Correlations between changes in wheelchair skills to ASIA score in both groups. ($r = -0.679$)</p>	<p>Wheelchair rugby is effective at increasing wheelchair skills, and therefore functional status, of individuals with incomplete tetraplegia.</p>
<p>da Silva et al. (28) Level II (10/16)</p>	<p>-Functional ability (Functional Independence Measure scale (FIM))</p>	<p>$n = 16$ ASIA A SCI EG: $n = 8$ 24:6 7:1 late CG: $n = 8$ 26:8 7:1 late</p>	<p>T0: prior to intervention, at hospital discharge T1: 4 months later</p>	<p>EG: swimming 45 min 2 × per week 4 months CG: not specified</p>	<p>-EG (+7.75 points) and CG (+2.75) significantly increased FIM scores. -EG improved significantly more than the CG in transfer capacity, overall motor score, and overall score.</p>	<p>A swimming program effectively improves physical condition and motor skills, which in turn increases functional capacity of SCI patients.</p>

Author (Ref) Level of Evidence (Quality)	Outcome Measures	Participants: <i>n</i> , Diagnosis Groups: <i>n</i> , Mean Age Men: Women Phase of Rehabilitation	Measure Points	Intervention Measures	Results	Conclusion
Valent et al. (29) Level II (9/16)	-Physical capacity (graded hand-rim wheelchair exercise test and a graded handcycle exercise test) -Upper extremity isometric peak muscle strength (dynamometer) -Pulmonary function (flow-volume curve)	<i>n</i> = 34 SCI EG: <i>n</i> = 17 46 13:4 early CG: <i>n</i> = 17 40 13:4 early	T0: prior to intervention T1: week before rehabilitation discharge	EG: group outdoor handcycling 35-45 min 2x per week until discharge 4-7/10 on Borg's scale CG: regular rehabilitation care	- PO_{peak} and oxygen pulse had greater increases in the EG. -Muscle strength improved significantly more (> 10%) in the EG than CG for elbow flexion and rotators of the shoulder. -No significant improvements of pulmonary function in neither groups	Adding hand cycle training to usual care during early rehabilitation has positive effects on physical capacity and muscle strength of SCI inpatients.
Matos-Souza et al. (30) Level II (9/16)	-Carotid atherosclerosis (clinical, laboratory, hemodynamic, and carotid ultrasonography analysis)	<i>n</i> = 17 SCI EG: <i>n</i> = 8 28:3 8:0 late CG: <i>n</i> = 9 33:7 9:0 late	T0: prior to intervention T1: 5 yr later	EG: rugby, basketball, tennis or jiu-jitsu mean of 6.3 (± 1.1) h·wk ⁻¹ mean of 3 (± 0.6) yr CG: not specified	-EG significantly decreased carotid intima-media thickness by 0.18 mm and diameter by 0.044 mm, which was not the case in the CG. -Heart rate significantly increased by 13 bpm in the CG.	Adapted sports participation reduces carotid atherosclerosis on a population of sedentary SCI men.
Hossain (31) Level III (7/16)	-Depression (culture-specific, standardized, structured Depression scale)	<i>n</i> = 40 SCI median age range: 18-38 37:3 early	T0: prior to intervention T1: 1 month later	wheelchair sports, central ball throw, table tennis, badminton, ring throw, dart throw ... ≥ 25 sessions	-Depression levels significantly reduced by 31.4 points.	Sport-participation effectively reduces depression levels among spinal cord injured patients. Sports thus play a fundamental role in i mproving psychological health.
Valent et al. (32) Level III (6/16)	-Physical capacity (graded hand cycle exercise test) -Upper extremity peak muscle strength (dynamometer) -Pulmonary function (spirometer).	<i>n</i> = 22 tetraplegic 39 (± 12) 18:4 late	T0: prior to intervention T1: 8-12 wk later	handcycling 35-45 min 2x per week for tetraplegics using electrical wheelchairs 3x per week for tetraplegics using handrim wheelchairs 8-12 wk	-Statistically significant increased PO_{peak} and VO_{2peak} at T2, by 20.2% and 8.7% respectively. -Significant improvements of shoulder abduction strength by 5.6%, but not of other upper limb muscles at T1. -No significant changes in pulmonary function.	Handcycle training improves physical capacity of individuals with tetraplegia without increasing upper-extremity pain.
Gorla J et al. (33) Level III (15/26)	-Body composition (dual-energy x-ray absorptiometry)	<i>n</i> = 13 SCI 26.6 (± 6.0) 13:0 late	T0: prior to intervention T1: 8-10 months later	wheelchair rugby mean of 10.5 h·wk ⁻¹ mean of 8.1 (± 2.5) months	-Fat mass significantly reduced in whole body, legs, and trunk, by 13%, 11%, and 19% respectively. Lean mass and bone mass content increased in the arms, by 11% and 6%. Decrease in bone mass content of the trunk by 5%.	Participating in wheelchair rugby training may improve body composition among tetraplegic subjects.

