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Effects of a 12-Week Strength Training Programme on Independent Living Skills and Wheelchair Control in Persons With Paraplegia

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Abstract

Background. The effects of strength training on independent living skills in persons with paraplegia are unclear.

Aim. To examine the effects of 12-week strength training for increasing upper body strength, independent living skills, and physical condition parameters in persons with spinal cord injury.

Methods. Preliminary and post intervention (after 12 weeks) testing were performed. The measurements consisted of the following assessments: the assessment of Functional Independence Measure, the assessment of wheelchair control skills, the assessment of physical parameters (strength, endurance, quickness) using field tests. Fourteen persons with paraplegia after complete thoracic or lumbar spinal cord injury participated in the study. Subjects with paraplegia were divided into intervention (7 participants) and control (7 participants) groups. The participants of the intervention group had one hour per training session in the gym (three times per week). The subjects of the control group had no training during the entire period of research.

Results. The 12-week strength exercise programme applied to persons with spinal cord injury improved almost all daily living skills in the intervention group, e.g. transferring (control group post intervention 4.3 ± 0.06, intervention group post intervention 6.5 ± 0.08*), moving skills (control group 3.3 ± 0.24, intervention group 6.2 ± 0.49, $p = 0.03$). Strength exercises had positive effect on independence in respect of wheelchair moving skills, for example: keeping balance, control group post intervention 1.5 ± 0.28, intervention group post intervention 1.6 ± 0.18, $p = 0.04$); overcoming bigger obstacles, control group 0.42 ± 0.14, intervention group 1.4 ± 0.30, $p = 0.02$). The 12-week programme improved maximum hand strength (control group post intervention 66.9 ± 3.09, intervention group post intervention 84.8 ± 3.15, $p = 0.02$), endurance (control group 1.3 ± 0.15, intervention group 2.3 ± 0.19, $p = 0.02$), quickness (control group 11.2 ± 0.22, intervention group 16.6 ± 0.51, $p = 0.03$) of persons with paraplegia.

Conclusions. The independent living, wheelchair control skills, and physical condition parameters of the intervention group improved after the 12-week strength training programme.

Keywords: Paraplegia; independent living skills; strength training

1. INTRODUCTION

Research on the independent living skills of persons with spinal cord injury (SCI) is important for evaluating rehabilitation perspectives and possibilities. Individuals with SCI who use wheelchairs experience significant challenges, especially in the period immediately following injury. The primary issue they face is the partial or complete loss of motor and/or sensory function. This often leads to psycho-emotional instability, including feelings of hopelessness and dissatisfaction with their current condition (Giacobbi et al., 2009; Kennedy et al., 2010; Martin Ginis et al., 2010).

Wheelchair users with SCI frequently experience physical, emotional, and psychological stress. As a result, they may become overly dependent, passive, and less willing to participate in daily life activities (Columna, 2010). Although improving independence is emphasised during early rehabilitation in hospitals and rehabilitation centres (Burns et al., 2017), these efforts are often insufficient (Martin Ginis et al., 2018). This issue is particularly relevant for individuals who have been living with SCI for more than five years (Fehlings et al., 2017).

During the first years after injury, persons with paraplegia typically acquire basic knowledge and techniques for wheelchair propulsion and transfer skills (Harvey, 2016). However, over time, reduced physical activity may lead to insufficient muscle strength and declining movement skills needed for independent performance of daily activities (Hicks et al., 2011; Martin Ginis et al., 2018). Individuals with paraplegia often have trouble maintaining optimal body positioning during transfer movements, and greater upper-body strength and trunk stability are required to safely perform transfers to and from the bed, wheelchair, or car (Boninger et al., 2005).

Numerous studies have examined the benefits of strength training for athletes with paraplegia (Santos et al., 2022). However, there remains a lack of research investigating the effects of strength training on functional performance parameters related to independent living skills in persons with paraplegia who are not athletes (Martin Ginis et al., 2016). Daily living performance and wheelchair control depend on proper movement technique, upper-extremity muscle strength, trunk stability, and body positioning in the wheelchair (Hicks et al., 2011; Santos et al., 2022).

