Effectiveness of resistance programs in wheelchair users shoulder function: A systematic review

Eficácia dos programas de exercício resistido na função do ombro de usuários de cadeira de rodas: Uma revisão sistemática

DOI: 10.46814/lajdv4n1-007

Recibimiento dos originais: 01/12/2021
Aceitação para publicação: 24/01/2022

María Campayo Piernas (Campayo-Piernas, M.)
Higher academic background: PhD
Independent autor
C/ Los Lucios 32, 2B, 30006, Murcia, Spain
E-mail: maria.campayo@goumh.es

José Luis Hernández Davó, (Hernández-Davó, J.L.)
Higher academic background: PhD
Faculty of Health Sciences, Universidad Isabel I
09003, Burgos, Spain
E-mail: jlhdez43@gmail.com

João Bruno Granada Maia (Granada-Maia, J.B.)
Higher academic background: BD
Faculty of Health Sciences, Universidad Isabel I
09003, Burgos, Spain
E-mail: brunoextremadura@gmail.com

Renata Matheus Willig (Willig, R.M.)
Higher academic background: PhD
Current Institution: KinesioLab - Unidade de Investigação em Análise do Movimento, Instituto Piaget de Almada, Almada, Portugal (Filiation 1)
Center of Studies in Physical Activity and Sports for People with Disabilities – NEAFEP/UNIFESP (Filiation 2)
Avenida Jorge Peixinho, nº30, Quinta da Arreinela, 2805-059, Almada, Portugal.
E-mail: rewillig@gmail.com

ABSTRACT

Literature presents promising results regarding exercise programs to reduce shoulder pain in manual wheelchair users. However, there is a lack of systematization and specific usefulness of resistance training programs. Thus, the study objective was to analyze the effectiveness of resistance training programs in reducing shoulder pain, and to increase shoulder strength and function in manual wheelchair users (MWUs). A Boolean search strategy adapted for Pubmed, EbSCO, Scopus, Web of Science and Scielo Science databases was undertaken (up to February 2021) to identify all studies measuring changes in shoulder strength, pain, and/or function after implementing a resistance training program in MWUs. Two independent reviewers selected articles based on following criteria: MWUs, participants’ age, study design and intervention types. Also, reviewers performed the study quality
assessment, risk-of-bias analysis and data extraction. Of the 124 obtained publications, a total of 9 studies met the inclusion criteria, being evaluated through PEDro Scale (mean quality score in four or below) and uncertain risk of bias according to Cochrane Scale assessment. The studies shows that: one-repetition maximum (12-60%), isometric peak force (25-36%) and isokinetic muscle strength (10-30%) increased following resistance training interventions. Significant reductions (22-85%) in shoulder pain (WUSPI score) were found after resistance training interventions. In addition, shoulder function (evaluated by DASH questionnaire) improved (12-60%) following resistance training. The present review highlights the usefulness of resistance training programs to improve muscular strength and shoulder function and to reduce shoulder pain in MWUs. These results have significant practical applications to improve the quality of life of MWUs.

**Keywords:** manual wheelchair user, resistance training and shoulder pain.

**RESUMO**

A literatura apresenta resultados promissores acerca de programas de exercício físico para reduzir a dor no ombro de usuários de cadeira de rodas manual. No entanto, existe uma carência da sistematização e da utilidade específica dos programas de treinamento resistido. Assim, o objetivo deste estudo foi analisar a eficácia dos programas de treinamento de resistência na redução da dor no ombro, aumento da força e função do ombro em usuários de cadeira de rodas manual (UCRM). Uma estratégia de busca booleana adaptada foi utilizada nos bancos de dados Pubmed, Ebsco, Scopus, Web of Science e Scielo Science (até fevereiro de 2021) para identificar todos os estudos que mediam mudanças na força, dor e/ou função do ombro após a implementação de um programa de treinamento resistido em UCRM. Dois revisores independentes selecionaram os artigos com base nos seguintes critérios: UCRM, idade dos participantes, desenho do estudo e tipos de intervenção. Além disso, os revisores realizaram a avaliação da qualidade do estudo, análise de risco de viés e extração dos dados. Das 124 publicações obtidas, um total de 9 estudos atenderam aos critérios de inclusão, sendo avaliados por meio da Escala PEDro (escor de qualidade médio de quatro ou menos) e risco de viés incerto, de acordo com a avaliação da Escala Cochrane. Os estudos mostram que: uma repetição máxima (12-60%), pico de força isométrica (25-36%) e força muscular isocinética (10-30%) aumentaram após intervenções de treinamento resistido. Reduções significativas (22-85%) na dor no ombro (pontuação do WUSPI) foram encontradas após as intervenções de treino resistido. Além disso, a função do ombro (avaliada pelo questionário DASH) melhorou (12-60%) após o treinamento resistido. A presente revisão destaca a utilidade de programas de treinamento resistido para melhorar a força muscular e função do ombro, e reduzir a dor no ombro em UCRM. Esses resultados têm aplicações práticas significativas para melhorar a qualidade de vida dos UCRM.

