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SYSTEMATIC REVIEW

Aerobic Adaptations from Resistance Training in Adults with a Chronic Condition

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Abstract

Background: Exercise is a non-pharmacological intervention for many chronic medical conditions. The evidence base demonstrates positive aerobic outcomes from resistance training; however, it remains unclear if aerobic benefits occur as an outcome of engaging in resistance training, for older adults with chronic medical conditions. *Purpose:* The aim of this study was to review whether RT could improve aerobic outcomes among older adults with CC. *Methods:* Literature review using Medline, Cinahl and Cochrane databases, last searched in March 2017. Study quality, cohort characteristics, interventions, and aerobic outcome data were extracted. *Results:* Eleven trials met inclusion criteria. Resistance training was shown to have significant aerobic outcomes in five of the eleven articles, with the other articles showing inconclusive or non-significant findings. *Conclusion:* Results suggest that resistance training should be prescribed to improve overall fitness in older adults with CC. Further research is required to confirm the extent to which RT can improve cardiovascular outcomes in older adults with CC. **Health & Fitness Journal of Canada 2017;10(2):3-20.**

Keywords: Exercise, Aged, Chronic Disease, Review, Physical Activity, Older Adults

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Introduction

Currently, there are nearly five million adults over the age of 65 in Canada (Statistics Canada, 2014). By the year 2040 older adults will comprise approximately 25% of the Canadian population (Statistics Canada, 2014). Given that, 89% of North American older adults have one or more chronic condition(s), the aging population has serious implications for our health care system (Ramage-Morin et al., 2010). For clinicians, it is imperative to provide therapies that are safe for a spectrum of chronic conditions, are feasible to deliver clinically, and offer relief for individuals' symptoms while reducing the risk of developing other chronic conditions.

Many chronic conditions are hypothesized to be in part due to physical inactivity (Fine et al., 2004; Handschin and Spiegelman, 2008; Owen et al., 2009). Current statistics suggest that only 13% of Canadian older adults between the ages of 60-79 yr engage in the recommended 150 minutes of weekly aerobic physical activity, making older adults the group of individuals engaged in the least amount of physical activity (Colley et al., 2013). Direct and indirect health care costs related to physical inactivity were $6.8 billion in 2001 (Katzmarzyk and Janssen, 2004) and it is assumed that 16 yr later the economic burden of inactivity is even greater. Therefore, it is apparent that increasing physical activity levels in older adults is necessary to alleviate the economic and health consequences (i.e., chronic disease) associated with physical inactivity.

Exercise (a form of physical activity) has been shown to reduce the development of, and premature death due to, chronic conditions (Arem et al., 2015). For example, among common age-related chronic diseases, exercise reduces primary complications related to cardiovascular disease by up to 35% (Macera and Powell, 2001), diabetes by 6% (Helmrich et al., 1991), cancer by up to 30% (Lee, 2003), and attenuates bone loss in individuals with osteoporosis (Howe et al., 2011). Two exercise interventions that show the greatest health benefits are resistance training and aerobic training, which is not surprising given that evidence-based exercise guidelines indicate the need to engage in both for health benefits (Nelson et al., 2007; Tremblay et al., 2011). However, many older adults lack self-efficacy for resistance training and therefore minimally engage in resistance training (Boehm et al., 2013) preferring to participate in walking programs (Nelson et al., 2007; Papaioannou et al., 2010; Tremblay et al., 2011).

Resistance training interventions have demonstrated improved overall physical activity participation and may have similar health benefits as aerobic training (Drenowatz et al., 2015). Resistance training is defined as a form of exercise that causes a muscle to contract against an external resistance, with the expectation of increasing muscle strength, endurance or hypertrophy (Nelson et al., 2007). Recently, it was demonstrated that following a resistance training program, individuals were more likely to complete greater moderate-to-vigorous-intensity physical activity (outside the program) on the days the program was completed (Drenowatz et al., 2015). Interestingly, moderate-to-vigorous physical activity was observed to decrease among those completing an aerobic intervention exclusively (Drenowatz et al., 2015). Furthermore, a literature review in healthy older adults concluded that resistance training was as effective at improving cardiovascular risk factors as aerobic training (Strasser and Schobersberger, 2011). Similarly, resistance training in adults with cardiovascular disease has been shown to improve cardiovascular outcomes (Gayda et al., 2012). Thus, it is necessary to explore whether resistance training is sufficient to improve aerobic fitness in older adults with a chronic condition, across a broad spectrum of conditions.