Persons with paraplegia can benefit from increased strength through improved movement control, enhanced ability to transfer force between body segments, and better balance during transfers (Lin et al., 2019). Improvements in muscular strength may positively influence independent living performance, help maintain proper body alignment, reduce the risk of failed transfer attempts, and enable more efficient task execution (Hodgkiss et al., 2023).

As far as is currently known, no previous study has specifically examined the effects of structured strength training on independent living skills in persons with paraplegia. To address this gap in the literature, the present study aimed to investigate the effects of a 12-week strength training programme on upper-body strength, independent living skills, wheelchair control abilities, and physical fitness parameters in persons with paraplegia.

2. METHODS

2.1. Study design and participants

This study employed a controlled intervention design to examine the hypothesis that individuals with paraplegia benefit from structured strength training in maintaining and improving independent living skills.

Fourteen individuals with chronic paraplegia resulting from complete thoracic or lumbar SCI participated in the study. Participants were allocated to either an intervention group ($n = 7$) or a control group ($n = 7$). Inclusion criteria were complete thoracic or lumbar SCI, injury duration between five and ten years, use of a manual wheelchair for mobility, and medical stability. All participants had acquired disabilities. The participants ranged in age from 23 to 47 years. Mean anthropometric characteristics were 176.0 ± 6.4 cm in height and 72.1 ± 5.8 kg in body mass. The intervention and control groups were comparable at baseline with respect to age, sex, living conditions, level of independence, and wheelchair mobility skills.

Table 1. **Characteristics of study participants**

	Intervention group (*n* = 7)	**Control group (*n* = 7)**	***P* between groups**
Age (yrs. ± SD)	36.15 ± 10.35	37.42 ± 9.29	0.59
Weight	73.80 ± 10.25	72.90 ± 10.36	0.42
Height	1.81 ± 10.24	1.79 ± 5.80	0.34
Injury duration	7.45 ± 2.62	6.38 ± 3.41	0.56

This study employed purposive sampling, a non-probability sampling technique in which participants are intentionally selected based on specific characteristics that align with the research objectives. Participant selection followed predetermined inclusion and exclusion criteria, resulting in a total of 14 respondents. Although the sample size is relatively small, this limitation reflects the specificity of the target population, as only a limited number of individuals met the inclusion criteria. Such sample size is common in purposive sampling studies, where the emphasis lies in the relevance and suitability of participants rather than the sample quantity. Therefore, despite its modest size, the data obtained are considered representative of the population that fits the research focus.

2.2. Randomisation

Participants were randomised in a 1:1 ratio using a computer-generated sequence to either the intervention group (*n* = 7) or control group (*n* = 7).

2.3. Ethical approval and informed consent

Before the test protocol, all the subjects were informed about the procedures that would be applied and signed a written consent to participate in the study. They also underwent a complete medical examination. Ethical approval for this study was obtained (Approval No. 36622, dated 05 12 2024). The study was conducted in accordance with the principles of the Declaration of Helsinki. Participants were recruited through social media and Lithuanian association of persons with paraplegia.

2.4. Intervention protocol

Participants in the intervention group completed three supervised training sessions per week for 12 weeks, with each session lasting approximately 60 minutes and conducted in a gym equipped with adapted exercise equipment.

Each session consisted of a warm-up, a main strength-training component, and a cool-down period. The warm-up lasted approximately 10 minutes and included mobility and stretching exercises primarily targeting the shoulder musculature. The main component consisted of circuit-based resistance training. Participants performed three sets of 8–12 repetitions of eight upper-body strength exercises targeting major shoulder and upper-extremity muscle groups. The exercises included lateral raises, latissimus pulldowns, seated horizontal rows, pullovers, bench presses, biceps curls, and internal and external shoulder rotations at 90 degrees of abduction.

Training intensity was set at approximately 60–70% of one-repetition maximum. Exercise intensity corresponded to approximately 70% of peak heart rate. The mean heart rate during training sessions was 142 beats per minute, with a recorded maximum of 175 beats per minute during the one-hour session.

Participants in the control group continued their usual daily activities and did not participate in structured strength training during the study period.