**Palavras-chaves:** usuário de cadeira de rodas manual, treinamento resistido e dor no ombro.

### 1 INTRODUCTION

The wheelchair is one of the most used mobility devices by people with disabilities for their mobility. The manual wheelchair users (MWUs) constantly depend on the upper limbs to provide independent mobility. Daily life activities, weight relief, transfers, and the repetitive load induced by the propulsion of the manual wheelchair cause considerable stress on the upper limbs, especially on the shoulders. Consequently, shoulder pain is prevalent among MWUs.
In this context, the pathologies associated with upper limbs in the MWUs may result in a loss of autonomy, a sedentary lifestyle and excluding social situations.\textsuperscript{5,16} Adapted physical activity is a route to social inclusion, with shoulder injuries complicating participation in this type of program, and consequently, affecting psychological well-being, leading to low self-esteem and sedentary lifestyles.\textsuperscript{13} Facing this problem, the inclusion of physical activities has been associated with greater independence, increased physical well-being and positive impact on rehabilitation.\textsuperscript{14} Previous research has shown that shoulder pain is significantly reduced after exercise-based interventions.\textsuperscript{9,29} Increasing the knowledge about the risk factors and mechanisms leading to shoulder pain in MWUs will help in the appropriate selection of exercise program contents.

It is widely accepted that the cause of shoulder pain in this population is multifactorial.\textsuperscript{15,19} Among these factors, presenting lower strength values in shoulder external rotator muscles is linked to an increased risk to suffer from shoulder pain.\textsuperscript{33,48,50} Consequently, some authors have suggested strength training as a viable strategy to decrease the risk of suffering shoulder pain.\textsuperscript{19} Specifically, the strengthening of shoulder adductors and shoulder internal rotators have been proposed as a key component of exercise programs aiming to reduce shoulder pain.\textsuperscript{7,11} Despite the promising results of exercise-based intervention in reducing shoulder pain in MWUs, to date, there is not a compendium of research assessing the specific usefulness of resistance training programs for this purpose. Thus, the aims of this review were (1) to examine the literature about effectiveness of resistance training programs in reducing shoulder pain in MWUs, (2) to assess the influence of resistance training programs on strength gains and shoulder function in MWUs.

2 METHODS

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) recommendation.\textsuperscript{31} The following inclusion criteria were adopted to study selection: (a) studies involved MWUs adults (> 18 years old); (b) studies that included a resistance training program; (c) randomized controlled trials, uncontrolled clinical trials and quasi-experimental studies that reported shoulder pain measures with data at baseline and post resistance training intervention. Also, exclusion criteria were: (a) studies that sample includes power wheelchair users, children or adolescents; (b) observational, cross-sectional, case and case-control studies; (c) intervention program that did not included resistance exercise, as well as did not report duration, frequency and intensity of the exercise program; d) studies that do not report measures by shoulder pain.
The Pubmed, Ebsco, Scopus, Web of Science and Scielo Science databases were searched only for full journal peer-reviewed articles published in English, Portuguese, and Spanish language until February 2021. The search was performed between the 1st and 10th of February 2021. The search strategy included a standard protocol using three keywords groups (manual wheelchair user, resistance training and shoulder pain, last two based in Mesh term for MEDLINE) and their respective synonymous: “manual wheelchair user*” OR “wheelchair user*” OR “wheelchair” AND “resist* exercise*” OR “resist* training” OR “resist*program*” OR “strength* exercise*” OR “strength* training*” OR “strength* program*” OR “weight* exercise*” OR “weight* training*” OR “weight* program*” AND shoulder OR “shoulder pain*”.