Mandelbaum et al. (34) Level III (6/16)	<ul style="list-style-type: none"> - Feasibility (tolerability) - Gait (Timed 25-Foot Walking Scale-12 (MSWS-12)) - Balance (TUG, DGI, and BBS) - Self-efficacy and motivation (IMS Self-Efficacy scale (IMSS), ABC, Motives for Physical Activity Measure-Revised (MPAM-R)) - Walking ability (Patient Determined Disease Steps (PDSS)) - Leisure time activity (Godin Leisure Time Exercise questionnaire) - MS-related symptoms (MS symptom checklist) 	<p>$n = 8$ relapsing-remitting, secondary progressive MS 39.6 3:5 late</p>	<p>T0: prior to experimental protocol T1: 4 wk later T2: 3-month follow-up T3: 6-month follow-up</p>	<p>dance 1 h 2 × per week 4 wk</p>	<ul style="list-style-type: none"> - Well tolerated. - Significant improvements for the TUG, DGI, ABC and Godin Leisure time questionnaire at T1. - TUG and DGI remained significantly greater at T2. - MSWS-12 significantly improved at T2. - Symptoms were equivalent to T0 at follow-ups. - No statistically significant differences in none of the measured variables between T0 and T3. - Correlations between MPAM-R scores and physical activity at T0 and T2 ($r < 0.81$), and engagement in physical activity postintervention at T2 and T3 ($r = 0.72$) 	<p>A 4-wk dance program is feasible, well-tolerated and improves gait and balance. It further shows promise in increasing physical activity and healthy behaviors among MS individuals.</p>
Barbin et al. (35) Level III (6/16)	<ul style="list-style-type: none"> - Self-perception (Physical Self Inventory questionnaire (PSI-6)) 	<p>$n = 10$ SCI 32.1 7:3 late</p>	<p>T0: 4-wk period prior to intervention T1: during intervention T2: 4-wk period postintervention</p>	<p>adapted skiing 5 h everyday 5 d</p>	<ul style="list-style-type: none"> - Significant level increase in all domains of the PSI-6, except physical strength at T1 and T2. - Significant stability increase in 3 domains of the PSI-6 (physical condition, sport competence, physical strength) but not in the remaining 3 (global self-esteem, physical self-worth, attractive body) at T2. 	<p>A 1-wk skiing program effectively modifies level and variability of self-perception over a 4-wk home period.</p>
Jackson et al. (36) Level III (6/16)	<ul style="list-style-type: none"> - Feasibility (compliance and occurrence of adverse events) - Balance (BBS and mini-BESTest) - Mobility (Dynamic Gait Index (DGI), Timed Up and Go (TUG), habitual and fast-paced gait speed, the Activities Specific Balance Confidence scale (ABC)) - Quality of life (IMS Quality of Life survey (MSQOL-54)) 	<p>$n = 11$ relapsing-remitting or secondary progressive MS 52.27 2:9 late</p>	<p>T0: prior to intervention T1: 5 wk later ("control" period where no intervention was administered) T2: 10 wk later</p>	<p>kickboxing 1 h 3 × per week 5 wk 75% of individual's heart rate reserve 5/10 on Borg's scale</p>	<ul style="list-style-type: none"> - High compliance and no adverse events. - 4 drop-outs occurred but only one was kickbox-related. - Significant improvements of Mini-BESTest, ($r = 0.5$) DGI ($r = 0.57$), TUG ($r = 0.45$), gait speed ($r = 0.61$) and ABC ($r = 0.77$) at T2. No significant effect on the BBS. - No significant effect on MSQOL-54. 	<p>Group kickboxing is a feasible sport activity for individuals with MS and leads to improved measured of balance and mobility, but not of quality of life.</p>

