Practice Guidelines for Cardiovascular Fitness and Strengthening Exercise Prescription After Burn Injury

Bernadette Nedelec, BSc OT(c), PhD,*†‡ Ingrid Parry, MS, PT,§ Hernish Acharya, BSc, MD, FRCPC,‖ Lynne Benavides, OT/CHT,¶ Sara Bills, PT,# Janelle L. Bucher, OTR/L, Joanne Cheal, BMR, OT,†† Annick Chouinard, BSc, PT,‡ Donna Crump, PT,‡‡ Sarah Duch, PT,§§ Matthew Godleski, MD,‖‖ Jennifer Guenther, MSPT,¶¶ Catherine Knox, OTR/L,§§ Eric LaBonte, PT,## David Lorello, DPT,*** J. Xavier Lucio, MS OTR/L,††† Lori E. Macdonald, MSc PT,†† Jennifer Kemp-Offenberg, OTR/L,‡‡‡ Candice Osborne, OT,‡‡‡§§§ Kara Pontius, PT,¶¶ Miranda Yelvington, MS,OTR/L, BCPR,‖‖‖ Ana de Oliveira, BSc,† Lorie A. Kloda BA, MLIS, PhD¶¶¶**

The objective of this review was to systematically evaluate the available clinical evidence for the prescription of strength training and cardiovascular endurance exercise programs for pediatric and adult burn survivors so that practice guidelines could be proposed. This review provides evidence-based recommendations specifically for rehabilitation professionals who are responsible for burn survivor rehabilitation. Summary recommendations were made after the literature was retrieved by systematic review, was critically appraised by multiple authors and the level of evidence determined in accordance with the Oxford Centre for Evidence-based Medicine criteria.[1] Although gaps in the literature persist and should be addressed in future research projects, currently, strong research evidence supports the prescription of strength training and aerobic conditioning exercise programs for both adult and pediatric burn survivors when in the presence of strength limitations and/or decreased cardiovascular endurance after evaluation. (J Burn Care Res 2016;37:e539–e558)

*From the *School of Physical and Occupational Therapy, McGill University, Montreal, Quebec, Canada; †Centre de recherche, Centre hospitalier de l'Université de Montréal (CRCHUM), Quebec, Canada; ‡Hôpital de réadaptation Villa Medica, Montreal, Quebec, Canada; §Shriners Hospitals for Children, Northern California, Sacramento; ‖Division of Physical Medicine and Rehabilitation, Department of Medicine, University of Alberta, Glenrose Rehabilitation Hospital, Edmonton, Alberta, Canada; ¶Rhode Island Hospital, Rehabilitation Medicine, Providence; #University of Nebraska Medical Center, Omaha, Nebraska; **University of Washington, Seattle, Washington; ††Alberta Health Services, Foothills Medical Centre, Calgary, Canada; ‡‡Parkland Health & Hospital System, Dallas, Texas; §§Westchester Medical Center, Valhalla, New York; ‖‖Medical Director of Inpatient Rehabilitation, University of Colorado Hospital, Aurora, Colorado; ¶¶Children's Hospital Colorardo, Aurora, Colorado; ##Connecticut Burn Center, Bridgeport Hospital, Bridgeport, Connecticut; ***Arizona Burn Center, Phoenix, Arizona; †††University of Utah Burn Center, Salt Lake City, Utah; ‡‡‡Shriners Hospitals for Children, Galveston, Texas; §§§University of Texas Medical Branch, Galveston, Texas; ‖‖‖Arkansas Children's Hospital Burn Center, Little Rock, Arkansas; and ¶¶¶Library, McGill University, Montreal, Quebec, Canada.*

This study was supported by the Edith and Richard Strauss Foundation.

Address correspondence to Bernadette Nedelec, PhD, McGill University, Faculty of Medicine, 3654 Promenade Sir William Osler, Montreal, Quebec, Canada H3G 1Y5. E-mail:bernadette.nedelec@mcgill.ca.

1559-047X/2015

DOI: 10.1097/BCR.0000000000000282

RECOMMENDATIONS

Standards

There are 20 reports in the literature evaluating exercise program prescription for burn survivors; 14 were randomized controlled trials (RCTs), 11 included pediatric burn survivors, and three included adult burn survivors. All of these studies found the prescription of exercise programs to be advantageous. The clinical outcomes that showed significant improvement in the RCTs included aerobic capacity, functional outcomes, lean body mass (LBM), mobility evaluations, occupational performance, pulmonary function, resting energy expenditure, strength, total work volume, treadmill times, and weight. All exercise training programs took place at burn centers; however, most included additional in-hospital standard of care (SOC) treatment components provided by burn team members. Many of these outcomes may have improved, in part, due to the quality and quantity of in-hospital SOC treatments compared with the outpatient community or home-based programs that were not quantified. It is our recommendation that further RCTs be conducted that are entirely in-hospital or community-based.

Recommended Practice Guidelines

- Burn survivors' strength and cardiovascular endurance should be evaluated in individuals 7 years of age and older. Those who test below normal levels should be prescribed a supervised resistance and/or aerobic exercise program.
- Exercise programs may begin as early as immediately postdischarge from acute care and as late as 14 years after burn.
- Exercise programs should last 6 to 12 weeks for adults and up to 12 weeks for children. Studies have not extended beyond 12 weeks therefore it is not known whether longer exercise programs would be more beneficial.

OVERVIEW

Purpose

The purpose of this review was to formulate guidelines for practice, based on the strength of the published evidence evaluating the benefit of exercise programs designed to increase the cardiovascular fitness or muscular strength of adult and/or pediatric burn survivors.

Users

These guidelines are designed to aid burn care team members (exercise physiologists, kinesiologists, occupational therapists [OT], physicians, physiotherapists [PT], etc.), who are responsible for the prescription of exercise programs as a component of burn survivor rehabilitation programs. In addition, the recommended guidelines can be implemented by health professionals who do not routinely treat burn patients at their facilities, such as community-based fitness centers, schools, rural facilities, etc.

Clinical Problem

Improvements in acute care and surgical management of burn survivors have resulted in increased survival rates.[2–5] As more individuals recover from major burn injuries there has been an increased focus on rehabilitation to ensure that optimal function and quality of life is achieved.[6,7] The need and potential value of cardiovascular endurance and strengthening exercise programs for burn survivors is particularly pertinent after prolonged periods of immobilization during acute care and the characteristic physiological responses to burn injury, such as marked hypermetabolism and skeletal muscle catabolism.[8–11] When comparisons have been made between nonburned children relative to pediatric burn survivors, it has been shown that their aerobic capacity, LBM,[12] strength,[12–14] quadriceps size, gait parameters,[14] pulmonary function, and treadmill times[15,16] are significantly reduced in pediatric burn survivors. Comparisons of nonburned adults with adult burn survivors have additionally shown that aerobic capacity,[17,18] ambulation speed,[19] physical activity participation,[17] pulmonary function,[17,20] and strength[19,21,22] are significantly reduced and oxygen consumption elevated[22] in adult burn survivors.

Currently, the resources required, such as testing and training equipment and rehabilitation personnel, to offer rehabilitation programs that continue for weeks or months after discharge from acute care are lacking at most burn centers. Thus, the objective of this review was to systematically evaluate the available evidence examining the effectiveness of exercise programs to increase cardiovascular fitness or muscular strength in adult and/or pediatric burn survivors so that practice guidelines can be developed that specifically describe the required rehabilitation interventions and resources.

PROCESS

The steps taken to develop the practice guidelines reported here are those outlined by Bowker et al.[23] These steps included setting up a guideline development group, forging links with stakeholder groups, agreeing on the scope of the guidelines, formulating a clinically relevant PICO (population, intervention, condition, outcome) question, searching the literature for evidence, systematically appraising the evidence found, and making recommendations. The guideline development group consisted of an international assembly of OTs, physicians, and PTs who were members of the American Burn Association Rehabilitation Committee, and clinicians recruited from the American Burn Association. This group met at the American Burn Association meeting in March 2014 for a practice guidelines development workshop where the steps associated with the development of practice guidelines were reviewed and several practice sessions, focused on critiquing the evidence, were performed until participants were comfortable with the critique form and process. The scope of the guideline is limited to the PICO question: "Does exercise increase the cardiovascular fitness and/or muscular strength of adult and/or pediatric burn survivors?"

Search Strategy

The literature search was designed to identify studies that focused on patients, either adults or children, who had sustained a burn injury and undergone a treatment involving exercise. All outcome measures that evaluated strength and cardiovascular endurance were considered. A broad literature search was conducted in the following bibliographic databases: MEDLINE, the Cumulative Index of Nursing & Allied Health Literature (CINAHL), EMBASE, Allied and Complementary Medicine (AMED), ProQuest Dissertations and Theses, Web of Science, OTseeker and PEDro, from the dates of inception until November 2014. Search results were limited to records available in either English or French. The search strategy was designed and conducted by a medical librarian (LAK) as described in Appendix. The search strategy was later validated by the librarian; all 20 citations included in the practice guidelines were indexed in the Medline database and retrieved by the search. The combined total of results retrieved from the databases was 3090; 815 duplicates were removed, yielding 2275 records for eligibility screening. Two additional publications were retrieved by scanning reference lists in the articles reviewed, bringing the total number of unique citations and abstracts that were screened to 2277.