Data were screened and extracted independently by reviewers (J.H and J.G) using standardized forms. Reviewers screened the titles and duplicates were eliminated. After each author screened titles and abstracts and the conflicts were automatically added to the full-text review. The full-text review and reasons for exclusion were also independently assessed. Conflicts were decided with the other reviewers (M.C. and R.W). Additionally, other systematic reviews and references of the included studies were manually consulted to ensure no other relevant studies had been missed in the search strategy. If necessary, the corresponding author was contacted to clarify the included articles data.

Sample characteristics (size, age and disability), intervention (type, duration, frequency and intensity), outcomes and shoulder pain data were extracted independently by J.H. The second reviewer (J.G.) checked the extracted outcomes. The disagreements were resolved with a debate among all reviewers.

The quality of studies was assessed by PEDro Scale. This scale evaluates the following 11 items: (1) participants’ eligibility; (2) random distribution; (3) concealed distribution; (4) comparison of groups at baseline; (5) blinding of participants; (6) blinding of therapist; (7) blinding of evaluators; (8) measurement of at least one key outcome in 85% of subjects allocated; (9) intention to treat; (10) comparison between groups; (11) measures of accuracy and variability. A study received 1 point if it met the requirement for the item and 0 points if it did not. The final score is the sum of 10 items (2–11 items), where the higher scores indicate better methodological quality.

Cochrane Scale assessed the risk of bias through a scale that contains 7 items: (1) randomization; (2) allocation concealment; (3) blinding of participants; (4) blinding of evaluators; (5) incomplete outcome data; (6) selective reporting; (7) other sources of bias. Each item was evaluated as low, high, or uncertain. The risk of bias was classified as: low risk – all items received a low-risk assessment; high risk – if any item received high-risk classification; uncertain risk – if at least one item received the uncertain classification.
3 RESULTS

Figure 1 shows the flow diagram for the extracted studies for this systematic review. The literature search provided a total of 124 records and three studies were identified in a manual search. A total of 127 were identified. Subsequently, 54 duplicate studies were eliminated. After excluding duplicates, 73 papers remained, from which 46 were excluded after reading the titles (18 papers) and abstracts (28 papers) since they did not meet the inclusion criteria. Moreover, 27 full-text studies assessed eligibility and a total of 18 papers were removed after failing to meet the eligibility criteria, 9 by type of study (7 type of study design and two were only the clinical trials registered), 2 by sample characteristics, 3 by intervention characteristics and 4 by reported outcomes. Therefore, 9 studies\textsuperscript{12,22,25,28,34-36,42,49} met the selection criteria and were included in this review. Moreover, Table 1 shows the selected study characteristics.

Table 2 presents the methodological quality of the Study. Through PEDro Scale analysis, on a range scale 1 to 10, only one study\textsuperscript{34} presented score nine. While the other studies had a score 4,\textsuperscript{25,35,36} 3\textsuperscript{22,49} and 2.\textsuperscript{12,28,42} Furthermore, Table 3 shows the risk of bias analysis. All studies\textsuperscript{12,22,25,28,35,36,42,49} had an uncertain risk of bias, except one\textsuperscript{34} that presented high risk.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{Figure1.png}
\caption{PRISMA flow diagram.}
\end{figure}
3.1 STRENGTH

Seven of the nine articles included in the review performed pre-to-post strength evaluations. Specifically, three studies\textsuperscript{12,22,35} included a 1-RM test, showing all of them significant improvements in 1-RM, with increases ranging from 11.9 to 59.7\%. Isokinetic muscle strength tests were used in three articles,\textsuperscript{22,34,42} and significant improvements (10-30\%) were found in all articles. Isometric peak force was evaluated in two articles\textsuperscript{25,28}, with both articles showing significant increases in isometric peak force (25-36\%), although Lins et al.\textsuperscript{28} showed non-significant increases in isometric shoulder internal rotation force. Finally, one study\textsuperscript{12} used a strength-endurance test, showing significant increases in the number of repetitions performed in 30 s (10-61\%).
TABLE 1. Characteristics of the studies included.