Author (Ref) Level of Evidence (Quality)	Outcome Measures	Participants: <i>n</i> , Diagnosis Groups: <i>n</i> , Mean Age Men: Women Phase of Rehabilitation	Measure Points	Intervention Measures	Results	Conclusion
Nooijen et al. (37) Level III (6/16)	-Feasibility (satisfaction) -Physical capacity (maximal handcycling test)	<i>n</i> = 45 SCI median age: 44 40:5 early	TO: prior to intervention, 8 wk before discharge T1: 8 wk later, at discharge	handcycling 45-60 min 3 × per week 8 wk 4-7/10 on Borg's scale	- No adverse events occurred and 80% of subjects enjoyed the program. Feasibility was lower among complete SCI individuals. -PO _{peak} and VO _{2peak} significantly improved at T1, by 36.4% and 9.6% respectively.	Handcycle training during the last 8 wk of inpatient rehabilitation is feasible, safe, and enjoyable for SCI patients during the early phase and improves physical capacity.
Jackson et al. (38) Level III (6/16)	-Feasibility (compliance and the occurrence of adverse events) -Balance (Berg Balance Scale (BBS)) -Mobility (Dynamic Gait Index (DGI), Timed Up and Go (TUG), habitual and fast-paced walking speed and the Activities Specific Balance Confidence (ABC))	<i>n</i> = 4 relapsing-remitting or secondary progressive MS 58.25 0:4 late	TO: prior to intervention T1: 8 wk later	kickboxing 1 h 2 × per week 8 wk 75% of individual's heart rate reserve 5/10 on Borg's scale	-High compliance was high and no adverse events. - % participants increased BBS scores. -All participants increased DGI scores. -TUG, ABC and walking speed changes were variable.	Group kickboxing is feasible and safe for MS individuals and improves specific measures of balance.
Medola et al. (39) Level III (6/16)	Quality of life (SF-36 questionnaire (SF-36))	<i>n</i> = 16 paraplegics 30.4 16:0 late	TO: prior to intervention T1: 1 yr later	wheelchair basketball 2 h 2 × per week 1 yr	-Significant improvements in SF-36 scores (+ 46.16 points) -Significant improvements in functional capacity, general health and emotional aspects categories.	Sport participation leads to greater life quality among SCI men and should complement rehabilitative care.
Patterson et al. (40) Level III (6/16)	-Feasibility (interest, enrolment, attendance, adverse events occurrence and satisfaction) -Spatiotemporal parameters of gait (walking at preferred speed and without walking aid on pressure-sensitive mat) -Balance (mini-BESTest)	<i>n</i> = 20 stroke 62.3 9:11 late	TO: prior to intervention T1: 10 wk later	dance 1 h 2 × per week 10 wk	-High interest, enrolment, attendance, and satisfaction. no adverse events. -No significant improvements in spatiotemporal gait parameters. -Significant improvements in total mini-BESTest scores (+ 2.1 points).	A poststroke dance program is safe and feasible, and improves balance of dynamic gait.
Demers et al. (41) Level III (6/16)	-Feasibility (tolerance to the exercises, intensity frequency, participation, satisfaction, level of risks, availability of equipment and space, support from the staff) -Balance (BBS)	<i>n</i> = 9 stroke 63.7 2:7 early	TO: prior to intervention T1: 4 wk later	adapted dance 45 min 2 × per week 4 wk moderate intensity adapted to patient's endurance and capacity	- High tolerability and satisfaction. Out of the 7 drop outs, only 3 did so because they did not enjoy the intervention. No adverse events. -All initially low BBS scores (< 40/56) increased by > 20 points.	An adapted dance class of moderate intensity is feasible and enjoyable for stroke in-patients with no formal dance training prior to stroke. It can be used as a complement to conventional care in rehabilitation settings.

de Groot et al. (42) Level III (5/16)	-Fitness (graded handycycling exercise test) -Body composition (bioimpedance analysis)	$n = 18$ SCI 39.1 13:5 late	T0: prior to intervention T1: 4 months later	handycycling self-guided by the individual in preparation for "HandbikeBattle" competition	-Significant improvements of fat mass measure ($d = 0.12$), % fat skinfolds ($d = 0.15$) and of PO_{peak} ($d = 0.51$) at T1. -Poor correlation between changes in body composition and in fitness ($r < -0.32$).	Self-guided handbike training in preparation for the Handbike Battle seems to increase fitness while having a more moderate effect on body composition among individuals with SCI and no previous handycycling experience.
Iturricastillo et al. (43) Level III (4/16)	-Body composition (anthropometry) -Physical performance (field and strength tests)	$n = 8$ elite wheelchair basketball players (motor disabilities not detailed) 29.6 8:0 late	T0: prior to competitive season start T1: season end (23 wk later)	wheelchair basketball 2 h 2x per week 23 wk + 16 competitive matches	-Body mass significantly increased ($d = 0.3$). -No significant changes in physical fitness tests.	Season-long, regular wheelchair basketball training is not efficient at improving body composition and physical performance of elite wheelchair basketball players.
Ayan et al. (44) Level III (4/16)	-Physical condition and performance skills (field tests)	$n = 12$ elite wheelchair basketball players (6 different motor disabilities) 29.6 11:1 late	T0: prior to competitive season start T1: 13 wk later T2: end of season (23 wk later)	wheelchair basketball 2 h 4x per week 23 wk + 18 competitive matches	-Nonsignificant improvements in fitness and skill as assessed by a range of field tests, except for ball-passing skills at T1 and T2.	Motor skills and fitness levels of elite wheelchair basketball players do not go through significant improvements over the course of a season.
Skukas et al. (45) Level III (4/16)	-Aerobic fitness (cycling exercise on an ergometer and spirometry)	$n = 8$ wheelchair basketball players (4 different motor disabilities) 27.9 8:0 late	T0: prior to intervention T1: 2 wk later	wheelchair basketball 2 h 7 x per week 2 wk 75% of individual's heart rate peak + wheelchair driving endurance training 2 h daily 2 wk 60% of individual's heart rate peak	- PO_{peak} and $\dot{V}O_{2peak}$ significantly improved by 28% and 9%.	An endurance training program made up of wheelchair basketball and wheelchair driving is efficient at improving aerobic fitness among already physically fit wheelchair basketball players.
Hoekstra et al. (46) Level III (3/16)	-Physical fitness (ergometer tests) -Health outcomes (BMI, waist circumference and spirometry)	$n = 57$ wheelchair users (5 different motor impacting disorders) 40 48:9 late	T0: prior to intervention T1: 4 months later	handycycling self-guided by the individual in preparation for "HandbikeBattle" competition.	- PO_{peak} , $\dot{V}O_{2peak}$, waist circumference significantly improved at T2 by 17%, 7%, and 4.1% respectively.	Wheelchair users training for competition undergo significant improvements in physical fitness and health outcomes.