2.5. Outcome measures and instruments

Functional independence in activities of daily living was evaluated using the Functional Independence Measure (FIM) (Middleton et al., 2005). The FIM is one of the most widely used instruments for assessing functional status and disability-related burden of care. It consists of 18 items, including 13 motor tasks and five cognitive tasks, representing basic activities of daily living. All 18 items were administered in the present study. Each FIM item is rated on a 7-point ordinal scale, where one indicates complete dependence and seven indicates complete independence. A score of one is given when the individual is able to perform less than 25% of the task independently. A score of two is given when the individual is able to perform 25–49% of the task independently. Three indicates moderate assistance (50–74% of the task performed independently) and four indicates minimal assistance (≥75% of the task performed independently). A score of five reflects supervision or setup assistance only, six indicates modified independence requiring assistive devices, and seven represents complete independence without assistance or devices. The FIM has demonstrated strong internal consistency, with Cronbach's alpha values exceeding 0.70 for total scores and subscales, as well as good reliability and reproducibility in large patient populations. Although the FIM provides a broad assessment of functional independence, it may be less sensitive to specific changes in wheelchair mobility skills among individuals with SCI. Therefore, a dedicated assessment of the wheelchair control skills was additionally applied to obtain a more detailed evaluation of mobility-related functional performance.

Wheelchair control skills were evaluated using a 14-item Wheelchair Mobility Test developed for individuals with SCI (Skučas, 2011). Each item was scored on a three-point scale according to the level of assistance required. A score of zero indicated inability to perform the task independently, one indicated performance with assistance, and two indicated independent performance. Assessed tasks included wheelchair propulsion, manoeuvring, ascending and descending slopes, and negotiating stairs. Testing was conducted using standardised equipment designed to evaluate and train wheelchair mobility skills. The obstacle course included platforms, slopes, stairs, and objects of varying complexity, arranged progressively from simple to more demanding tasks. Balance control and safe falling techniques were also assessed.

Physical capacity was evaluated using field-based tests adapted for wheelchair users (Skučas, 2011). The following components were assessed: aerobic endurance, anaerobic endurance, speed, and agility (quickness). Aerobic endurance was measured using a 12-minute wheelchair propulsion test. Anaerobic endurance was assessed using a 30-second maximal propulsion test. Speed was evaluated with a 20-metre wheelchair propulsion test, in which each participant completed two trials within a two-minute period. Agility was assessed using a figure-eight propulsion test performed around cones within one minute.

All outcome measures were assessed at baseline prior to the initiation of the strength training programme and again after completion of the 12-week intervention. Testing sessions were conducted by specialists in adapted physical activity. The order of assessment was standardised: daily living skills were evaluated first, followed by wheelchair control skills, and then physical capacity tests. Endurance testing was conducted separately to avoid fatigue-related interference with other performance measures.

Three assessment sessions were performed before the intervention and three after the intervention for daily living skills, wheelchair control skills, and physical capacity. Each testing session lasted approximately one hour, and each participant completed two sessions, resulting in a total testing time of approximately two hours per assessment phase.

2.6. Statistical analyses

The results were processed using SPSS version 17.0. All the results are reported as mean and standard deviations (SD). A paired-samples t-test was used to compare pre- and post-test values for the control and intervention groups to determine statistical significance. Differences between groups were evaluated using independent-samples t-tests. The significance level was set at $p < 0.05$.

3. RESULTS

The analysis of functional independence skills of persons with SCI indicated that transferring, movement, and personal hygiene skills improved after the intervention (Table 2). No statistical difference was found in the intervention group for values of perception, mind expression, social relationships, or solution of problems before the intervention in comparison with the values after the intervention. Values of functional independence of the control group before and after the intervention were similar.