<table>
<thead>
<tr>
<th>Article</th>
<th>Sample</th>
<th>Training intervention</th>
<th>Outcomes</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durán et al.12</td>
<td>13 subjects (12 M, 1 F) 26.3 ± 8.3 years</td>
<td>16 weeks 3 sessions of 120 min/week Combined aerobic, mobility, coordination, and strength 7 exercises (BP, MP, BUP, DB, DT, SA, CBN) No information about number of sets, repetitions, intensity, or movement velocity</td>
<td>1-RM in BP, MP, BUP Repetitions in 30 seconds in DB, DT, SA and CBN Functional Independence Measure (FIM)</td>
<td>1-RM increased 14-46% Repetitions in 30 seconds increased 10-61% FIM improved 5.3-7.6 points</td>
</tr>
<tr>
<td>Jacobs et al.22</td>
<td>10 male subjects 39.4 ± 6 years Paraplegia</td>
<td>12 weeks 3 sessions of 45 min/week Circuit resistance training 6 exercises (MP, HOR, PD, PUD, CB, SD) 3 sets x 10 repetitions with 50-60% 1-RM using a 3 s tempo</td>
<td>Concentric and eccentric isokinetic strength: elbow flexion and extension, shoulder external and internal rotation, shoulder flexion and extension, shoulder abduction and adduction Isoinertial strength: 1-RM for the exercises included in the training program</td>
<td>Concentric isokinetic strength improved in 6 exercises Eccentric isokinetic strength improved in 3 exercises 1-RM increased 11.9-30.2%</td>
</tr>
<tr>
<td>Kim et al.25</td>
<td>11 subjects 36.8 ± 6.9 years Spinal cord injury (C4-L1)</td>
<td>6 weeks 3 sessions of 60 min/week Combined aerobic and resistance training 9 muscle groups (exercises based on the level of injury) 1-3 sets x 10-20 repetitions with a RPE intensity increasing over the weeks (from 4 to 8)</td>
<td>Isometric peak force: Elbow flexion and extension, shoulder abduction and adduction, shoulder flexion and extension</td>
<td>Isometric peak force increased in all the exercises (32-36%)</td>
</tr>
<tr>
<td>Lins et al.28</td>
<td>17 subjects 40.0 ± 10.0 years Spinal cord injury (tetraplegia C4-C7)</td>
<td>12 weeks 4 sessions/week 5 exercises with elastic band (shoulder external rotation x2, low-row, push-ups and horizontal abductions) 3 sets of 15 repetitions Medium-resistance band (weeks 1-6) and heavy-resistance band (weeks 7-12)</td>
<td>Isometric peak force: Internal and external rotation Upper-limb functionality (DASH score)</td>
<td>Isometric peak external rotation force increased significantly (25-30%) Isometric peak internal rotation did not significantly change Clinically relevant decreases in DASH score</td>
</tr>
<tr>
<td>Mulroy et al.34</td>
<td>40 subjects (31 M, 9 F) 47 ± 9 years</td>
<td>12 weeks 3 sessions/week</td>
<td>Isokinetic peak force: Shoulder adduction, elevation, internal and</td>
<td>Isokinetic peak force increased in all the exercises 18-30%</td>
</tr>
<tr>
<td>Study</td>
<td>Group Description</td>
<td>Intervention Details</td>
<td>Outcome Measures</td>
<td></td>
</tr>
<tr>
<td>------------------------------</td>
<td>--------------------------------------------</td>
<td>--------------------------------------------------------------------------------------</td>
<td>-------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Nash et al. 2022</td>
<td>7 male subjects 39-58 years</td>
<td>Spinal cord injury (paraplegia; T5-T12) 16 weeks 3 sessions of 45 min/week</td>
<td>ISNM strength increased 38.6-59.7%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spinal cord injury: Paraplegia or incomplete tetraplegia (Cervical n = 3; T2-T7 n = 7; T8-T12 n = 7; lumbar n = 4)</td>
<td>Circuit resistance training 6 exercises (MP, BP, HR, CB, PUD, SD) 3 sets x 10 repetitions with 50-60% 1-RM using a 3 s tempo</td>
<td>WUSPI scores decreased 71% No changes in wheelchair propulsion speed Subjective quality of life increased 10%</td>
<td></td>
</tr>
<tr>
<td>Nawoczenski et al. 2022</td>
<td>21 subjects (15 M, 6 F) 47.1 ± 11.7 years</td>
<td>Spinal cord injury: Paraplegia or incomplete tetraplegia (T2-T7 n = 7; T8-T12 n = 7) 8 weeks 3-4 sessions/week Stretching and resistance training with elastic bands 4 exercises (trapezius x2, serratus anterior and SER)</td>
<td>Shoulder pain (WUSPI)  Isokinetic strength: shoulder external and internal rotation, shoulder flexion and extension, shoulder abduction and adduction Shoulder function: Shoulder Rating Questionnaire (SRQ)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spinal cord injury: Paraplegia or incomplete tetraplegia (Cervical n = 3; T2-T7 n = 7; T8-T12 n = 7; lumbar n = 4) 8 weeks 3-4 sessions/week Stretching and resistance training with elastic bands 4 exercises (trapezius x2, serratus anterior and SER)</td>
<td>Shoulder pain (WUSPI)  Isokinetic strength: shoulder external and internal rotation, shoulder flexion and extension, shoulder abduction and adduction Shoulder function: Shoulder Rating Questionnaire (SRQ)</td>
<td>Significant reductions in WUSPI scores (50%) Significant improvements in SRQ (24%)</td>
<td></td>
</tr>
<tr>
<td>Serra-Añó et al. 2022</td>
<td>15 male subjects 40.3 ± 11.1 years</td>
<td>Spinal cord injury (T4-T12) 8 weeks 3 sessions/week 8 exercises (LR, PUD, HOR, CB, SIR, SER) 3 sets x 8-12 repetitions with an RPE intensity of 7-8</td>
<td>Shoulder pain (WUSPI)  Isokinetic strength increased 10-17% Significant reductions in WUSPI scores (55%) Significant decreases in DASH scores (12%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spinal cord injury (T4-T12) 8 weeks 3 sessions/week 8 exercises (LR, PUD, HOR, CB, SIR, SER) 3 sets x 8-12 repetitions with an RPE intensity of 7-8</td>
<td>Shoulders function: Shoulder Rating Questionnaire (SRQ)</td>
<td>Significant reductions in WUSPI scores (45%) Significant decreases in DASH scores (60%) Significant improvements in SQR (9%)</td>
<td></td>
</tr>
<tr>
<td>Van Straaten et al. 2022</td>
<td>16 subjects (13 M, 3 F) 41 years (range 25-64)</td>
<td>Spinal cord injury (C6-T7 n = 1; T2-T7 n = 5; T8 and below n = 9) Polio n = 1 12 weeks ≥ 3 sessions/week 3 exercises (LWR, SER, SP) 3 sets x 30 repetitions</td>
<td>Shoulder pain (WUSPI)  Isometric peak force: shoulder external and internal rotators, scapular abductors and retractors, lower trapezius Shoulder function: Shoulder Rating Questionnaire (SRQ)</td>
<td></td>
</tr>
</tbody>
</table>