Selection for Inclusion

Since studies focusing on this clinical question were expected to be sparse, all study designs that provided original data on burn survivors were selected. The title and abstract of each article were assessed by two individuals for inclusion. Only full-length, primary articles were selected for review, with review articles being excluded to allow the critical appraisal of original publications; however, the reference list of review articles were scanned as described above. Ultimately, 25 articles were deemed appropriate for the full review process. Figure 1 maps out the records that were identified and depicts the flow through the phases of identification, screening for exclusion and inclusion in full-review as recommended by the PRISMA Statement.[24]

Data Extraction and Analysis

All studies were systematically critiqued and scored by at least two independent reviewers, drawing on

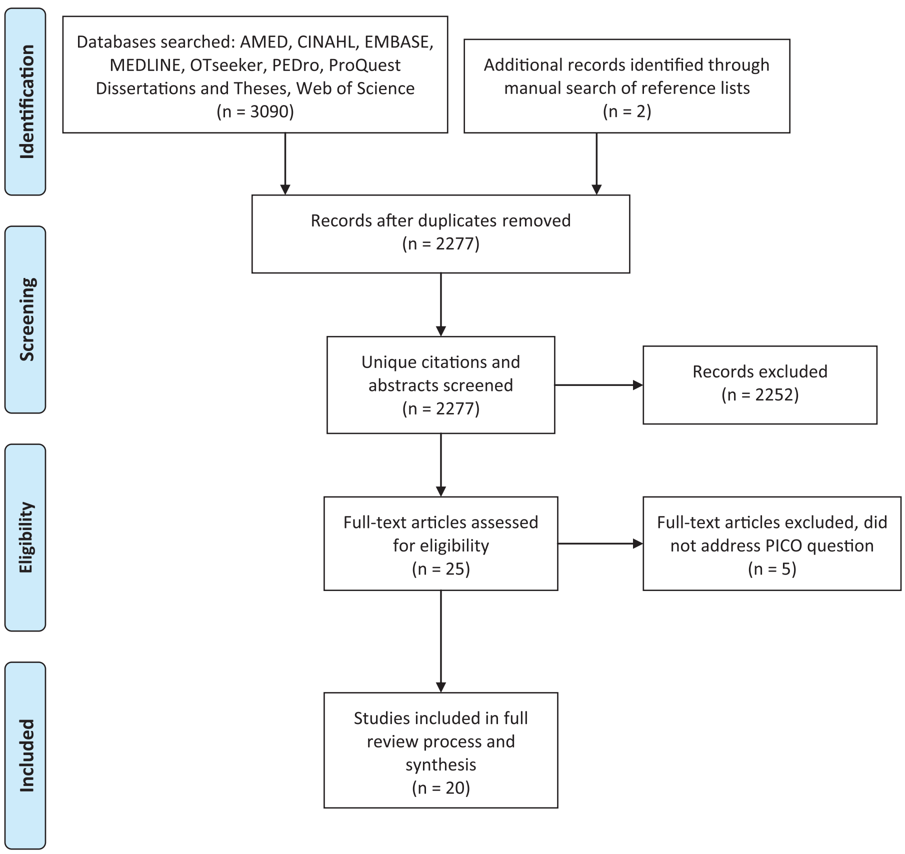

Figure 1. PRISMA flow diagram mapping out the number of records identified, screened, assessed for eligibility, and included in the full review process and synthesis.

Table 1. Evidentiary Table: Evaluation of the Quality of Intervention Studies

Citation	Study Purpose	Literature Review	Design	Sample			Outcomes		
				Size	Details	Justified	Reliable	Valid	Detailed Description
Ahmed et al (2011)	1	1	CC	30	1	0	1	1	1
Al-Mousawi et al (2010)	1	1	RCT	21*	1	0	1	1	1
Cronan et al (1990)	0	1	CC	16	0	0	0	0	0
Cucuzzo et al (2001)	1	1	RCT	21*	1	0	1	1	1
de Lateur et al (2007)	1	1	RCT	35	1	0	1	1	1
Ebid et al (2012)	1	1	RCT	31	1	0	1	1	1
Ebid et al (2014)	1	1	RCT	33*	1	1	1	1	1
Ebid et al (2012)	1	1	RCT	40	1	1	1	1	1
Grisbrook et al (2012)	1	1	CC	18	1	0	1	1	1
Grisbrook et al (2013)	1	1	CC	18	1	0	1	1	1
Hardee et al (2014)	1	1	RCT	47*	1	0	1	1	1
Paratz et al (2012)	1	1	Non-RCT	30	1	0	1	1	1
Parrot et al (1988)	1	1	HC	40	0	0	0	0	0
Porro et al (2012)	1	1	RCT	222*	1	1	1	1	1
Porro et al (2013)	1	1	RCT	58*	1	0	1	1	1
Prkzora et al (2007)	1	1	RCT	51*	1	0	1	1	1
Suman et al (2002)	1	1	RCT	51*	1	0	1	1	1
Suman et al (2001)	1	1	RCT	35*	1	1	1	1	1
Suman et al (2003)	1	1	RCT	44*	1	1	1	1	1
Suman et al (2007)	1	1	RCT	20*	1	0	1	1	1

Design: *CC*, case-controlled study; *HC*, historically controlled studies; *non-RC*, nonrandomized controlled cohort/follow-up study; *RCT*, randomized, controlled, trial.
YES = 1; NO = 0; N/A = 0.
*Pediatric burn survivors.

the critical appraisal form designed by Law et al.[25] Fourteen items comprised in the scoring of this form relate to study purpose, literature review, study sample, outcomes, interventions, results, conclusions, and clinical implications. The two to three reviewers independently extracted details required to complete the critical appraisal form. Each item was rated numerically as (1) for Yes and (0) for No or Not Applicable. A total score was then calculated and compared with the other reviewers' results. If there were minor differences (±2 points), the discrepancies were discussed until a consensus was reached. When larger differences occurred, an additional reviewer was called upon to critique the article and consensus was achieved among all reviewers. After this process, five articles were removed[22,26–29] because the authors' clinical question was not addressed.

SCIENTIFIC FOUNDATION

Study Characteristics

Table 1 summarizes the critique results for the 20 retained citations. Citations are categorized based on the population of patients included: (1) pediatric burn survivors only (denoted by single asterisk) and (2) adult burn survivors. As shown on the last column of this table, 2/20 citations (10%) received a score of <5 out of a possible total score of 14 but were included for completeness sake. Of the remaining citations 18 (90%) received a score ≥10 therefore are considered high quality studies.

Table 2 summarizes the study characteristics, results, and level of evidence for each of the 20 citations. Fourteen were RCTs,[12,14,16,19,31,32,34–36,38,41–44] one was a follow-up study,[39] four were case–control studies,[20,30,33,37] and one a historically controlled study.[40] The sample sizes of all studies ranged from 16 to 222. Those including only pediatric participants ranged from 20 to 222 while those with only adult participants ranged from 16 to 40. Sample size of the RCTs ranged from 21 to 222 for those that included only pediatric participants and 31 to 40 for those that included only adult participants. The level of evidence was assigned according to the updated Oxford Centre for Evidence-based Medicine Levels of Evidence.[1]

Pediatric Burn Survivor Studies

Eleven of the 20 publications included in this review specifically addressed exercise prescription

Intervention		Results					
Contamination	Co-intervention	Statistical Significance	Analysis Appropriate	Clinical Importance	Drop Outs Reported	Conclusions Appropriate	Total Score
0	0	1	1	1	1	1	11
1	1	1	1	1	1	1	13
0	0	0	0	1	0	0	2
1	0	1	1	1	1	1	12
0	0	1	1	1	1	1	11
1	1	1	1	1	1	1	13
1	1	1	1	1	1	1	14
1	1	1	1	1	1	1	14
0	0	1	1	1	1	1	11
0	0	1	1	1	1	1	11
1	1	1	1	1	0	1	12
0	0	1	1	1	1	1	11
1	0	0	0	1	0	0	4
1	1	1	1	1	1	1	14
1	1	1	1	1	1	1	13
1	1	1	1	1	0	1	12
1	1	1	1	1	1	1	13
0	1	1	1	1	1	1	13
0	0	1	1	1	1	1	12
0	0	1	1	1	0	1	10

for pediatric burn survivors. Of these 11, 10 were carried out at the Shriners Hospital for Children, Galveston. All of the pediatric studies were RCTs and all received a rating of between 10 and 14 of 14 on the critique form. The prescribed resistance and/or aerobic exercise program had positive benefits, that are outlined in detail in Table 2, for a number of outcome measures including bone mineral content,[41] gait measures,[14,34] LBM,[12,31,32,38,41,43,44] pulmonary function,[16] quad size,[14] resting heart rate,[34] strength,[12,14,31,32,34,41–44] total work volume,[32,34] treadmill time,[16,32] and VO_{2peak}.[12,16,32,38,42,43] Two pediatric studies[26,29] were excluded from full review and incorporation into the final recommendation as they did not respond directly to the PICO question but did nonetheless demonstrate benefits from exercise for the outcomes that they examined. No adverse events were reported in any of these studies.

Adult Burn Survivors

There were several case series published in 1988 and 1990 that reported on the benefits of exercises or exercise programs specifically prescribed for burn survivors[33,40] but had many methodological limitations that were identified during the critique (Table 1). Since 2007, there have been seven additional reports that were rated between 11 and 14 of 14. Three were case–control studies, one was a follow-up study and three were RCTs. The prescribed resistance and/or aerobic exercise program had positive benefits, that are outlined in detail in Table 2, for a number of outcome measures including function,[20,39] gait measures,[19,39] LBM,[37] quality of life,[39] strength,[19,30,36,37,39] total work volume,[19] and $VO_{2max\ or\ peak}$.[20,39] One case–control study, which was published in two different manuscripts with two different sets of outcomes reported in each,[20,37] reported an improvement with exercise but the improvement in the burn survivor group did not significantly differ from the improvement reported in their healthy controls. This group also reported on the impact of the exercise program on the participants' self-reported quality of life[28] but this article was excluded from full review as it did not include any muscle strength or cardiovascular fitness measure, therefore did not respond to the PICO question.