Table 2. **Functional independence scores of persons with SCI who participated in the study (before and after the intervention)**

Functions	Intervention group (n = 7) (Scores ± SD)		Control group (n = 7) (Scores ± SD)		*P* between groups post intervention
	Pre	Post	Pre	Post	
Eating	6.4 ± 0.25	6.5 ± 0.15	6.5 ± 0.05	6.5 ± 0.11	0.63
Personal hygiene	6.2 ± 0.13	6.6 ± 0.03	6.3 ± 0.12	6.3 ± 0.08	0.25
Bathing	5.9 ± 0.28	6.3 ± 0.12	5.8 ± 0.17	5.9 ± 0.15	0.37
Dressing of upper part of the body	6.3 ± 0.38	6.5 ± 0.42	6.3 ± 0.38	6.5 ± 0.42	0.47
Dressing of lower part of the body	6.1 ± 0.49	6.2 ± 0.76	6.1 ± 0.49	6.2 ± 0.76	0.52
Toilet	5.6 ± 0.31	5.8 ± 0.83	5.6 ± 0.31	5.8 ± 0.83	0.54
Urinary control	5.5 ± 0.34	5.6 ± 0.77	5.5 ± 0.34	5.6 ± 0.77	0.43
Bowel control	5.3 ± 0.02	5.5 ± 0.73	5.2 ± 0.12	5.3 ± 0.73	0.41
Transferring: bed, chair, wheelchair	4.2 ± 0.3	6.5 ± 0.08*	4.3 ± 0.9	4.3 ± 0.06	0.04
Transferring: toilet	4.1 ± 0.21	6.3 ± 0.16 *	4.2 ± 0.12	4.3 ± 0.14	0.04
Transferring: bathroom, shower	3.8 ± 0.08	6.1 ± 0.15 *	3.9 ± 0.14	4.1 ± 0.28	0.04
Walking, wheelchair	3.2 ± 0.74	6.2 ± 0.49*	3.4 ± 0.63	3.3 ± 0.24	0.03
Climbing stairs	1.63 ± 0.17	3.1 ± 0.25*	1.60 ± 0.12	1.62 ± 0.15	0.04
Perception	6.4 ± 0.61	6.9 ± 0.4	6.4 ± 0.54	6.9 ± 0.8	0.28
Mind expression	6.8 ± 0.11	7.0 ± 0.07	6.8 ± 0.15	7.0 ± 0.02	0.35
Social relationships	6.7 ± 0.32	6.9 ± 0.14	6.7 ± 0.39	6.9 ± 0.17	0.33
Solving problems	6.4 ± 0.48	6.7 ± 0.24	6.2 ± 0.18	6.2 ± 0.12	0.24

Note: * indicates statistically significant differences ($p < 0.05$) within groups; SD – standard deviation.

Following the intervention, statistically significant improvements were observed in most of the intervention group's wheelchair control and obstacle-navigation skills. Control group's values of wheelchair control skills before and after the intervention remained relatively similar (Table 3).

Table 3. **Wheelchair control skill scores of persons with SCI who participated in the study (before and after the intervention)**

Wheelchair control skills	**Intervention group (n = 7) (Scores ± SD)**		**Control group (n = 7) (Scores ± SD)**		***P* between groups post intervention**
	Pre	Post	Pre	Post	
1. Wheelchair manoeuvring	1.7 ± 0.27	1.8 ± 0.22	1.6 ± 0.32	1.7 ± 0.14	0.59
2. Safe falling	1.0 ± 0.44	1.7 ± 0.38 *	1.1 ± 0.29	1.0 ± 0.42	0.03
3. Keeping balance	1.32 ± 0.26	1.6 ± 0.18*	1.41 ± 0.15	1.5 ± 0.28	0.04
4. Overcoming minor obstacles	1.47 ± 0.26	1.6 ± 0.22	1.58 ± 0.19	1.6 ± 0.38	0.78
5. Overcoming bigger obstacles	0.48 ± 0.46	1.4 ± 0.30*	0.39 ± 0.11	0.42 ± 0.14	0.02
6. Overcoming 'railings'	0.83 ± 0.33	1.2 ± 0.17*	0.95 ± 0.15	0.92 ± 0.12	0.04
7. Climbing on a low platform	0.84 ± 0.47	1.6 ± 0.22*	0.87 ± 0.09	0.88 ± 0.07	0.03
8. Climbing on an average platform	0.63 ± 0.55	1.5 ± 0.22*	0.61 ± 0.25	0.63 ± 0.19	0.02
9. Climbing on a high platform	0.33 ± 0.28	0.9 ± 0.16*	0.30 ± 0.05	0.32 ± 0.06	0.04
10. Going uphill	1.3 ± 0.26	1.7 ± 0.19*	1.1 ± 0.12	1.2 ± 0.09	0.04
11. Going downhill	0.5 ± 0.15	0.9 ± 0.45*	0.5 ± 0.05	0.5 ± 0.13	0.04
12. Climbing upstairs	0.3 ± 0.05	1.2 ± 0.07*	0.2 ± 0.06	0.2 ± 0.04	0.02
13. Going downstairs backwards	0.4 ± 0.09	0.9 ± 0.05*	0.5 ± 0.09	0.5 ± 0.08	0.04
14. Going downstairs keeping balance	0.1 ± 0.07	1.4 ± 0.03*	0.1 ± 0.02	0.1 ± 0.03	0.04