**Abbreviations:**
- BP = Bench press; BUP = Butterfly press; CB = curl biceps; CBN = Curl back neck; DB = Dumbbell biceps; DT = Dumbbell triceps; F = Females; HOR = Horizontal row; HRR = Heart rate recovery; LR = lateral rises; LWR = low row; M = males; MP = Military press; PD = Pec deck; PESS = Physical examination of the shoulder scale; PNRS = Pain numerical rating scale; PUD = Pull-down; RM= repetition maximum; SA = shoulder abduction; SD = seated dips; SER = shoulder external rotation; SIR = shoulder internal rotation; SP = shoulder punch; USPR S = Ultrasound shoulder pathology rating scale; WUSPI = Wheelchair user’s shoulder pain index.
### TABLE 2. PEDro Scale analysis.

<table>
<thead>
<tr>
<th>Study</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durán et al.</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2/10</td>
</tr>
<tr>
<td>Jacobs et al.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>3/10</td>
</tr>
<tr>
<td>Kim et al.</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4/10</td>
</tr>
<tr>
<td>Lins et al.</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2/10</td>
</tr>
<tr>
<td>Mulroy et al.</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>9/10</td>
</tr>
<tr>
<td>Nash et al.</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4/10</td>
</tr>
<tr>
<td>Nawoczenski et al.</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4/10</td>
</tr>
<tr>
<td>Serra-Añó et al.</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2/10</td>
</tr>
<tr>
<td>Van Straaten et al.</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3/10</td>
</tr>
</tbody>
</table>