Outcome Measures

The outcome measures that were used in these reports varied across studies. Those outcomes that

Table 2. Characteristics of Included Studies

Authors	Design	Sample	Outcome Measures	Intervention	Results	Level of Evidence
Ahmed et al (2011)[30]	Case–control study	• n = 30 males (burn survivors = 15; healthy = 15) • Mean age (yrs): burn s urvivors = 24.4; healthy = 24.8 • %TBSAB: range 30–40 • Deep partial thickness anterior thigh burn• Baseline: 21–25 days post-burn	• Strength (Biodex System-3 dynamometer) • Evaluated at baseline and 6 weeks post-training	• 6-week treatment period (2×/52) • Ex: isokinetic strengthening	• Burn survivors and healthy subjects eccentric and concentric peak torque 30° and 90°/sec significantly improved • % peak torque improvement was significantly greater for burn survivors than healthy subjects for eccentric 90∘/sec and 30∘/sec as well as concentric 30∘/sec • Peak torques were significantly greater for healthy subjects during concentric peak torques at 30° and eccentric torques at 30° and 90°	4
In 2011, Ahmed et al[30] performed a case-controlled follow-up study where a group of burn survivors and healthy participants were evaluated and then trained with exercises on an isokinetic dynamometer. After 6 weeks, of twice-per-week training, the eccentric and concentric muscle peak torque improved in both groups. The authors reported a significantly greater percentage of improvement for the burn survivors as compared with the healthy participants for eccentric contractions at both 30° and 90° per second and concentric contractions at 30° per second after training.						
Al-Mousawi et al (2010)[31]	RCT	• n = 21 (Ex = 11, SOC = 10) • Mean age (yrs): Ex = 12.2; SOC = 13.7 • Mean %TBSAB: Ex = 61; SOC = 56 • Baseline: 6 mos post-burn	• REE • LBM (DEXA) • Strength (Biodex System-3 dynamometer: isokinetic) • Height, weight	• 12-week treatment period • SOC: same as Suman et al (2001) • Ex: (Figure 2)	• Mean weight gain was significant for the Ex group, but no difference between groups • No significant difference in the mean change in REE or percent predicted REE • Subjects in the Ex group gained significantly greater LBM, even when normalized to height • Ex group demonstrated significantly greater strength improvements, which persisted when normalized to LBM index	2
In 2010, Al-Mousawi et al[31] reported on a study using the exercise program described in Figure 2 plus SOC compared with SOC only. The authors confirmed previous findings that LBM and strength improved but contrary to their previous findings[32] they reported that REE did not significantly increase with time in either group and that there was no significant difference between groups. Unlike their previous publication they normalized the REE measures to the corresponding changes in LBM, which resulted in the differences in REE becoming negligible, thus, exercise training did not exacerbate postburn hypermetabolism.						

(*Continued*)

Table 2. (*Continued*)

Authors	Design	Sample	Outcome Measures	Intervention	Results	Level of Evidence
Cronan et al (1990)[33]	Case–control study	• n = 16 (8 isokinetic; 8 isometric/isotonic) patient-matched joints with full AROM • Age range: 20–40 yrs • %TBSAB: range 9–64 • Baseline: 5–9 mos post-burn	• Strength (Cybex II dual isokinetic dynamometer)	• SOC: splinting, stretching, isometric, and isotonic work loads • Ex: cardiovascular training and isokinetic protocol	• % deficit of peak torque was less in Ex group compared with SOC group for all joints tested • No statistical analysis	4
Cronan et al[33] compared burn survivors who had received SOC to burn survivors who had received SOC plus cardiovascular and strength training utilizing the isokinetic dynamometer. The patients served as their own controls by comparing an involved extremity to an uninvolved extremity. Those who received exercise training and SOC performed better when tested on an isokinetic dynamometer than the comparison joint. The authors report significant peak torque deficit in the nonisokinetic treatment group, although no statistical analyses were reported. In addition, details of the study population and intervention program were extremely limited.						
Cucuzzo et al (2001)[34]	RCT	• n = 21 (Ex = 11; SOC = 10) • Mean age (yrs): 10.6; (range 5.9–19.9) • %TBSAB: mean 59.7; range 40–87 • Baseline: 6 mos post-burn	• Weight, height, resting heart rate, 6 MWT • Strength (3RM) • Evaluated at baseline & 12 weeks later (6 and 9 mos post-burn)	• 12-week treatment period • SOC: OP OT and PT twice daily × 1 hr • Ex: Figure 2 except aerobic exercise 3×/week plus OT and PT daily × 1 hr, school 2–3 hrs/d, play therapy and psychological counselling as necessary	• Significant change for the following outcomes: weight Ex group and SOC group, resting heart rate for the Ex group, 3RM for the Ex group (biceps, triceps, forearms, quadriceps, hamstrings) and SOC group (forearms, quadriceps, hamstrings), total volume work for the Ex and SOC group, 6MWT for the Ex and SOC group • Improvements were significantly greater for the Ex than SOC group for: 3RM (hamstrings), total volume work, 6MWT	2
Cucuzzo et al[34] reported on 21 participants that were randomized to either an exercise group or a SOC group. The baseline age, percent burn, height, weight, and resting heart rate did not significantly differ between groups. The post-treatment evaluation revealed that weight, total volume of work, and the 6-minute walk test increased significantly in both groups. The resting heart rate improved in the exercise group but not the SOC group. All five of the 3RM increased for the exercise group and three of the five for the SOC group. The group comparisons revealed significant differences between groups for hamstring 3RM, total volume of work and the 6-minute walk test. There were no adverse events or dropouts.						
deLateur et al (2007)[35]	RCT	• n = 35 (WTQ = 13; WTT = 11; SOC = 11) • Mean age (yrs): WTQ = 35.4; WTT = 43.5; SOC = 34.9 • Mean %TBSAB: WTQ = 19.5; WTT = 16.8; SOC = 21.6	• Max aerobic capacity ($VO_{2\,max}$) • Evaluated at baseline and 12 weeks	• 12-week treatment period • SOC: OT and PT (ROM, massage, splinting, stretching, strengthening, mobility training, ADL training) • SOC + WTQ SOC + WTT	• WTT and WTQ group: significant improvements in aerobic capacity ($VO_{2\,max}$) from baseline to 12/52 and compared with SOC but not between groups • SOC group: no significant improvement in aerobic capacity • No adverse effects reported	2

(*Continued*)

Table 2. (*Continued*)

Authors	Design	Sample	Outcome Measures	Intervention	Results	Level of Evidence
In 2007, de Lateur et al[35] published the first RCT involving adult burn survivors. Participants were randomly assigned to one of three groups: (1) "functional restoration" (SOC); (2) work-to-tolerance group (WTT); and (3) work-to-quota (WTQ). The WTT group performed aerobic exercise at their target heart rate for as long as tolerated to a maximum of 30 minutes. The WTQ group exercised to preset quotas that gradually increased the exercise intensity. The maximal oxygen consumption of the WTT and WTQ groups significantly increased more than the SOC group. There was, however, no difference between the two exercise groups.						
Ebid et al (2012)[36]	RCT	• n = 31 adults (Ex = 15; SOC = 16) • Mean age (yrs): Ex = 35.86; SOC = 36.06 • %TBSAB range: 36–45 • Baseline: ~50 d post-burn	• Strength (Biodex isokinetic dynamometer) • Evaluated at baseline and 8 weeks later • Matched healthy controls compared with baseline measures	• 8-week treatment period • SOC: home program (ROM, splinting, stretching of LE, daily walking, functional ambulation, resistance exercises, ADL training) • Ex: whole body vibration 3×/52	• Knee and ankle strength was significantly greater in healthy subjects compared with burn survivors • Knee and ankle strength significantly increased in both treatment groups across time • Mean % change in strength was significantly greater for Ex group compared with SOC	2
In 2012, Ebid et al[36] conducted a RCT studying two groups of burn survivors who received either whole body vibration (WBV) plus SOC or SOC only. Whole body vibration involved the subject standing in a 90° squat position on a vibrating platform. The authors measured strength outcome and compared it to healthy, matched controls at baseline. Both groups demonstrated an increase in strength after 8 weeks of treatment, although the WBV group's strength gains were significantly greater than the SOC group. The burn survivors' strength was significantly reduced relative to the healthy controls at baseline but nearly returned to the healthy, matched, controls after the 8 weeks.						
Ebid et al (2014)[14]	RCT	• n = 33 (Ex = 16; SOC = 17; healthy = 20) • Mean age (yrs): Ex = 13.46; SOC = 13.6; healthy = 14.2 • Mean %TBSAB: Ex = 48.86; SOC = 42.4 • LE burns	• Strength (Biodex System-3 dynamometer) • Quadriceps size (tape measure) • Gait parameters (GAITRite system) • Evaluated at baseline and 12 weeks later • Matched healthy controls compared with baseline measures	• 12-week treatment period • SOC: home program • Ex: SOC + 3×/52, treadmill warm-up, hotpacks, stretching, isokinetic exercises	• Quad strength: significantly less for burn survivors compared with healthy subjects at baseline; significantly increased for Ex and SOC group but significantly more for Ex • Quad size: significantly greater for healthy subjects compared with burn survivors at baseline; significant increase in Ex group • All gait parameters: significantly different for burn survivors compared with healthy subjects at baseline; significantly increased for Ex and SOC but significantly more for Ex group	2
The one pediatric study not conducted by the Galveston group was a RCT in 2014, by Ebid et al.[14] Children with lower extremity burns were randomized to either a 12 week isokinetic quad strengthening program in addition to SOC or just SOC. They evaluated the effect of an isokinetic quad strengthening program on the size and strength of the quadriceps and on gait parameters. All measures significantly improved for both groups during the 12-week treatment period except quad size for the SOC group. The improvements were significantly greater for the exercise group compared with the SOC group for all measures. They also compared baseline measures of quad size and strength and gait parameters to age-matched healthy children. All baseline measures differed significantly from those of healthy children. It should be noted that the resistance training program prescribed used the same equipment that was used for testing therefore some of the strength benefits may be attributed to increased familiarity with the testing equipment.						