EDSS: Expanded Disability Status Scale, PDDS: Patient Determined Disease Steps, PO peak: peak power output, $\dot{V}O_{2peak}$: peak oxygen uptake, VE peak: peak pulmonary ventilation, EG: Experimental Group, CG: Control Group.

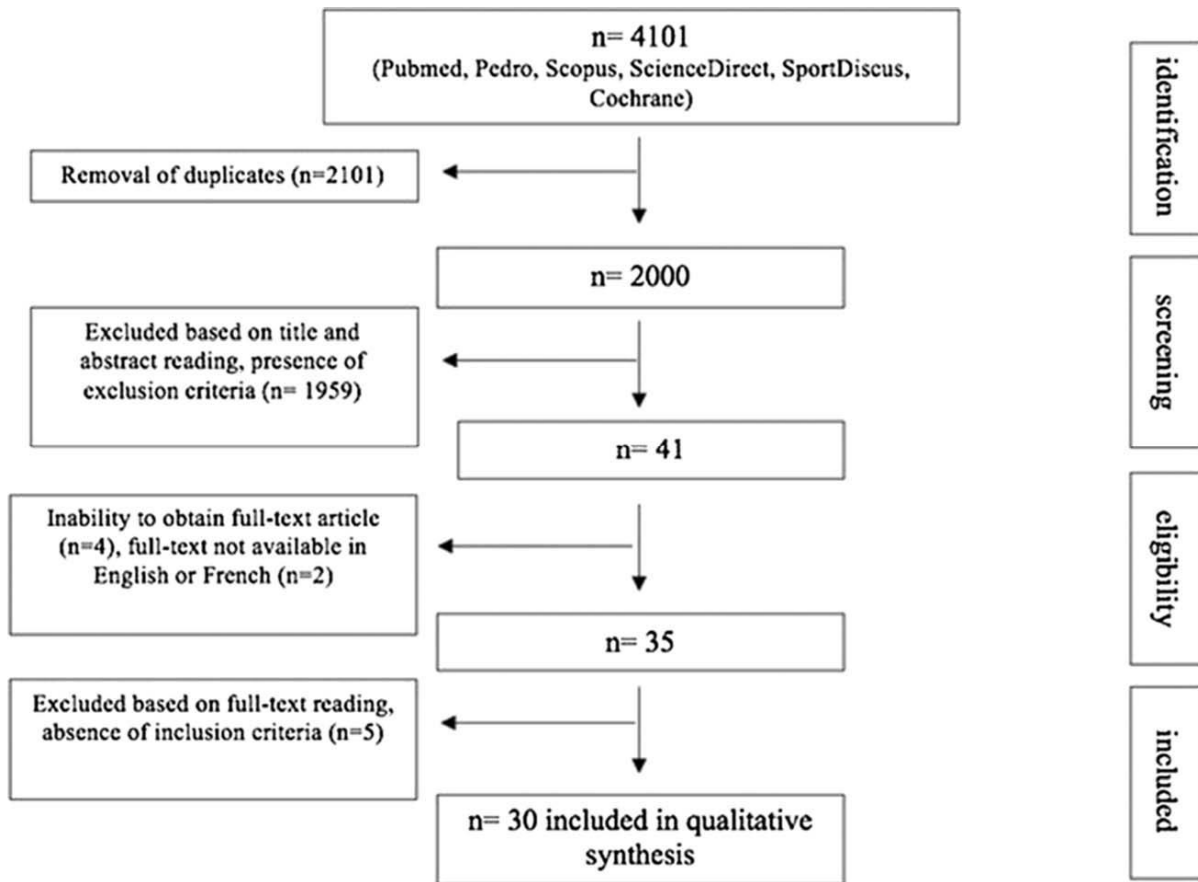


Figure 1. Prisma 2009 flowchart.

Two studies investigated a mixed approach, where various sports were practiced. The modal intervention span was 8 wk (range of 5 d to 5 years) and modal frequency was twice weekly (range of once weekly to daily). Median volume of the adaptive sport intervention was 21 h (range of 6 to 982 h). Intensity was rarely reported. Finally, 87% of the studies analyzed postinterventional changes only, and 13% integrated follow-up measures, varying from 1 to 6 months posttrial.

FEASIBILITY OF ADAPTIVE SPORTS

A 5-wk or 8-wk group kickboxing program among 15 individuals with MS was estimated to be safe. Compliance was maintained in the 90%, and adverse events did not occur (36,38). A likewise study taking place in a community-setting found equally high compliance to a dance intervention among eight individuals with MS (34). Similarly, nine stroke patients undergoing 4 wk of dance and 45 SCI patients undergoing 8 wk of handcycling displayed excellent compliance and safety (37,41). Both were performed in hospital settings during early rehabilitation.