### TABLE 3. Risk of bias of analyzed studies.

<table>
<thead>
<tr>
<th>Study</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durán et al.</td>
<td>Uncertain</td>
<td>Uncertain</td>
<td>Uncertain</td>
<td>Uncertain</td>
<td>Uncertain</td>
<td>Low</td>
<td>Uncertain</td>
<td>Uncertain</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jacobs et al.</td>
<td>Uncertain</td>
<td>Uncertain</td>
<td>Uncertain</td>
<td>Uncertain</td>
<td>Uncertain</td>
<td>Low</td>
<td>Uncertain</td>
<td>Uncertain</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kim et al.</td>
<td>Uncertain</td>
<td>Uncertain</td>
<td>Uncertain</td>
<td>Uncertain</td>
<td>Uncertain</td>
<td>Low</td>
<td>Uncertain</td>
<td>Uncertain</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lins et al.</td>
<td>Uncertain</td>
<td>Uncertain</td>
<td>Uncertain</td>
<td>Uncertain</td>
<td>Uncertain</td>
<td>Low</td>
<td>Uncertain</td>
<td>Uncertain</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mulroy et al.</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nash et al.</td>
<td>High</td>
<td>Uncertain</td>
<td>Uncertain</td>
<td>Uncertain</td>
<td>Low</td>
<td>Low</td>
<td>Uncertain</td>
<td>Uncertain</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nawoczenski et al.</td>
<td>Uncertain</td>
<td>High</td>
<td>High</td>
<td>Uncertain</td>
<td>High</td>
<td>Low</td>
<td>Uncertain</td>
<td>Uncertain</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Serra-Añó et al.</td>
<td>Uncertain</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>Uncertain</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Van Straaten et al.</td>
<td>Uncertain</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Uncertain</td>
<td>Uncertain</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.2 SHOULDER PAIN
A total of five studies\textsuperscript{34-36,42,49} included shoulder pain assessment. All of them used the WUSPI, showing significant reductions ranging from 22 to 85%.

3.3 SHOULDER FUNCTION
The DASH index was used as a measure of shoulder function in three studies,\textsuperscript{28,42,49} reporting all of them significant decreases in DASH score ranging from 12 to 60%. It should be noted that a decrease in DASH score means an improved shoulder function. Two studies\textsuperscript{36,49} used the SQR to assess shoulder functionality, showing both of them significant increases (9-24%).

3.4 OTHERS
Durán et al.\textsuperscript{12} reported significant increases in functional independence measure, while Mulroy et al.\textsuperscript{34} showed a 10% increase in subjective quality of life. Finally, Mulroy et al.\textsuperscript{34} reported non-significant changes in wheelchair propulsion speed.

4 DISCUSSION
The aims of the present review were to assess the usefulness of resistance training interventions in eliciting strength gains, shoulder pain reductions and improvements in shoulder function in manual wheelchair users. The main findings of this study were that upper-body strength and shoulder function increased after resistance training interventions, together with significant reductions in shoulder pain. However, due to the disparity in training interventions and testing procedures, further research is needed to elucidate the optimal resistance training regime for MWUs.

Resistance training has been suggested as a key factor to reduce both acute and overuse injury incidence,\textsuperscript{3,27} likely due to the established relationship between muscular weakness and a higher injury risk.\textsuperscript{37,39,44} The results of the present review highlight the great effectiveness of resistance training in improving shoulder strength. This has been proved in studies assessing either isometric,\textsuperscript{25,28} isokinetic\textsuperscript{22,34,42} or isotonic\textsuperscript{12,22,35} shoulder strength values, which is in line with previous studies showing increases in shoulder strength after resistance training interventions in overhead athletes,\textsuperscript{38,45} and in subjects suffering from shoulder injuries.\textsuperscript{8} Although not measured in the articles included in the present review, improvements in strength as a result of resistance training are underpinned by multiple neural and morphological changes, such as increased rate and magnitude of motor unit activation,\textsuperscript{10,47} altered muscle architecture,\textsuperscript{1,6} and increased tendon stiffness.\textsuperscript{21,52} Previous research have revealed lower values of shoulder rotation strength as a predictive variable for upper-body injuries,\textsuperscript{2,4,18,23} suggesting that strength training interventions may play a key role in reducing shoulder injuries. The
wide variety of resistance training interventions, including different equipment (e.g., elastic bands vs free weight) and specially, different programming variables (e.g., volume, intensity, density) and the small number of articles meeting inclusion criteria, makes impossible to propose any specific resistance training methodology as the most appropriate to increase muscular strength in MWUs. It should be highlighted that some of the research does not provide a proper description of key programming variables as training intensity, movement velocity and load progression. As adaptations following resistance training appears to be dependent on the optimal choice of resistance training programming variables, including the load mobilized and the movement velocity, there is a clear need for future high-quality studies assessing the effectiveness of well-described different resistance training programs in improving shoulder strength in MWUs.