Note: * – indicates statistically significant differences ($p < 0.05$) within groups; SD – standard deviation.

All the tested physical parameters of the intervention group were found to improve over the strength training programme (Table 4).

Table 4. **Physical parameter scores of persons with SCI who participated in the study (before and after the intervention)**

Test	**Physical parameter**	**Intervention group (n = 7) (Scores ± SD)**		**Control group (n = 7) (Scores ± SD)**		***P* between groups post intervention**
		Pre	Post	Pre	Post	
30-second ride (m)	Anaerobic endurance	72.6 ± 3.22	93.7 ± 2.12*	70.8 ± 2.82	71.6 ± 2.94	0.03
20-meter sprint (s)	Speed	8.2 ± 0.27	6.59 ± 0.55*	8.3 ± 0.16	8.56 ± 0.25	0.04

Test	Physical parameter	Intervention group (n = 7) (Scores ± SD)		Control group (n = 7) (Scores ± SD)		P between groups post intervention
		Pre	Post	Pre	Post	
Figure eight riding (times)	Quickness	11.4 ± 0.71	16.6 ± 0.51*	11.0 ± 0.29	11.2 ± 0.22	0.03
12-minute ride (km)	Endurance	1.5 ± 0.11	2.3 ± 0.19*	1.4 ± 0.23	1.3 ± 0.15	0.02
Weight bench press (kg)	Maximum hand strength	63.4 ± 2.32	84.8 ± 3.15*	65.7 ± 3.14	66.9 ± 3.09	0.02

Note: * – indicates statistically significant differences ($p < 0.05$) within groups; SD – standard deviation.

4. DISCUSSION

The 12-week strength training programme significantly improved the performance of independent living skills and physical condition parameters of persons with paraplegia. The current study is the first to demonstrate that a 12-week strength training programme significantly improves performance of daily living skills in persons with paraplegia with 5–10 years of SCI history. The data of the study show that the improvement of the performance of independent living skills and physical condition parameters is closely related to the type of training and the period of training. A 12-week moderate-intensity strength training programme has more potential to improve strength and the performance of independent living skills and physical condition parameters than shorter term (e.g. 4 or 8 weeks) programmes. The 12-week training programme appears to have been effective for people with paraplegia in helping them achieve a high level of strength and independent living skills.

Strength in the intervention group improved by 14%, from 63.4 ± 2.32 kg to 84.8 ± 3.15 kg. Previous studies have shown a wide range in strength values between pre-test and post-test, ranging from 12% to 30% (Valent et al., 2007). The current study demonstrated higher strength value compared to the mean values reported in literature (Valent et al., 2007). Thus, the 12-week strength training programme had an impact on strength value for persons with paraplegia. The increase in strength could be considered small compared to the findings of other authors (de Groot et al., 2003; Sutbeyaz et al., 2005). However, it is difficult to compare data because of the different nature of the programme applied in this study and very low initial data of the participants. Despite this, it could be concluded that a 12-week strength training programme positively influenced the improvement of strength of the upper body, the trunk stability, and muscular coordination in persons with paraplegia.

Undoubtedly, wheelchair manoeuvring skills are one of the most important for persons with SCI, as they enable them to move around in partially accessible environments (Kennedy et al., 2010; Martin Ginis et al., 2018). These skills improved significantly during the intervention in comparison to other research data, as the subjects had little or no wheelchair control skills prior to the intervention. This could be an important motivating factor to learn wheelchair control movements. In addition, the wheelchairs of the participants were individually adapted during the intervention to improve moving conditions and enable the performance of difficult movements.