The Effects of Adaptive Sports According to the ICF Framework

BODILY FUNCTIONS AND STRUCTURES

COGNITIVE AND MENTAL PERFORMANCE (B110-B139)

Two level II (22,24) and one level I (20) trials found improvements in cognitive and mental performances following sports. Golf and social communication equally improved visual spatial memory of 14 individuals with stroke, though golf was superior at improving visual imagery, with a high effect size ($d = 1.49$) (24). Ballroom dancing improved global cognitive function of six participants with MS by 0.9 points (22). Hatha yoga, but not sports climbing, improved selective attention among 20 individuals with MS. Executive functions did not alter in either group but sports climbing significantly reduced chronic fatigue by 32.5%, whereas yoga (20) and ballroom dancing did not (22).

CARDIOVASCULAR FUNCTION (B410-B429)

Level II evidence demonstrates that among 17 men with SCI, the group engaged in various sport activities over a 5-year course had significantly decreased overall carotid intima-media thickness and diameter, by 0.18 and 0.044 mm, respectively. The control group did not show improvements in cardiovascular function (30).

PULMONARY FUNCTION (B440-B449)

Forced vital capacity, forced expired volume after 1 s and maximal voluntary ventilation of 15 male tetraplegic subjects significantly increased after a year of wheelchair rugby, by 9.12%, 9.05%, and 6.5% respectively, in a level II trial. Correlations between total training time and forced vital capacity ($r^2 = 0.97$) and maximal voluntary ventilation ($r^2 = 0.58$) were found (26). However, handcycling did not induce significant improvements in pulmonary function of 56 SCI participants in one level III (32) and one level II trial (29).

PHYSICAL ENDURANCE (B450-B469)

Four level III trials ($n = 136$ subjects) found that engaging in adaptive sports significantly improved $\dot{V} \text{O}_{2\text{peak}}$ and PO_{peak} of wheelchair users, by percentage increases ranging from 7% to 9.6% and 17.7% to 36.4%, respectively (32,37,45,46). Another trial of equal evidence-level found that self-guided handcycling had a moderate effect size on PO_{peak} among 18 subjects with SCI ($d = 0.51$) (42). However, no significant improvements in physical fitness were observed among 24 tetraplegic subjects who had participated in at least 6 months of wheelchair rugby training in a level II study (25).

Table 2.
 Items present or absent on the modified Downs and Black scale.

Study	Item Number																Total
	11	12	13	15	16	17	18	19	20	21	22	23	24	25	26	27	
Bunketrop-Kall et al. (17)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	16/16
Najadabadi et al. (18)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	16/16
Beinotti et al. (19)	x	x	x	x	x	x	x	x	x	x	x	x	x				14/16
Velikonja et al. (20)	x	x	x	x	x	x	x	x	x	x	x	x	x				14/16
Park et al. (21)	x	x	x		x	x	x	x	x	x	x	x	x	x	x		14/16
Ng et al (22)	x	x	x		x	x	x	x	x	x	x			x	x		12/16
Munoz-Lasa et al. (23)	x	x	x		x	x	x	x	x	x	x			x	x		12/16
Schachten et al. (24)	x	x	x		x	x	x	x	x	x	x			x			11/16
Dallmeijer et al. (25)	x	x	x		x	x	x	x	x	x				x			10/16
Moreno et al. (26)	x	x	x		x		x	x	x	x	x			x			10/16
Furmaniuk et al. (27)	x	x	x		x		x	x	x	x	x			x			10/16
da Silva et al. (28)	x	x	x		x		x	x	x	x	x			x			10/16
Valent et al. (29)	x	x	x		x		x	x	x	x				x			9/16
Matos-Souza et al. (30)	x	x	x		x		x	x		x	x			x			9/16
Hossain (31)	x	x	x	x			x	x	x								7/16
Valent et al. (32)	x	x	x				x	x	x								6/16
Gorla et al. (33)	x	x	x				x	x	x								6/16
Mandelbaum et al. (34)	x	x	x				x	x	x								6/16
Barbin et al. (35)	x	x	x				x	x	x								6/16
Jackson et al. (36)	x	x	x				x	x	x								6/16
Nooijen et al. (37)	x	x	x				x	x	x								6/16
Jackson et al. (36)	x	x	x				x	x	x								6/16
Medola et al. (39)	x	x	x				x	x	x								6/16
Patterson et al. (40)	x	x	x				x	x	x								6/16
Demers et al. (41)	x	x	x				x	x	x								6/16
de Groot et al. (42)	x	x	x				x		x								5/16
Iturricastillo et al. (43)			x				x	x	x								4/16
Ayan et al. (44)			x				x	x	x								4/16
Skukas et al. (45)			x				x	x	x								4/16
Hoekstra et al. (46)			x				x		x								3/16

x, item present.

BODY COMPOSITION (B598-B599)

Three level III trials found significant changes in body composition following sports. Eighteen individuals with SCI preparing for the “Handbike battle” during 4 months underwent significant improvements in body composition but effect size was very low ($d = 0.12$) (42). Waist circumference reduced significantly by 4% among 57 wheelchair users preparing for the “Handbike Battle” (46). Thirteen tetraplegic subjects significantly improved trunk, arms, legs, and total body leanmass, fat mass, and bone mineral content, measured by dual-energy X-ray absorptiometry, after 8 months of wheelchair rugby (33).