(*Continued*)

Table 2. (*Continued*)

Authors	Design	Sample	Outcome Measures	Intervention	Results	Level of Evidence
Ebid et al (2012)[19]	RCT	• n = 40 (Ex = 20; SOC = 20; healthy = 23) • Mean age (yrs): Ex = 24.6; SOC = 27.3; healthy = 24.6 • Mean %TBSAB: 45.5 (range 35–55%) • Baseline: 6 mos post-burn	• Strength (Biodex System-3 dynamometer) • Ambulation speed • Baseline comparison to healthy subjects • Evaluated at baseline and 12 weeks later (6 and 9 mos post-burn)	• 12-week treatment period • SOC: OT & PT • Ex: 3×/wk, treadmill warm up, quadriceps and hamstrings stretching, concentric strengthening	• Peak knee extensor and flexor torque significantly increased for Ex group from baseline to post-training • Ex group's peak torque and total work significantly improved more than SOC • Peak torque and total work of healthy subjects was significantly greater than both burn survivors groups post-training • Ex group ambulation speed significantly increased from baseline and compared with SOC • Ambulation speed was significantly greater for healthy subjects compared with both burn survivor groups at baseline	2
Ebid et al[19] published a RCT in 2012 comparing burn survivors randomly assigned to either a 12-week isokinetic training program or a SOC group. They compared strength and ambulation speed. The exercise group demonstrated a significant improvement for all outcome measures from baseline to post-training and significantly greater improvement than the SOC group for all outcomes. A comparison of burn survivors to healthy participants revealed that healthy participants' peak torque and total work was significantly greater than both groups of burn survivors post-training (9 months post-burn) and ambulation speed was significantly faster at baseline (6 months post-burn).						
Grisbrook et al (2012)[20]	Case–control study	• n = 18 (burn survivors = 9; healthy = 9) • Mean age (yrs): Burn survivors = 39; healthy = 38.67 • Mean %TBSAB: 42 • Baseline: 6.56 yrs post-burn (range 2–14) • Evaluation at baseline and 12 weeks	• Pulmonary function (Spirometry) • Peak oxygen consumption ($VO_{2\ peak}$) • Canadian occupational performance measure	• 12-week treatment period • Ex: supervised, individual goal-directed, interval training and resistance Ex sessions, 3×/52; • treadmill, strengthening (Biodex System-3 Dynamometer), machine and free weights, then occupational performance-based tasks with resistance	• Predicted and raw $FEV_{1.0}$/FVC ratio values were significantly lower for burn survivors compared with healthy subjects both at baseline and post-treatment • No significant improvement in pulmonary function in either group after exercise training • $VO_{2\ peak}$, max minute ventilation and work performed on treadmill all significantly improved post-treatment for both groups • Clinically significant change in COPM post-treatment for both groups	4

(*Continued*)

Table 2. (*Continued*)

Authors	Design	Sample	Outcome Measures	Intervention	Results	Level of Evidence
In 2012, Grisbrook et al[20] conducted a case–control study examining the effects of a 12-week exercise training program on pulmonary function and aerobic capacity of burn survivors compared with healthy controls. Nine burn survivors and nine healthy control participants were recruited into a supervised, individualized, occupational performance, and goal-directed training program. All burn survivors were at least 2 years post-burn with at least a 20% surface area burn. There was a statistically significant difference in the force expiratory volume/forced vital capacity ratios of burn survivors compared with healthy controls, both at baseline and post-exercise program. After the exercise program, aerobic capacity as measured by VO_{2peak}, maximal minute ventilation and work performance on the treadmill significantly improved relative to baseline for both groups, but there was no improvement in pulmonary function for either group with time. There was also a clinically significant increase in occupational performance for both groups, thus their ability to participate in activities that were important to them and their satisfaction with their performance significantly improved.						
Grisbrook et al (2013)[37]	Case–control study	• Same as Grisbrook et al (2012)	• Strength (Biodex System-3 dynamometer) • LBM (DEXA)	• Same as Grisbrook et al (2012)	• Peak torque, work, and power: reported on a subgroup of burn survivors and all nine healthy subjects: significant improvement across all muscle groups with treatment • Significant increase in LBM with exercise for both groups	4
Further analysis of the case–control study published in 2012[20] was published in 2013[37] and reported on the effect of the exercise training program on muscle strength and LBM. For the analysis, the authors combined the data of the burn survivors and nonburned healthy controls to determine the within group effect, which demonstrated an increase for all of the strength outcomes. There was no between group effect for any of the strength outcomes. They also reported that there was an increase in LBM postexercise for the group when they combined the burn survivors and healthy participants.						
Hardee et al (2014)[38]	RCT	• n = 47 (Ex = 24; SOC = 23) • Mean age (yrs): Ex = 13; SOC = 13 • Mean %TBSAB: Ex = 60; SOC = 59	• Height, weight • Strength (Biodex System-3 dynamometer) • LBM (DEXA) • Peak oxygen consumption (VO_{2peak}) • Mixed muscle fractional synthetic rate (stable isotope infusion study)	• 12-week treatment period beginning immediately post-discharge • SOC group: OT/PT home program • Ex: Figure 2	• Significant difference between groups for peak torque when corrected for body weight, VO_{2peak}, % change in LBM discharge to post treatment and whole-body, leg, arm, and % change in LBM discharge to 12 months post-burn for whole-body and leg • Significant change with treatment: both Ex and SOC group's muscle fractional synthetic rate reduced between discharge and post-treatment but there was no difference between groups	2
In 2014, Hardee et al[38] conducted a RCT studying the effect of a 12-week exercise program initiated immediately after discharge from the acute care center compared with SOC, as opposed to 6 months post-burn, which was the case with all of their previous reports from this group. There was no difference between the exercise group and the SOC group at baseline for age, height, weight, TBSA burned, length of stay, or female to male ratio. After completion of the exercise program comparison between groups revealed that the exercise group had significantly greater relative peak torque, VO_{2peak}, percent change in whole-body, leg and arm LBM between discharge and post-treatment, and percent change in whole-body and leg LBM between discharge and 12 months post-burn. Both groups demonstrated a reduction in muscle fractional synthetic rate between discharge and post-treatment, which is consistent with a decrease in hypermetabolism, but there was no difference between groups, demonstrating that exercise training did not negatively affect hypermetabolism in burn survivors.						

(*Continued*)

Table 2. (*Continued*)

Authors	Design	Sample	Outcome Measures	Intervention	Results	Level of Evidence
Paratz et al (2012)[39]	Nonrandomized controlled follow-up study	• n = 30 (Ex =16; SOC = 14) • Mean age (yrs): Ex = 30.4; SOC = 42.64 • Mean %TBSAB: Ex = 47; SOC 29.9 • Ex group: significantly younger, larger surface area burn, longer hospital and ICU stay, increase % hand burns and # of septic episodes	• MSWT • Peak oxygen consumption (VO_{2peak}) • Strength, grip • Function and quality of life (*Quick*DASH, LEFS, BSHS-A)	• 12-week treatment period • SOC: self-management program of exercises and referral to local therapist • Ex: supervised aerobic and resistance training	• Significant change with treatment: quad, latissimus dorsi, R & L grip strength, LEFS, *Quick*DASH • Significant difference between groups: at baseline R & L grip strength; at 6 weeks quad, latissimus dorsi, VO_{2peak}, *Quick*DASH; at 3 mos quads, latissimus dorsi, VO_{2peak}, MSWT, *Quick*DASH • No adverse effects reported	3

A nonrandomized, follow-up study conducted in Australia was also reported in 2012.[39] Burn survivors recruited into this study were assigned to the exercise plus SOC group if they lived in close proximity to the burn center to attend therapy sessions on a regular basis for a 6-week period of time or were assigned to SOC if they lived far enough from the burn center that they could only attend intermittent follow up appointments. Study outcomes included the modified shuttle walk test, VO_{2peak}, muscle and grip strength, *Quick*DASH, lower extremity functional scale and burn-specific health scale (BSHS)—abbreviated version. At baseline, the exercise group was significantly younger, had larger surface area burns, stayed longer in the intensive care unit and hospital, less grip strength, and was twice as likely to have hand burns and septic episodes during the acute stay. For the BSHS, the motor and skills subdomain was significantly higher for the exercise group at baseline. All outcome measures significantly improved over time for the exercise group and all except VO_{2peak}, resting heart rate, shuttle distance, lower extremity functional scale and *Quick*DASH for the SOC group. In addition, there was no significant improvement in any of the domains or the total score for the SOC group with time, in fact the psychological domain significantly worsened with time for this group. Hand function improved for both groups with time. The group allocation procedure employed in this study makes it very difficult to conclude that the aerobic and resistive exercise training components were responsible for the difference in outcomes since there are so many differences between their baseline characteristics and the after discharge care that these patients received. However, despite the fact that the exercise group had larger burns that required longer inpatient care and were more likely to involve their hands, their improvement across time for impairment, functional and quality of life outcomes were more substantial than the SOC group that was not treated at the burn center. Thus, the overall rehabilitation program that was received by the group treated at the burn center had substantial benefits relative to the "self-management" SOC program.