The minor changes in self-care skills related to activities of daily living could be explained by the fact that most participants already possessed some level of self-care skills prior to the intervention, as they had received basic training in hospitals and rehabilitation centres. On the other hand, the study has revealed that the level of daily living activities among people with disabilities who use wheelchairs and have had an SCI for less than five years is insufficient, and this could be addressed through adapted physical activity. To sum up, participants in the intervention programme could be described as minimally dependent on others for assistance, since they are able to perform most self-care activities on their own.

The results of this study also corroborate those of other studies indicating that strength training improves the physical capacity of wheelchair users with SCI (Hodgkiss et al., 2023). Therefore, it can be concluded that incorporating a variety of comprehensive approaches into the development of physical skills and the rehabilitation of wheelchair users during similar training sessions can also improve daily living skills, mobility skills, transferring skills, and physical capacity.

The variety of rehabilitation methods applied in this and other studies makes it difficult to compare them and assess their efficiency (Lili et al., 2023; Lili et al., 2024; Santos et al., 2022). However, the results of this study confirm that a greater variety of means and methods in the rehabilitation of disabled persons with SCI provides a more significant progress. Applying different means and methods enables faster and more effective determination of changes in the functional state of disabled persons. The FIM and wheelchair control skill tests employed in the study were relevant for persons with under five years since SCI, as could be seen in the results, which, although initially poor, increased during the study. However, once the results reach a certain level of improvement, these measures may no longer be appropriate. Though the FIM test revealed an improvement in wheelchair control skills in groups with varied injuries, it is not sensitive enough for researching the wheelchair control skills of SCI patients. Hence, methods focused on evaluating the SCI patients' wheelchair control skills are needed. Moreover, all the applied tests determine only functional, motor, and fitness abilities and fail to address their advantages as part of a daily routine in usual conditions, such as evaluating speed of action, amount of energy, and physical effort. This confirms the necessity to expand the methodology and define new methods to evaluate functional, motor, and fitness abilities in persons with SCI in everyday life.

There is reason to state that organising activities aimed at improving independence, applying systematic and complex means focused on physical education and physical rehabilitation for people with disabilities who use wheelchairs can help develop the independence skills of these persons.

The study has some limitations that need to be considered when interpreting the results and/or planning future studies. First, a small sample size including only a few levels of SCI limits the scope to generalise the results to a wider population. Second, the author was unable to collect impairment-specific data such as strength of trunk muscles, spasticity, and coordination. These data would have helped explain within and between class variability in the strength parameters. Finally, the author did not report measurements related to muscular activation, thus the information regarding the involvement of nervous system mechanisms in strength production processes was not obtained.

5. CONCLUSIONS AND PERSPECTIVES

The 12-week strength training programme produced positive effects on functional independence in persons with SCI. Improvements were observed primarily in wheelchair mobility performance, with participants in the intervention group demonstrating enhanced performance in most wheelchair control tasks. However, no significant changes were identified in wheelchair manoeuvring and balance maintenance skills, nor in the ability to overcome minor obstacles. These findings suggest that while resistance-based training improves several aspects of wheelchair mobility, certain complex or fine motor control tasks may require more task-specific training approaches.

Overall, the results confirm that although individuals with SCI experience substantial limitations in movement and independence, targeted, progressive, and supervised training programmes can lead to measurable functional gains. Improvements in independence appear to be influenced not only by the physiological effects of training but also by the quality of programme implementation, including professional competence in adapted physical activity and participant engagement in the rehabilitation process.

From a practical perspective, rehabilitation programmes for individuals with SCI should be individualised according to injury duration, functional status, and personal goals. In the early post-injury period, interventions should prioritise the development of fundamental activities of daily living and basic transfer skills. In later stages, rehabilitation may progressively emphasise advanced wheelchair mobility skills, obstacle negotiation, and further physical strengthening to optimise long-term functional independence and community participation. The strength training programme applied to persons with SCI demonstrated a generally positive effect on independence, particularly with respect to wheelchair control skills. Participants in the intervention group showed improvements in nearly all wheelchair mobility tasks, except for wheelchair manoeuvring and balance maintenance skills. The programme also enhanced the ability to negotiate obstacles, although no significant improvement was observed in overcoming minor obstacles.