MUSCLE FUNCTION (B730-B749)

Level II evidence found handcycling was more efficient than conventional care at improving isometric peak strength of elbow flexors and shoulder rotators of 34 SCI subjects, with more than a

10% difference in change between the groups (29). This is verified by a level III trial who demonstrated 5% increased isometric peak abductor strength following handcycling (32). Two level II trials found conflicting results regarding the impact of wheelchair rugby on muscle strength. One reported significant improvement greater than 10 Newtons in isometric upper limb strength among untrained tetraplegic player (25), while the other reported no significant increases in upper-limb muscle strength, assessed manually, following wheelchair rugby or conventional care among 40 tetraplegic subjects (27). Sports climbing decreased spasticity by 25% in one level I trial, measured by the Expanded Disability Status Scale—Pyramidal Functions among 20 individuals with MS (20).

MOVEMENT FUNCTION (B750-B789)

Level I evidence supports the use of sports to enhance movement functions. Six weeks of sitting-boxing resulted in significantly greater Manual Function Test scores of 26 stroke patients than the control group receiving conventional therapy (21). A 7-wk group volleyball program improved measures of upper limb function, such as the Box-and-Block Test and the Wrist Position Test, significantly more than conventional rehabilitation on a sample of 48 stroke participants (18).

PHYSICAL PERFORMANCE (B798-B799)

Level III trials found physical performance did not significantly improve over the course of a season among 20 elite wheelchair basketball players when measured through field tests (43,44). Level I (17,21,23) and III (24,34,36,38,40,41) data show balance significantly improves following golf, dance, horse-riding, sitting boxing, or kickboxing interventions among 242 participants with stroke or MS. Improvements in dynamic balance were found among MS individuals after a month-long dance intervention in one level III trial. Improvements remained significant at a 3-month follow-up though not at 6 months postintervention (34). Ballroom dancing did not significantly improved balance of 12 participants with MS in one level II trial (22).

ACTIVITY AND PARTICIPATION

MOBILITY (D450-D469)

Level III evidence showed that a 10-wk dance program did not significantly improve spatiotemporal gait parameters of 20 stroke patients (40). This opposes level I evidence demonstrating improved Timed Up and Go scores which were maintained at a 6-month follow-up following 12 wk of horseriding therapy among 123 individuals with stroke (17), and improved 10 m walk tests scores by 5.78 s following 6 wk of boxing among 20 stroke participants in the early phase (21). Level II (23,27) and III (34,36,38) evidence verify these improvements. Eight and 5 wk of kickboxing improved Timed Up and Go measures and gait speed of 15 subjects with MS, with a moderate effect size ($r > 0.45$) (36,38). A 4-wk dance intervention improved Timed Up and Go scores of a similar group of patients posttraining and at a 3-month follow-up (34). Horse riding improved stride time and ground-reaction forces, of 27 individuals with MS (23). The Wheelchair Skill Test improved significantly more following 2 years of wheelchair rugby training than conventional therapy among 40 tetraplegic subjects (27).

INVESTIGATED ADAPTIVE SPORTS

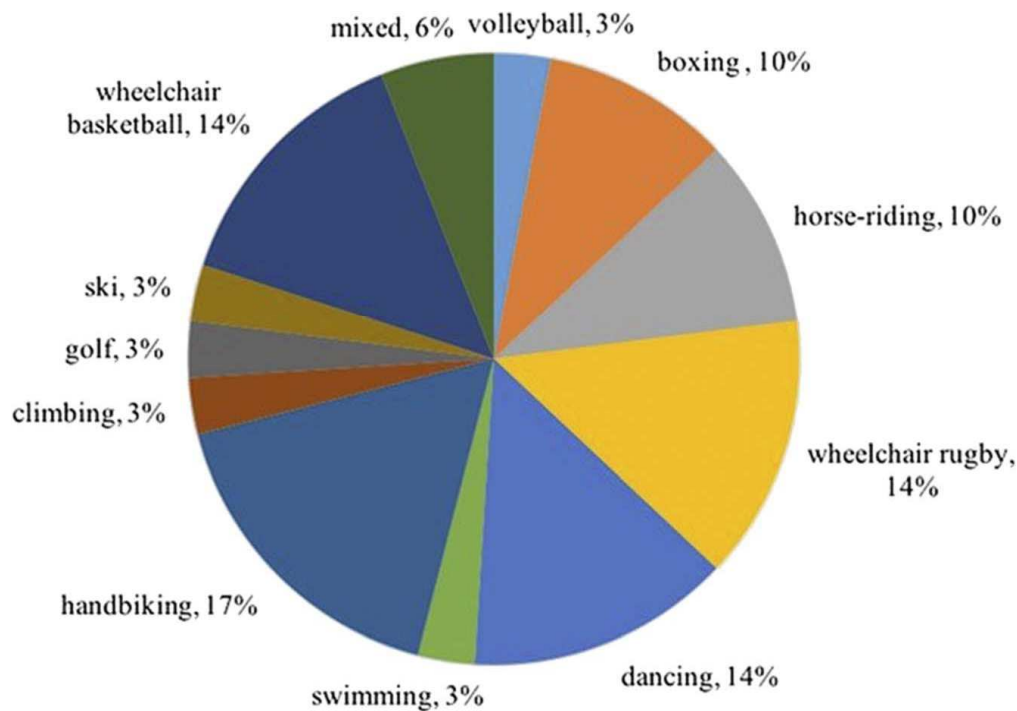


Figure 2. Adaptive sports evaluated and percentage of included trials investigating it.