Authors	Design	Sample	Outcome Measures	Intervention	Results	Level of Evidence
Parrott et al (1988)[40]	Historically controlled study	• n= 40 (Ex = 20; historical controls = 20) • Age range: 18–65 yrs • %TBSAB: range 15–50	• LOS • Number of OT/PT visits • Time returning to work • Subjective questionnaire	• Control: 1–2 hrs/d OT/PT (unstructured individualized program) • Ex: 2 hrs/d of IP OT/PT (structured circuit of pulley work, bicycle work, UE ergometer, LE mat work, chin-ups, stair step work, writing on and cleaning a mirror, macramé or belt work, UE wand exercise, a pipe project)	• Similar LOS • Ex compared with control: decreased number of OP visits and earlier return to work • Positive participant feedback on questionnaire • No statistical analysis	4

Parrott et al[40] reported on a structured inpatient exercise program that was implemented for 20 adult burn survivors. This group's outcomes were then compared with a historical control group. They showed that although the length of stay for the two groups were comparable, the group who participated in the structured exercise program required less outpatient OT/PT visits and returned to work sooner, although no statistical analyses were reported.

(*Continued*)

Table 2. (*Continued*)

Authors	Design	Sample	Outcome Measures	Intervention	Results	Level of Evidence
Porro et al (2012)[41]	RCT	• n = 222 (4 groups: Ox + Ex = 14; Ox + SOC = 56; P + Ex = 21; P + SOC = 131) • Mean age (yrs): Ox + Ex and Ox + SOC = 8; P + Ex and P + SOC = 8 (range 0–18) • Mean %TBSAB: Ox + Ex and Ox + SOC = 57; P + Ex and P + SOC = 54	• REE (Sensor-Medics V_{max} 29 metabolic cart) • Height, weight • Whole body fat, LBM, bone mineral content, bone mineral density (DEXA) • Cardiac function • Sexual maturation • Concentration of serum inflammatory cytokines, hormones, and liver enzymes • Strength (Biodex System-3 dynamometer) • Evaluated at admission, discharge, 6, 9, 12, 18, 24, 36, 48, 60, and 72 months post-burn	• Same as Prkzora et al (2007)	NOTE: only results related to exercise reported here • Bone mineral content significantly differed between Ox + Ex compared with P + Ex group • LBM significantly increased in Ox + Ex compared with P + Ex group at 24 to 72 mos follow-up • Strength significantly greater in Ox + Ex group compared with all other groups at 9, 12, 18, and 24 mos	2
In 2012, Porro et al[42] published a long-term follow up paper to Przkora et al's[12] 2007 article. Although this manuscript did not directly respond to our PICO question, since their focus was on the safety and efficacy of oxandrolone, it was retained since they reported on the long-term effects of oxandrolone and exercise on bone mineral content, lean body mass, and strength. Their long-term follow up results demonstrated that the muscle strength of the group that received oxandrolone and participated in the exercise program (Figure 2) was significantly greater than the other three groups at 9, 12, 18, and 24 month post-burn. For children aged 7–18 years old there was a significant difference in bone mineral content and LBM compared with the exercise control group at 2 years post-burn and at the end of the study or at 5 years post-burn.						
Porro et al (2013)[42]	RCT	• n = 58 (propranolol + Ex = 27; Ex = 31) • Mean age (yrs): Propranolol + Ex = 13.7; Ex = 13.1 (range 7–18) • Mean %TBSAB: Propranolol + Ex = 60; Ex = 60 • Baseline: 6 mos post-burn	• Strength (Biodex System-3 dynamometer) • LBM (DEXA) • Peak oxygen consumption (VO_{2peak})	• Propranolol: dosage titrated to decrease resting heart rate by 15–20% from admission value • Ex: (Figure 2)	• Strength, LBM, VO_{2peak} all significantly increased with treatment for both groups • Significant change in VO_{2peak} for propranolol + Ex compared with Ex • Strength, LBM, VO_{2peak} percent change was significantly higher than SOC historic controls • No adverse effects reported	2

(*Continued*)

Table 2. (*Continued*)

Authors	Design	Sample	Outcome Measures	Intervention	Results	Level of Evidence
In 2013, Porro et al[41] published a report examining the effects of propranolol and exercise. The two groups received propranolol and exercise or exercise alone with the exercise program described in Figure 2. There was a significant increase in muscle strength, lean body mass, and VO_{2peak} after the 12-week exercise program for both groups with the VO_{2peak} being significantly higher in the group receiving propranolol compared with exercise alone. The authors also compared both groups to historic controls who received SOC but did not participate in the exercise program and did not receive propranolol and found the exercise groups had significantly greater percent change in strength, lean body mass and VO_{2peak}.						
Pkzora et al (2007)[12]	RCT	• n = 51 (4 groups: Ox + Ex = 14; Ox + SOC = 9; P + Ex = 17; P + SOC = 11), • Mean age (yrs): Ox + Ex = 12.1; Ox + SOC = 11.8; P + Ex = 10.9; P + SOC = 11.8 (range 7–18) • Mean %TBSAB: Ox + Ex = 52.1; Ox + SOC = 54.7; P + Ex = 55.6; P + SOC = 51.6 • Baseline: 6 mos post-burn	• Strength (Biodex System-3 dynamometer • Peak oxygen consumption (VO_{2peak}) • LBM (DEXA) • Hormone panel	• Ox or P administered discharge to 9 mos post-burn • SOC: same as Suman et al (2003) • Ex (Figure 2)	NOTE: only results related to exercise reported here. • No baseline differences in height, weight, LBM, strength, or VO_{2peak} • Weight significantly increased in Ox + Ex group compared with all other groups and for Ox + SOC compared with P + SOC • LBM showed a significant mean % change in Ex compared with SOC groups and Ox + SOC and P + Ex compared with P + SOC • Ex groups showed significantly greater increases in mean % strength change than P + SOC • VO_{2peak} mean % change significantly increase in Ex groups compared with SOC	2
Using the same design and study groups as Suman et al,[43] Przkora et al[12] examined the effects of oxandrolone (instead of rhGH) and exercise on muscle strength and cardiopulmonary fitness were. There was a significant increase in body weight associated with oxandrolone and exercise compared with the other three groups and with oxandrolone alone compared with placebo. Lean body mass showed a significant mean percent increase associated with oxandrolone and exercise compared with the other three groups and with oxandrolone alone compared with placebo with exercise and placebo with SOC. Muscle strength significantly increased in all groups compared with the placebo and SOC. Aerobic capacity (VO_{2peak}) significantly increased in both exercise groups compared with the SOC groups suggesting that oxandrolone alone has no demonstrable impact on this variable.						
Suman et al (2002)[16]	RCT	• n = 51 (Ex = 17; SOC = 14, healthy = 20) • Mean age (yrs): healthy = 12.6; Ex = 10.6; SOC = 10.7 (range 7–18) • Mean %TBSAB: Ex = 59.8; SOC = 57.2 • Baseline: 6 mos post-burn	• Pulmonary function ($FEV_{1.0}$, FVC, max voluntary ventilation) • Peak oxygen consumption (VO_{2peak}) • Treadmill time (modified Bruce protocol)	• 12-week treatment period • SOC: as Suman et al (2001) • Ex: Figure 2	• All baseline measures of pulmonary function were significantly decreased in burn compared with healthy children • Significant increases in pulmonary function and VO_{2peak} in Ex group after 12/52 • Significant between groups difference for mean % change in max voluntary ventilation, treadmill time, and VO_{2peak}	2

(*Continued*)

Table 2. (*Continued*)

Authors	Design	Sample	Outcome Measures	Intervention	Results	Level of Evidence
In 2002, Suman et al[16] published a study examining the effect of exercise training (Figure 2) compared with SOC on pulmonary function. The pediatric burn survivors were randomly assigned to the exercise group or the SOC group and a group of nonburn children were included as a comparison group. At baseline, the exercise and SOC group did not differ with respect to age, percent burn surface area, height, weight, and body surface area but the non-burn groups were significantly heavier. Baseline pulmonary function was normal for the nonburn group and there was no difference in pulmonary function between the exercise and SOC group. However, all pulmonary function tests were significantly lower in the exercise and SOC groups compared with the nonburn children. After 12 weeks of exercise there was a significant increase in FEV_1, FVC and MVV with a significant between group difference (exercise vs SOC) for MVV, treadmill time, and VO_{2peak}.						
Suman et al (2001)[32]	RCT	• n = 35 (Ex = 19; SOC =16) • Mean age (yrs): Ex = 10.5; SOC = 11 • Mean %TBSAB: Ex = 59.4; SOC = 58.0 • Baseline: 6 mos post-burn	• Height, weight • Strength (Cybex dynamometer) • LBM (DEXA) • Peak oxygen consumption (VO_{2peak}) • REE (metabolic cart) • Evaluated at baseline and 12 weeks later (6 and 9 mos post-burn)	• 12-week treatment period • SOC: OP OT & PT 2x/d x 1 hr • Ex: (Figure 2)	• Significant change with treatment: Ex group – mean increased change peak torque, total work, average power, LBM, VO_{2peak}, peak treadmill time; SOC group – REE significantly increased from baseline • Significant between group differences: mean change peak torque, total work, average work, LBM, change in treadmill time, VO_{2peak}	2
Suman et al[32] studied the effect of a 12-week exercise program (Figure 2) compared with SOC on pediatric burn survivors strength, total work average power, LBM, peak treadmill time, and peak oxygen consumption (VO_{2peak}). Subjects were randomly assigned either to the exercise group or the SOC group. They found a significant improvement in all of these parameters, in the exercise group and a significant improvement in time when comparing between the exercise and the SOC group.						
Suman et al (2003)[43]	RCT	• n = 44 (GH + Ex = 10; P + Ex = 13; GH + SOC = 10; P + SOC = 11) • Mean age (yrs): GH + Ex = 11.0; P + Ex = 10.5; GH + SOC = 11.5; P + SOC = 10.8 (range: 7–17) • Mean %TBSAB: GH + Ex = 60.3; P + Ex = 58.5; GH + SOC = 55.9; P + SOC = 53.4 • Baseline: 6 mos post-burn	• Height, weight • Strength (Biodex System-3 dynamometer) • LBM (DEXA) • Fat-free mass (whole body potassium) • Peak oxygen consumption (VO_{2peak}) • Hormone panel • Evaluated at baseline and 12 weeks later (6 and 9 mos post-burn)	• rhGH or P administered post-discharge • SOC: same as Suman et al (2001) • Ex: Figure 2	NOTE: only results related to exercise reported here • No differences height & weight between 6 and 9 mos post-burn • LBM increased significantly after 12/52 in all groups except P + SOC • No significant difference in fat-free mass at baseline or after 12/52 • Strength (peak torque) increased significantly for GH + Ex, P + Ex, GH + SOC, and P + SOC • VO_{2peak} increased significantly for GH + Ex and P + Ex but not for GH + SOC or P + SOC • No side effects noted with administration of GH	2