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References

Boninger, M. L., Koontz, A. M., Sisto, S. A., Dyson-Hudson, T. A., Chang, M., Price, R., & Cooper, R. A. (2005). Pushrim biomechanics and injury prevention in spinal cord injury: Recommendations based on CULP-SCI investigations. *Journal of Rehabilitation Research and Development*, *42*(3), 9. https://doi.org/10.1682/JRRD.2004.08.0103

Burns, A. S., Marino, R. J., Kalsi-Ryan, S., Middleton, J. W., Tetreault, L. A., Dettori, J. R., Mihalovich, K. E., & Fehlings, M. G. (2017). Type and timing of rehabilitation following acute and subacute spinal cord injury: A systematic review. *Global Spine Journal*, *7*(3 Suppl), 175S–194S. https://doi.org/10.1177/2192568217703084

Columna, L. (2010). Principles and methods of adapted physical education and recreation. *Adapted Physical Activity Quarterly*, *27*(1), 73–74. https://doi.org/10.1123/apaq.27.1.73

de Groot, P. C. E., Hjeltnes, N., Heijboer, A. C., Stal, W., & Birkeland, K. (2003). Effect of training intensity on physical capacity, lipid profile and insulin sensitivity in early rehabilitation of spinal cord injured individuals. *Spinal Cord*, *41*, 673–679. https://doi.org/10.1038/sj.sc.3101534

Fehlings, M. G., Tetreault, L. A., Wilson, J. R., Kwon, B. K., Burns, A. S., Martin, A. R., Hawryluk, G., & Harrop, J. S. (2017). A clinical practice guideline for the management of acute spinal cord injury: Introduction, rationale, and scope. *Global Spine Journal*, *7*(3 Suppl), 84S–94S. https://doi.org/10.1177/2192568217703387

Giacobbi, P. R., Stancil, M. Jr., Hardin, B., & Bryant, L. (2009). Physical activity and quality of life experienced by highly active individuals with physical disabilities. *Adapted Physical Activity Quarterly*, *26*(3), 189–207. https://doi.org/10.1123/apaq.25.3.189

Harvey, L. A. (2016). Physiotherapy rehabilitation for people with spinal cord injuries. *Journal of Physiotherapy*, *62*(1), 4–11. https://doi.org/10.1016/j.jphys.2015.11.004

Hicks, A. L., Martin Ginis K. A., Pelletier, C. A., Ditor, D. S., Foulon, B., & Wolfe, D. L. (2011). The effects of exercise training on physical capacity, strength, body composition and functional performance among adults with spinal cord injury: A systematic review. *Spinal Cord*, *49*, 1103–1127. https://doi.org/10.1038/sc.2011.62

Hodgkiss, D. D., Bhangu, G. S., Lunny, C., Jutzeler, C. R., Chiou, S.-Y., Walter, M., Lucas, S. J. E., Krassioukov, A. V., & Nightingale, T. E. (2023). Exercise and aerobic capacity in individuals with spinal cord injury: A systematic review with meta-analysis and meta-regression. *PLoS Medicine*, *20*(11), e1004082. https://doi.org/10.1371/journal.pmed.1004082

Kennedy, P., Smithson, E., McClelland, M., Short, D., Royle, J., & Wilson, C. (2010). Life satisfaction, appraisals and functional outcomes in spinal cord-injured people living in the community. *Spinal Cord*, *48*, 144–148. https://doi.org/10.1038/sc.2009.90

Lili, L., Sunnerhagen, K. S., Rekand, T., & Murphy, M. A. (2021). Associations between upper extremity functioning and kinematics in people with spinal cord injury. *Journal of Neuroengineering and Rehabilitation*, *18*(1), 147. https://doi.org/10.1186/s12984-021-00938-9

Lili, L., Sunnerhagen, K. S., Rekand, T., & Murphy, M. A. (2023). Independence and upper extremity functioning after spinal cord injury: A cross-sectional study. *Scientific Reports*, *13*, 3148. https://doi.org/10.1038/s41598-023-29986-y