INDEPENDENCE (D510-D599)

Level I (17) and level II (28) trials support the use of sports to enhance independence. Paraplegic and tetraplegic individuals assigned to a 4-month swimming intervention improved their Functional Independence Measure score by 7.75 points, which was significantly more than the control group receiving usual care (28). Perception of recovery measured by the Stroke Impact Scale improved by 23.8%, which was significantly more after a horse-riding program than standard care among stroke patients (17). On the other hand, 6 months of horseback riding or conventional physiotherapy did not induce significant improvements in performance of activities of daily living, measured by the Barthel Index, among 27 individuals with MS in a level II trial (23).

CONTEXTUAL FACTORS

Mood

Golf and social communication interventions equally improved mood of 14 participants with stroke (24). A level III study found significantly reduced depression following sport participation of 40 SCI patients (31). Conversely, mood did not augment after sports climbing or ballroom dancing programs among 32 individuals with MS (20,22).

Self-perception

Level and stability of self-perception increased following a 5-d skiing program in a trial including 10 individuals with SCI of level III evidence. These increases remain significant at a 4-wk follow-up (35).

Motivation for leisure time. A 1-month dance intervention increased levels of physical activity at a 3-month follow-up, measured by the Godin Leisure Time questionnaire, of eight individuals with MS. These increases correlated to scores on the Motives for Physical Activity Measure-Revised (34).

THE EFFECT OF ADAPTIVE SPORTS ON QUALITY OF LIFE

A 6-wk boxing program significantly increased quality of life by 12% on the Stroke Specific Quality of Life questionnaire, which was significantly more than following physical therapy, among 26 stroke patients (21). Level III evidence showed improvements of in the Short-Form health survey scores by 7% among 16 paraplegics following 1 year of wheelchair basketball. Significant changes occurred in the functional capacity, general health, and emotional aspects categories while decreasing in the mental health (39). Level I evidence shows that horse-riding produced significantly greater improvements on the functional capacity, physical aspects, and mental health among 24 stroke patients than conventional physiotherapy (19). Quality of life did not significantly improve after 5 wk of group kickboxing program for 11 individuals with MS (36) but did improve by 42 points after 6 wk of ballroom dancing among a similar sample (22).

Discussion

To our knowledge, this systematic review is the first to investigate the effect of adaptive sports on individuals with acquired neurological disabilities by relying solely on prospective evidence.

FEASIBILITY

Adaptive sports are feasible in both early and late phases (34,36,38,41), allowing for continuity. Participants are compliant and satisfied with this intervention (34,36,38,41). Sports can be practiced on a regular and long-term basis. Its practice is cost-effective by increasing the instructor to participant ratio (34) which could reduce the high medical costs associated to rehabilitation (48).

EFFICIENCY: BODILY FUNCTIONS AND STRUCTURES

Bodily functions and structures improve following adaptive sport interventions, as shown by trials of mostly II to III evidence-level. Sport practice shields individuals from the harmful effects of a sedentary lifestyle (30,33) and cross-sectional data indicates that athletes with SCI require fewer medical appointments than their nonactive peers (49). However, adaptations of bodily functions and structures seem to depend on key factors and should be measured through sensitive testing. Field tests and manual assessments should be avoided (50).

Training volume (= frequency X duration) and intensity are two determining factors. Higher volumes of training, which exceed 100 h, are more efficient at inducing changes in aerobic fitness and pulmonary function than shorter trainings (29,32,45). Moreno et al. (26) demonstrated that tetraplegic subjects undergoing larger volumes of rugby training experienced greater pulmonary

improvements. Further research is needed to investigate the exact volume required. Similarly, though the exact intensity needed to induce bodily adaptations still remains unknown, moderate to high intensity sports are preferred. Adaptive rugby seems less efficient at improving physical endurance than handbike training (25,32,37,42,46). This sport has been found to be less intense and result in lower energy expenditure than other wheelchair sports (51). Improvements in mental and cognitive functions, such as fatigue, similarly depend on training-intensity. Whereas sports climbing significantly reduced chronic fatigue of subjects with MS, yoga did not (20).

A third factor is the presence of competition, which enhances the benefits achieved from sport practice (18). The anticipation of competition also increases commitment to training, inducing improvements in physical fitness and health outcomes (42,46).

Finally, physical effects of sport-training largely depend on the type of sport being practiced. Handbiking results in increased upper-limb strength (29,32), which correlates to activities of daily living among paraplegics and tetraplegics (52). Balance improves following golf (24), dancing (34,40,41), boxing (21,36,38) and horse-riding (17,23) among stroke or MS participants. However, Ng et al. (22) did not find that ballroom dancing significantly improved balance of individuals with MS. This type of dancing requires physical contact and participants may have leaned on non-MS partners. It is thus preferable, for skill-improvement, to rely on as little outside assistance as possible.