(*Continued*)

Table 2. (*Continued*)

Authors	Design	Sample	Outcome Measures	Intervention	Results	Level of Evidence
In 2003, Suman et al[43] published a report examining the effect of exogenous growth hormone and exercise on LBM and muscle strength. Burned children were randomly assigned to four groups 1 day before being discharged from hospital: (1) those who received recombinant human growth hormone (rhGH) and participated in the exercise program (Figure 2) that was initiated 6 months post-discharge, (2) those who received rhGH and SOC, (3) those who received saline placebo and participated in the exercise program that was initiated 6 months post-discharge, and (4) those who received saline placebo and SOC. During the 12-week period, there was a significant increase in LBM for all groups, with the exception of the group that received the placebo and SOC, but there was no between group differences. Strength and VO_{2peak} significantly increased in the two exercise groups but was not significantly impacted by growth hormone administration.						
Suman et al (2007)[44]	RCT	• n = 20 (Ex = 9; SOC = 11; healthy = 26) • Mean age (yrs): Ex = 11.8; SOC = 13.4; healthy = 13.5 (range 7–17) • Mean %TBSAB: Ex = 61; SOC = 56 • Baseline: 6 mos post-burn	• Height, weight • LBM (DEXA) • Strength (Biodex System-3 dynamometer) Evaluated at baseline and 12 weeks later and 3 mos after exercise cessation (6, 9, and 12 mos post-burn)	• 12-week treatment period (6 to 9 mos post-burn) then 3 month follow-up (12 mos post-burn) • SOC: same as Suman et al (2003) • Ex: Figure 2	• Significant weight gain in the Ex group only between 6 and 9 mos • LBM mean % change: significantly increased between 6 and 9 months in the Ex group but not the SOC group; continued to significantly increase at the 12 months follow up in the Ex group compared with the SOC group • Strength mean % change: significantly increased in the Ex group compared with SOC; continued to increase at the 12 months follow-up in the Ex group compared with SOC but this was not statistically significant nor were there any group differences	2
In 2007, Suman et al[44] examined the long-term effect after stopping the 12-week exercise program. The study design was similar to their 2001 study[32] with the addition of a follow-up evaluation 3 months after exercise cessation (12 months post-burn). The authors reported that LBM and strength increased during the 12 week exercise program for the exercise group compared with the SOC and continued to improve after the program stopped but this later improvement was not significant.						

ADL, activities of daily living; *AROM*, active range of motion; *BMI*, body mass index; *BSHS-A*, burn-specific health scale – abbreviated; *BSHS-B*, burn-specific health scale – brief; *C*, control; *COPM*, Canadian Occupational Performance Measure; *d*, day; *DEXA*, dual-energy X-ray absorptiometry; *Ex*, exercise; *ext*, extension; $FEV_{1.0}$, forced expiratory volume; *flex*, flexion; *FVC*, forced vital capacity; *GH*, growth hormone; *hr*, hour; *IGF-1*, insulin-like growth factor-1; *IGFBP-3*, insulin-like growth factor binding protein-3; *IP*, inpatient; *LBM*, lean body mass; *LE*, lower extremity; *LEFS*, lower extremity functional scale; *LOS*, length of stay; *mos*, months; *max*, maximum; *MWT*, minute walk test; *MSWT*, modified shuttle walk test; *n*, sample size number; *OP*, outpatient; *OT*, occupational therapy; *Ox*, oxandrolone; *P*, placebo; *PT*, physiotherapy; *RCT*, randomized controlled trials; *REE*, resting energy expenditure; *reps*, repetitions; *ROM*, range of motion; *SF-36*, Medical Outcomes Study 36-Item Short Form; *SOC*, standard of care; *TBSAB*, total body surface area burned; *UE*, upper extremity, VO_{2peak}, peak O_2 consumption; *vs*, versus; ×, times; *W&E*, Wellness and Exercise; *WBV*, whole body vibration; *WTQ*, work-to-quota; *WTT*, work-to-tolerance; *yrs*, years; ×/52, number of weeks; #, number; *3RM*, three repetition maximum; °/s, degrees per second.
In all cases significant changes refers to a reported *P* value of <0.05.

are more commonly accessible to clinicians will be thoroughly reviewed to facilitate rehabilitation professionals' ability to document baseline values and outcomes postintervention.

For studies that measured aerobic capacity the vast majority used a modified Bruce Protocol.[45] As outlined in Figure 2, this is a standard procedure for ambulatory stress testing that begins at 2.7 kilometer/hr (1.7 mph) at 0% grade. The workload was then increased every 3 min by increasing the speed and/or grade. The maximum[35] or peak oxygen consumption[12,16,20,32,38,39,41,43] was then calculated. Since the Bruce protocol requires expensive equipment, a validated equation has been generated for children to predict maximal aerobic capacity using treadmill time[46] offering a clinically accessible option. Predictive equations for estimating VO_{2max} have been developed for adults and can be used with the original or modified tests.[47] Bruce et al[45] developed the first predictive equations, which are population specific for active and sedentary adults with and without cardiac conditions, but to the best of our knowledge these have not specifically been tested with adult burn survivors. For the adult burn survivor population, the modified shuttle walk test has been recommended to evaluate cardiovascular fitness[48] and has been validated as a clinically accessible, safe evaluation for monitoring aerobic capacity during the early postacute discharge rehabilitation phase.[49]

For studies that measured strength the vast majority used an isokinetic, computerized dynamometer. The testing was most commonly performed on the dominant leg extensors at an angular velocity of 30°/sec,[30] 60°/sec,[20,33] 90°/sec,[30,32] 120°/sec,[39] or 150°/sec.[12,14,19,31,35,36,38,41,43,44] The only study that used two different angular velocities and reported specific outcome showed improvements with time for both measures, but the between group differences were significant for both eccentric and concentric measures at 30°/sec but only the eccentric measures at 90°/sec.[30] However, the impact of performing the prescribed exercise program on the same equipment used for testing is unknown. To the best of our knowledge, there are no studies examining the clinimetric advantages or disadvantages of using a particular angular velocity or concentric vs eccentric contractions when evaluating burn survivors. However, isokinetic computerized dynamometers are not always clinically feasible but some studies used more commonly accessible equipment, such as 3RM using free weights[34,39] or grip strength dynamometer[39] to evaluate strength outcomes.

Other related clinical outcomes that benefited from exercise programs included the Burn Specific Health Scale (BSHS)-abbreviated,[39] the Canadian Occupational Performance Measure,[20] gait parameters,[14,19] lower extremity functional scale,[39] quad size,[14] the *Quick*DASH,[39] resting heart rate,[34] 6-minute walk test,[34] and weight,[12,31,34] all of which are clinically accessible. The BSHS-brief, the SF-36,[28] the Child Health Questionnaire,[29] and the need for surgical release[26] were also used in studies that were excluded from full review.

Progressive Resistive Training	**Aerobic Conditioning Program**
Baseline evaluation	**Baseline evaluation**
Instruct in correct weight lifting technique Warm up with lever arm and bar or wooden dowel Attempt to lift a weight 4 times If successful, with correct technique, 1 min rest Lift progressively increased amount Continue until unable to perform 4th repetition Final weight/load=3RM	Standardized treadmill exercise test (modified Bruce Protocol) Oxygen consumption and heart rate measured Begin to walk on treadmill 1.7 mph 0% grade 3-minute intervals - increase speed and incline VO_{2peak}=respiratory exchange ratio≥1.10 and peak volitional effort achieved
Resistance Exercises	**Aerobic Exercises**
Eight exercises: bench press, leg squats, shoulder press, leg press, biceps curl, leg curl, triceps curl, toe raises 1st week: 50-60% 3RM 4-10 reps x 3 sets 2nd-6th week: 70-75% 3RM 4-10 reps x 3 sets 7th-12th week: 80-85% 3RM 8-12 reps x 3 sets 1 minute rest between sets	5 minutes warm up (<50% treadmill or cycle ergometer VO_{2peak}) 30 minutes (70-85% treadmill or cycle ergometer VO_{2peak}) 5 minutes cool down (<50% treadmill or cycle ergometer VO_{2peak})
30 minutes/3 non-consecutive days/week x 12 weeks	30 minutes/5 days/week x 12 weeks

mph = miles per hour; RM = repetition maximum; VO_{2peak} = peak oxygen consumption

Figure 2. Progressive resistive training and aerobic conditioning program evaluation and training program details in Galveston studies.