The high muscular demands on the upper extremities in MWUs frequently result in shoulder pain and injury. Although the specific factors causing shoulder pain are not fully established, previous research has shown decreased muscle strength as a predictor of shoulder pain. Consequently, there is a rationale for implementing resistance training in MWUs training programs. Two previous reviews have shown that multicomponent exercise-based interventions are an effective strategy to reduce shoulder pain in MWUs. The present review demonstrates that exercise interventions based on resistance training are a powerful tool to reduce shoulder pain in MWUs. Although the sample used in the studies may have differed between them, shoulder pain assessed by the WUSPI showed significant reductions ranging from 22 to 85% (5 to 36 points). It should be noted that Cratsenberg et al. suggested a minimal detectable change in shoulder pain of 5.1 points when using the WUSPI score to assess the usefulness of an exercise-based intervention, which highlights the great effect of resistance training on shoulder pain reductions in MWUs. The high peak forces affecting shoulder joint together with the large number of movement repetition (i.e., wheelchair propulsion) have been linked to shoulder pain and injury in MWUs, which is usually manifested by decreases in strength and range of motion. Shoulder external rotator strength, scapular kinematics and shoulder external range of motion are the variables most likely affected in subjects suffering from shoulder pain. Therefore, resistance training interventions focused on shoulder external rotator muscles and scapular muscles (e.g., serratus, rhomboid, trapezius, supraspinatus) are highly recommended in MWUs with shoulder pain.

A concomitant effect of shoulder pain is a decrease in shoulder function, which affects MWUs quality of life. Exercise-based interventions have previously shown to enhance quality of life through improvements in shoulder function. The current review specifically presents resistance training as an optimal exercise strategy to improve shoulder function. This is supported by 5 out of 5
articles showing significant improvements ranging from 9 to 60% in shoulder function following a resistance training intervention. Due to the highly negative influence of increased shoulder pain and reduced shoulder function in daily-living activities, including work outside the home and housework, there is a need to seek exercise-based strategies to increase shoulder function and consequently, the quality of life of MWUs. Based on the results found in the present review, resistance training is highly recommended when aiming to improve shoulder function in MWUs. Further, Durán et al. reported significant increases in functional independence, and Mulroy et al. reported a 10% increase in subjects’ quality of life, which highlight the wide variety of benefits provided by strength training interventions.

The main limitations of the present study rely on the relatively small number of articles that meet inclusion criteria, and the discrepancies in methodologies used, which makes unable to suggest a superior effect of any resistance training program against others. The wide variety of intervention lengths (6-16 weeks), number of exercises used (from 3 to 9), type of muscular action assessed (e.g., isometric, isokinetic, isotonic), and the discrepancies in training intensity used and managed (i.e., RPE, elastic band resistance, [x] RM load) do not allow to provide recommendations for the most appropriate design of resistance training programs for MWUs. A training frequency of at least 3 sessions per week was used in all studies, which suggest this frequency as appropriate for strength training programs for MWUs, although future research should assess if lower training frequencies (e.g., 2 sessions per week) could result in similar functional improvements. Despite it was not a requisite in our search, all subjects have spinal cord injury in the make-up of the final sample, which do not allow extrapolation of the results to other populations. Furthermore, it was not achieved to make a comparison among injury types.

5 CONCLUSION

In conclusion, the present review highlights the usefulness of resistance training programs to improve muscular strength in MWUs. In addition, resistance training has been shown to significantly reduce shoulder pain and to improve shoulder function. These results have significant practical applications not only for rehabilitation processes, but also to improve the quality of life of MWUs. Despite the limitations found in the literature, resistance training appears as a highly recommended exercise-based strategy to reduce shoulder pain, and to increase muscular strength and shoulder function in MWUs.
REFERENCES