EFFICIENCY: ACTIVITY AND PARTICIPATION

Participating in adaptive sport programs allows individuals to recover performance in activities of daily living (18,21) and in mobility, as shown by trials of strong evidence level (23,27,34,36,38,40). Furmuniak et al. (27) demonstrated that participants with inferior ASIA scores at baseline underwent greatest increases in wheelchair skills after wheelchair rugby, as these subjects had more room for improvement. However, sensitive testing methods are required to note improvements in activity and participation. Ceiling effects may account for a lack of significant changes, especially among groups with adequate levels of activity at baseline (23). Global measures of mobility, such as the Dynamic Gait Index and the Timed Up and Go, are appropriate to objectify improvements (17,30).

Adaptive sport participation increases independence and perception of recovery more efficiently than conventional care (17,28). Improving autonomy decreases the economic burden of disability and the burden placed on the participant's informal care giver (17,53). Cross-sectional data further found correlations between adaptive sport practice and improved autonomy in everyday life activities, social participation, integration in the community, and rate of employment (54). No longitudinal study has measured these variables thus far.

EFFICIENCY: CONTEXTUAL FACTORS

Personal factors such as mood improve following an adaptive sport program, especially when there is presence of a team (19,31,35,39). Motivation to engage in physical activity increases following adaptive sports participation (29,32,36,38,40). Mandelbaum et al. (34) found that 4 wk of salsa class

achieved to induce significant increases in leisure time activity postintervention and at the 3-month follow-up period among individuals with moderate MS. Long-term improvements in level and stability of self-perception also occur following adaptive sport participation (35). Improving physical performance and motor control through sports allows participants to reconnect with their body.

EFFICIENCY: QUALITY OF LIFE

Trials of varying evidence-levels demonstrate the long-term effect of sport participation on quality of life after stroke (19,21) and SCI (17,39). However, a 5-wk group kickboxing program did not significantly augment quality of life among participants with MS (38). A ceiling effect may account for this lack of effect as the sample was made up of individuals with mild disability who were not clinically depressed at baseline. Using more sensible testing methods to assess quality of life, such as the PROMIS-GH, yields more encouraging results among this population (22).

LIMITATIONS

The literature available on adaptive sports is extensive, but only few studies have analyzed the effect of this approach through prospective trials, and most have not adopted an RCT design. Nonblinding of the evaluators further deteriorated methodological quality. Moreover, the frequent use of questionnaires and self-assessment evaluations predisposed the data to subjective interpretation and bias.

Numerous inclusion criteria limited the samples to small numbers. More severely affected subjects were frequently excluded, which limits the applicability of results. Participants were often recruited through volunteer-based processes thus selecting motivated individuals. Valent et al.'s 2009 study, who recruited tetraplegic individuals discharged from rehabilitation centers, found that participants dropping out had significantly lower physical capacity than those completing the intervention (32). Conclusions drawn from individuals completing the study difficultly extend to the population. Moreover, it was not always reported whether participants had engaged in adaptive sports before beginning the trial. While $n = 4$ trials evaluated individuals involved in adapted sports clubs, and $n = 5$ trials were conducted in the early phase, thereby including sample groups which did not engage in such activities previously, this confounding factor was generally not disclosed. Bias could subsequently occur as previous experience in adaptive sports practice may influence reaction to intervention.

Heterogeneity of the sample groups, intervention protocols, and outcome measures further complicated between-study comparisons. Within-study comparisons were difficult as control groups undergoing conventional therapy received less treatment than the intervention group. As improvements occurring in rehabilitation are strongly correlated to the volume of treatment (55), it is difficult to attribute the changes occurring in the intervention group solely to the sport.

Finally, a lack of follow-up evaluations makes it difficult to draw conclusions regarding long-term efficacy. Follow-up data may considerably differ from postintervention data, especially among individuals with degenerative deficiencies such as MS (34). Partial to complete losses of exercise-

induced adaptations also have been observed 4 wk after training cessation among physically-abled adults (9). One can assume that a detraining phenomenon also is present among individuals with physical disabilities. Maintaining benefits thus entails sustained participation.

GUIDELINES FOR FUTURE RESEARCH

Future research should continue investigating the effects of adaptive sport programs on individuals with acquired central neurological lesion, especially during early stages. Optimal intensity and volume should be explored, as well as how these factors are best adapted according to the patient. Prospective studies should further investigate psychosocial effects of adaptive sports.

Randomization of subjects and blinding of evaluators should be assured. Objective data should complement subjective measures. The control and intervention groups should receive equal amounts of therapy and follow-up measures should not be neglected. This will allow to adopt an evidence-based approach when integrating adaptive sports programs in clinical fields.

Conclusions

Adaptive sports programs seem to be a feasible, safe, and cost-effective complement to all phases of rehabilitation. Participants are satisfied and compliant to this approach, and adverse events are scarce. Patients with motor disabilities stemming from neurological lesions experience an array of positive outcomes following adaptive sport participation, and this on all domains of the ICF. However, these effects largely depend on the volume, intensity, and type of sport, as well as the presence of a team and competition. Its feasibility and effectiveness are essential factors in making adaptive sport a valuable therapeutic tool, which can be instated as a complement to conventional therapy.

Conflicts of interest

This work was supported by a grant received from the Cap48 Initiative. The authors declare no conflict of interest.

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