Exercise Program Prescription

When reported, the exercise training programs were either 6,[30] 8,[36] or 12 weeks[12,14,16,19,20,31,32,34,35,37–39,41–44] in length and all but one were initiated after discharge from the acute care center.[40] Since the later report was published in 1988 and considering the accelerated rate at which patients are discharged from hospital since then the feasibility and applicability of prescribing a similar conditioning and strengthening program during the acute care stay at the present moment would be questionable. Thus, at this point, the evidence supporting the prescription of exercise programs to increase muscle strength or cardiovascular fitness is applied after the burn survivor has been discharged from the acute care center.

The specifics of the training programs for the studies performed in Galveston[12,16,31,32,34,38,41–44] were similar across the studies and have been described in Figure 2. Some exercise resistance training programs used the isokinetic dynamometer as the basis of the training program.[14,19,20,30,37,38] Whole body vibration was also used for lower extremity strengthening.[36] Several studies also incorporated functional activities into their strengthening or cardiovascular fitness programs.[20,37,40]

All studies that included an aerobic conditioning program included treadmill or cycle ergometer training[12,16,20,31,32,34,35,37–44] although one study did not provide any details.[33] One study examined an aerobic conditioning or cardiovascular retraining program that had participants work to quota or to tolerance on a treadmill. Although they reported an improvement across time for both groups compared with the SOC group there was no difference between those assigned to work to quota vs work to tolerance.[35]

Standard of Care Regimens

For those studies that compared with a SOC treatment regime there was enormous variation in the details reported. Some provided no details at all, others provided a list of different types of interventions but no details with respect to treatment parameters (intensity, frequency, or duration) and others provided hours/day. None of the studies appear to monitor the SOC that was delivered using monitoring tools, such as treatment diaries. Future studies would benefit from more thorough documentation and monitoring of the SOC received by both groups.

DISCUSSION

The objective of this review was to systematically appraise the available evidence with regards to the use of exercise programs to increase the cardiovascular fitness or muscle strength of pediatric or adult burn survivors so that rehabilitation-specific clinical practice guidelines could be generated. Twenty studies were included in this review of which 11 were RCTs that included pediatric burn survivors and three were RCTs that included adult burn survivors. There has been one systematic review[50] that combined the pediatric and adult evidence. This review was excluded from the analysis to allow for a systematic critique of the original articles. All of the evidence incorporated in this review reported improved cardiovascular fitness and/or muscle strength with no identified adverse effects. However, it should be noted that a thorough review of the literature evaluating heat intolerance was not incorporated into this review so caution should be exercised when performing exercise programs in hot and/or humid environments. In addition, the literature evaluating the potential overall benefit of propranolol, growth hormone, and oxandrolone was not thoroughly reviewed as prescription of these medications is not the responsibility of rehabilitation therapists. Although improvements in aerobic capacity with propranolol administration[41] and significantly greater increases in strength with growth hormone[43] or oxandrolone administration combined with exercise[12] have been noted in the literature; no conclusions were made with respect to their overall benefit in this review. Overall, there is strong evidence to support the prescription of resistance and aerobic exercise training programs for burn survivors. Nonetheless there are some methodological issues that should be considered and gaps in the literature that need to be addressed in future studies.

With respect to the pediatric literature 10 of the 11, RCTs were performed at the Shriners Hospital for Children in Galveston. The strength of this literature is the fact that a wide variety of outcomes were evaluated using a consistent exercise regimen (Table 2). The results of all of these investigations have been positive demonstrating that exercise programs enhance cardiovascular fitness and muscle strength when they are initiated immediately postdischarge or if initiated 6 months postdischarge and that there continues to be measurable exercise benefits for at least 3 months after the exercise program has been discontinued.[42,44] The limitation associated with the majority of literature coming from one center is that there is a potential lack of generalizability to other populations. In addition, many of the studies of Galveston are part of a larger project with "rolling" enrollment (personal communication O.E. Suman September 2014); therefore, the participants included in the publications may or may not include distinct populations of participants.

It must also be kept in mind that all of the pediatric exercise programs reported in the literature were 12 week in-hospital programs that in addition included SOC treatment provided by other burn team members including OTs, PTs, and psychologists, which were then compared with outpatient or home-based programs. Community therapists who provided the outpatient treatment may not have specific expertise in treating burn survivors, their dedicated time for face-to-face treatment may have been limited, there may have been limited access to a variety of health professionals and the adherence rates of these community or home-based programs were not reported, all of which may bring into question whether the SOC component was equivalent between groups. Thus, the benefits attributed to the exercise programs may partially reflect the added value of an in-hospital, highly specialized inter-professional burn care team. All of the burn survivors recruited also had very large surface area burns (greater than 40% TBSA in all except one report which was greater than 30%) that are significantly larger burns than the average burn injury.[50] Studies from a variety of burn rehabilitation settings that investigate whether the same benefits are seen with smaller burn injuries are also needed.

In addition, all of the evidence in the literature has employed an in-hospital exercise program and the majority of these regimens have been 30 minutes per day, 3 days per week for 12 weeks. It would be valuable to determine if the total dosage of exercise could be concentrated in shorter time period (ie, 5 days per week for 45 minutes for 2 weeks) or whether spreading it across time (ie, 3 days per week for 15 minutes for 10 weeks) is equally as beneficial. It would also be valuable to determine if the benefits of a community-based program would have comparable benefits to the in-hospital programs. Finally, evaluation of the long-term benefits of these programs and the extent to which the participants chose to, or are required to, continue these exercise regimes to maintain the benefits gained would provide additional guidance.

AREAS FOR FUTURE INVESTIGATION

There are a number of research questions that would be important to address in future investigations.

It would be extremely valuable to determine whether community-based exercise facilities would be able to provide exercise training programs for burn survivors that have the same reported benefits as the in-hospital programs described in the literature or whether the expertise and environment associated with a burn center is a critical component of the success of these exercise programs.

There have been a number of studies initiated at different time points after burn that confirm that there are benefits to exercise programs initiated immediately postdischarge from acute care as well as 6 months or later post-discharge. It would be beneficial to further investigate whether there is an ideal time point to initiate these programs and whether the exercise program cessation results in a loss of the gained benefits at an equal rate to healthy control subject. Several studies of adult subjects[36,37] demonstrated that the burn survivors were able to increase their strength to levels comparable with the gains demonstrated by healthy controls performing the same exercise program, but long-term follow-up was not performed therefore it is unknown whether they were able to maintain the strength gains after exercise cessation to the same extent as healthy controls. It would also be beneficial to further investigate the effect of isokinetic training at various speeds in both adults and children.

Most of the studies recruited participants with moderate to large surface area burns (40% TBSA or greater). It would be important to determine the extent of the problem with smaller burn injuries as well as the benefits of these exercise programs with this population.

Further investigations of the impact of cardiovascular endurance and strengthening programs on other outcomes, such as return to work, quality of life, community reintegration, and the need for reconstructive surgery would be particularly beneficial in the adult population.

ACKNOWLEDGMENTS

The editorial assistance of Suzana Anjos, Research Support Office, Research Centre, CHUM is gratefully acknowledged. Additional librarian support from Diane Monheit, Shriners Hospitals for Children, Northern California is gratefully acknowledged.

REFERENCES

1. Howick J, Chalmers I, Glasziou P, et al; Oxford Centre for Evidence-Based Medicine Working Group. The Oxford 2011 Levels of Evidence. 2011. http://www.cebm.net/index.aspx?o=5653. Accessed September 12, 2013.
2. Bloemsma GC, Dokter J, Boxma H, Oen IM. Mortality and causes of death in a burn centre. Burns 2008;34:1103–7.
3. Muller MJ, Pegg SP, Rule MR. Determinants of death following burn injury. Br J Surg 2001;88:583–7.
4. Saffle JR, Davis B, Williams P. Recent outcomes in the treatment of burn injury in the United States: a report from the