Lili, L., Sunnerhagen, K. S., Rekand, T., & Murphy, M. A. (2024). Participation and autonomy, independence in activities of daily living and upper extremity functioning in individuals with spinal cord injury. *Scientific Reports*, *14*(1), 9120. https://doi.org/10.1038/s41598-024-59862-2

Lin, J.-T., Hsu, C.-J., Dee, W., Chen, D., Rymer, W. Z., & Wu, M. (2019). Motor adaptation to weight shifting assistance transfers to overground walking in people with spinal cord injury. *PM & R: The Journal of Injury, Function, and Rehabilitation*, *11*(11), 1200–1209. https://doi.org/10.1002/pmrj.12132

Martin Ginis, K. A., Jetha, A., Mack, D. E., & Hetz, S. (2010). Physical activity and subjective well-being among people with spinal cord injury: A meta-analysis. *Spinal Cord*, *48*, 65–72. https://doi.org/10.1038/sc.2009.87

Martin Ginis, K. A., Ma, J. K., Latimer-Cheung, A. E., & Rimmer, J. H. (2016). A systematic review of review articles addressing factors related to physical activity participation among children and adults with physical disabilities. *Health Psychology Review*, *10*(4), 478–494. https://doi.org/10.1080/17437199.2016.1198240

Martin Ginis, K. A., van der Scheer, J. W., Latimer-Cheung, A. E., Barrow, A., Bourne, C., Carruthers, P., Bernardi, M., Ditor, D. S., Gaudet, S., de Groot, S., Hayes, K. C., Hicks, A. L., Leicht, C. A., Lexell, J., Macaluso, S., Manns, P. J., McBride, C. B., Noonan, V. K., Pomerleau, P., … Goosey-Tolfrey, V. L. (2018). Evidence-based scientific exercise guidelines for adults with spinal cord injury: An update and a new guideline. *Spinal Cord*, *56*(4), 308–321. https://doi.org/10.1038/s41393-017-0017-3

Melo, F. C. M., de Lima, K. K. F., Silveira, A. P. K. F., de Azevedo, K. P. M., Dos Santos, I. K., de Medeiros, H. J., Leitão, J. C., & Knackfuss, M. I. (2019). Physical training and upper-limb strength of people with paraplegia: A systematic review. *Journal of Sport Rehabilitation*, *28*(3), 288–293. https://doi.org/10.1123/jsr.2017-0062

Middleton, J. W., Harvery, L. A., Batty, J., Cameron, I., Quirk, R., & Winstanley, J. (2005). Five additional mobility and locomotor items to improve responsiveness of the FIM in wheelchair-department individuals with spinal cord injury. *Spinal Cord*, *44*, 495–504. https://doi.org/10.1038/sj.sc.3101872

Sand, S., Karlberg, I., & Kreuter, M. (2006). Spinal cord injured persons conceptions of hospital care, rehabilitation, and a new life situation. *Scandinavian Journal of Occupational Therapy*, *13*(3), 183–192. https://doi.org/10.1080/11038120500542187

Santos, L. V., Pereira, E. T., Reguera-García, M. M., Patrocínio de Oliveira, C. E., & Costa Moreira, O. (2022). Resistance training and muscle strength in people with spinal cord injury: A systematic review and meta-analysis. *Journal of Bodywork and Movement Therapies*, *29*, 154–160. https://doi.org/10.1016/j.jbmt.2021.09.031

Skučas, K. (2011). Improvement of self-of persons with spinal cord injury. *Special Education*, *2*(25), 25–29. https://www.lituanistika.lt/content/33234

Sutbeyaz, S. T., Koseoglu, B. F., & Gokkaya, K. O. (2005). The combined effects of controlled breathing techniques and ventilatory and upper extremity muscle exercise on cardiopulmonary responses in patients with spinal cord injury. *International Journal of Rehabilitation Research*, *28*(3), 273–276. https://pubmed.ncbi.nlm.nih.gov/16046923/

Valent, L., Dallmeijer, A., Houdijk, H., Talsma, E., & van der Woude, L. (2007). The effects of upper body exercise on the physical capacity of people with a spinal cord injury: A systematic review. *Clinical Rehabilitation*, *21*(4), 315–330. https://www.ncbi.nlm.nih.gov/books/NBK74276/

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