American Burn Association Patient Registry. J Burn Care Rehabil 1995;16(3 Pt 1):219–32; discussion 288–9.
5. Pruitt BA Wolf SE Mason AD. Epidemiological, demographic, and outcome characterisitcs of burn injury. Chapter 3. In: Herndon DN, editors. Total burn care. 3rd ed. Philadelphia, PA: Saunders Elsevier; 2007.
6. Esselman PC, Thombs BD, Magyar-Russell G, Fauerbach JA. Burn rehabilitation: state of the science. Am J Phys Med Rehabil 2006;85:383–413.
7. Richard R, Baryza MJ, Carr JA, et al. Burn rehabilitation and research: proceedings of a consensus summit. J Burn Care Res 2009;30:543–73.
8. Hasselgren PO. Burns and metabolism. J Am Coll Surg 1999;188:98–103.
9. Pereira C, Murphy K, Jeschke M, Herndon DN. Post burn muscle wasting and the effects of treatments. Int J Biochem Cell Biol 2005;37:1948–61.
10. Hart DW, Wolf SE, Mlcak R, et al. Persistence of muscle catabolism after severe burn. Surgery 2000;128:312–9.
11. Jeschke MG, Chinkes DL, Finnerty CC, et al. Pathophysiologic response to severe burn injury. Ann Surg 2008;248:387–401.
12. Przkora R, Herndon DN, Suman OE. The effects of oxandrolone and exercise on muscle mass and function in children with severe burns. Pediatrics 2007;119:e109–16.
13. Alloju SM, Herndon DN, McEntire SJ, Suman OE. Assessment of muscle function in severely burned children. Burns 2008;34:452–9.
14. Ebid AA, El-Shamy SM, Draz AH. Effect of isokinetic training on muscle strength, size and gait after healed pediatric burn: a randomized controlled study. Burns 2014;40:97–105.
15. Desai MH, Mlcak RP, Robinson E, et al. Does inhalation injury limit exercise endurance in children convalescing from thermal injury? J Burn Care Rehabil 1993;14:16–20.
16. Suman OE, Mlcak RP, Herndon DN. Effect of exercise training on pulmonary function in children with thermal injury. J Burn Care Rehabil 2002;23:288–93; discussion 287.
17. Willis CE, Grisbrook TL, Elliott CM, Wood FM, Wallman KE, Reid SL. Pulmonary function, exercise capacity and physical activity participation in adults following burn. Burns 2011;37:1326–33.
18. Ganio MS, Pearson J, Schlader ZJ, et al. Aerobic fitness is disproportionately low in adult burn survivors years after injury. J Burn Care Res 2014 [Epub ahead of print].
19. Ebid AA, Omar MT, Abd El Baky AM. Effect of 12-week isokinetic training on muscle strength in adult with healed thermal burn. Burns 2012;38:61–8.
20. Grisbrook TL, Wallman KE, Elliott CM, Wood FM, Edgar DW, Reid SL. The effect of exercise training on pulmonary function and aerobic capacity in adults with burn. Burns 2012;38:607–13.
21. St-Pierre DM, Choinière M, Forget R, Garrel DR. Muscle strength in individuals with healed burns. Arch Phys Med Rehabil 1998;79:155–61.
22. Black S, Carter GM, Nitz AJ, Worthington JA. Oxygen consumption for lower extremity exercises in normal subjects and burned patients. Phys Ther 1980;60:1255–8.
23. Bowker R, Lakhanpaul M, Atkinson M, Armon K, MacFaul R, Stephenson T. How to write a guideline from start to finish: a handbook for healthcare professionals. Toronto, Canada: Elsevier; 2008.
24. Moher D, Liberati A, Tetzlaff J, Altman DG; PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med 2009;6:e1000097.
25. Law M, Stewart D, Pollock N, Letts L, Bosch J, Westmorland M. McMaster University 1998. Available at: http://www.srs-mcmaster.ca/ResearchResourcesnbsp/ResearchGroups/CentreforEvidenceBasedRehabilitation/EvidenceBasedPracticeResearchGroup/tabid/630/Default.asp. Accessed November 14, 2013.
26. Celis MM, Suman OE, Huang TT, Yen P, Herndon DN. Effect of a supervised exercise and physiotherapy program on surgical interventions in children with thermal injury. J Burn Care Rehabil 2003;24:57–61; discussion 56.
27. Demling RH, DeSanti L. Oxandrolone induced lean mass gain during recovery from severe burns is maintained after discontinuation of the anabolic steroid. Burns 2003;29:793–7.
28. Grisbrook TL, Reid SL, Edgar DW, Wallman KE, Wood FM, Elliott CM. Exercise training to improve health related quality of life in long term survivors of major burn injury: a matched controlled study. Burns 2012;38:1165–73.
29. Rosenberg M, Celis MM, Meyer W 3rd, et al. Effects of a hospital based wellness and exercise program on quality of life of children with severe burns. Burns 2013;39:599–609.
30. Ahmed ET, Abdel-aziem AA, Ebid AA. Effect of isokinetic training on quadriceps peak torgue in healthy subjects and patients with burn injury. J Rehabil Med 2011;43:930–4.
31. Al-Mousawi AM, Williams FN, Mlcak RP, Jeschke MG, Herndon DN, Suman OE. Effects of exercise training on resting energy expenditure and lean mass during pediatric burn rehabilitation. J Burn Care Res 2010;31:400–8.
32. Suman OE, Spies RJ, Celis MM, Mlcak RP, Herndon DN. Effects of a 12-wk resistance exercise program on skeletal muscle strength in children with burn injuries. J Appl Physiol (1985) 2001;91:1168–75.
33. Cronan T, Hammond J, Ward CG. The value of isokinetic exercise and testing in burn rehabilitation and determination of back-to-work status. J Burn Care Rehabil 1990;11:224–7.
34. Cucuzzo NA, Ferrando A, Herndon DN. The effects of exercise programming vs traditional outpatient therapy in the rehabilitation of severely burned children. J Burn Care Rehabil 2001;22:214–20.
35. de Lateur BJ, Magyar-Russell G, Bresnick MG, et al. Augmented exercise in the treatment of deconditioning from major burn injury. Arch Phys Med Rehabil 2007;88(12 Suppl 2):S18–23.
36. Ebid AA, Ahmed MT, Mahmoud Eid M, Mohamed MS. Effect of whole body vibration on leg muscle strength after healed burns: a randomized controlled trial. Burns 2012;38:1019–26.
37. Grisbrook TL, Elliott CM, Edgar DW, Wallman KE, Wood FM, Reid SL. Burn-injured adults with long term functional impairments demonstrate the same response to resistance training as uninjured controls. Burns 2013;39:680–6.
38. Hardee JP, Porter C, Sidossis LS, et al. Early rehabilitative exercise training in the recovery from pediatric burn. Med Sci Sports Exerc 2014;46:1710–6.
39. Paratz JD, Stockton K, Plaza A, Muller M, Boots RJ. Intensive exercise after thermal injury improves physical, functional, and psychological outcomes. J Trauma Acute Care Surg 2012;73:186–94.
40. Parrott M, Ryan R, Parks DH, Wainwright DJ. Structured exercise circuit program for burn patients. J Burn Care Rehabil 1988;9:666–8.
41. Porro LJ, Herndon DN, Rodriguez NA, et al. Five-year outcomes after oxandrolone administration in severely burned children: a randomized clinical trial of safety and efficacy. J Am Coll Surg 2012;214:489–502; discussion 502–4.
42. Porro LJ, Al-Mousawi AM, Williams F, Herndon DN, Mlcak RP, Suman OE. Effects of propranolol and exercise training in children with severe burns. J Pediatr 2013;162:799–803.e1.
43. Suman OE, Thomas SJ, Wilkins JP, Mlcak RP, Herndon DN. Effect of exogenous growth hormone and exercise on lean mass and muscle function in children with burns. J Appl Physiol (1985) 2003;94:2273–81.
44. Suman OE, Herndon DN. Effects of cessation of a structured and supervised exercise conditioning program on lean mass and muscle strength in severely burned children. Arch Phys Med Rehabil 2007;88(12 Suppl 2):S24–9.

45. Bruce RA, Kusumi F, Hosmer D. Maximal oxygen intake and nomographic assessment of functional aerobic impairment in cardiovascular disease. Am Heart J 1973;85:546–62.
46. Porro L, Rivero HG, Gonzalez D, Tan A, Herndon DN, Suman OE. Prediction of maximal aerobic capacity in severely burned children. Burns 2011;37:682–6.
47. Noonan V, Dean E. Submaximal exercise testing: clinical application and interpretation. Phys Ther 2000;80:782–807.
48. Falder S, Browne A, Edgar D, et al. Core outcomes for adult burn survivors: a clinical overview. Burns 2009;35:618–41.
49. Stockton KA, Davis MJ, Brown MG, Boots R, Paratz JD. Physiological responses to maximal exercise testing and the modified incremental shuttle walk test in adults after thermal injury: a pilot study. J Burn Care Res 2012;33:252–8.
50. Disseldorp LM, Nieuwenhuis MK, Van Baar ME, Mouton LJ. Physical fitness in people after burn injury: a systematic review. Arch Phys Med Rehabil 2011;92:1501–10.

APPENDIX. Search Strategy

Medline (OvidSP)	
1.	Burns/
2.	Burns, Electric/
3.	Burns, Chemical/
4.	Burn Units/
5.	or/1–4
6.	exercise*.tw.
7.	exercising.tw.
8.	fitness.tw.
9.	physical activit*.tw.
10.	physical conditioning.tw.
11.	physical rehabilitation.tw.
12.	resistance training.tw.
13.	resistive.tw.
14.	(weight adj2 lift*).tw.
15.	weight train*.tw.
16.	weight bearing.tw.
17.	strength training.tw.
18.	circuit training.tw.
19.	treadmill*.tw.
20.	bicycl*.tw.
21.	running*.tw.
22.	jogging.tw.
23.	walking.tw.
24.	swimming.tw.
25.	pilates.tw.
26.	yoga.tw.
27.	tai chi.tw.
28.	tai ji.tw.
29.	dance*.tw.
30.	dancing.tw.
31.	aerobic*.tw.
32.	sports.tw.
33.	endurance*.tw.
34.	strengthening.tw.
35.	muscle function*.tw.
36.	muscle strength*.tw.
37.	Muscle Strength/
38.	exp Physical Endurance/
39.	Physical fitness/
40.	Exercise Test/
41.	exp Exercise/
42.	exp Exercise Therapy/
43.	exp Exercise Movement Techniques/
44.	exp Sports/
45.	or/6–44
46.	5 and 45
47.	Animals/
48.	Humans/
49.	47 not (47 and 48)
50.	46 not 49
51.	limit 50 to (english or french)
52.	limit to Medline