Resistance training has been prescribed as an exercise intervention in certain chronic conditions for the benefit of increasing strength (Giangregorio et al., 2014; Roberts and Barnard, 2005), maintaining muscle mass, (Roberts and Barnard, 2005), and improving balance (Giangregorio et al., 2014). The impact of resistance training on older adults' aerobic fitness is unclear. Therefore, the purpose of this literature review was to determine if resistance training is a feasible method to improve cardiovascular health in older adults (≥65 yr) with a chronic condition. It was hypothesized that resistance training will improve cardiovascular health in older adults with a chronic condition.

Methods

MEDLINE (Pubmed), CINAHL, and the Cochrane library databases were used for this review. The search was constructed around four major concepts: resistance training (weight lifting, weight bearing, strength, resistance training, and resistance exercise), cardiovascular health outcomes (cardio, cardiovascular, aerobic, heart rate, pulse, oxygen consumption (VO_2), cardiovascular deconditioning, exercise test, physical fitness, oxygen consumption, exercise tolerance), older adults (old people, older people, older adult, and aged) and randomized controlled trials (randomized controlled trial, random*, and RCT) (see Appendix 1 for the full search strategy). The construct "older adults" was used to capture the population of individuals ≥65 yr of age. An individual search for "chronic conditions" was not employed to minimize the risk of selection bias. The Pubmed and Cochrane library searches were advanced using Medical Subject Headings (MeSH terms). CINAHL headings were identified similarly to MeSH terms, in the CINAHL database. A review of the articles allowed for further refinement and iterations of key terms. The final search strategy yielded 1,224 articles in PubMed, 509 articles from CINAHL, and 575 articles from the Cochrane library. The final search was conducted on March 12, 2017.

Inclusion and Exclusion Criteria:

Study Design and Subjects. Randomized controlled trials published in peer-reviewed journals were included until March 2017. Abstracts, reviews and protocol papers were excluded. Those with older adult subjects with a mean or median age of ≥65 yr with a chronic condition were included. Chronic condition was defined as a human condition that is persistent or has long-lasting effects or a disease that comes with time. The disease had to be present for at least 3 months. (National Center for Health Statistics (US) & National Center for Health Services Research, 2012)

Intervention Characteristics. Studies that employed resistance training in isolation but through any modality were included. Resistance training was defined as any training that involves concentric, eccentric or isometric contractions of the muscles and that are designed to increase the body's strength, power and muscular endurance (Caspersen, Powell, & Christenson, 1985). Interventions could include upper body, lower body or whole body. Articles were excluded if other modes of training were used in combination with resistance training interventions (i.e., aerobic and resistance training). The comparator group can be any group that did not participate in resistance training in isolation. This could include performing usual activities, no activities, stretching, etc. The resistance training program was required to be longer than a single bout of exercise.

Outcome measures. For inclusion, studies must have reported outcome measures for at least one construct of endurance or aerobic capacity. Aerobic outcome was defined as the ability of the heart and lungs to supply oxygen rich blood to the working tissue over a prolonged period of time (> 3 minutes), or a measurement of the highest amount of oxygen consumed during maximal exercise in activities that use large muscles in the arms or legs (American College of Sports Medicine, 2013). Studies were excluded if strength-related outcomes were the only outcome measures.

Data extraction and analysis:

One author conducted the search (CZ). All articles were compiled into a reference management site (Refworks, ProQuest LLC, 2016), and duplicate articles were removed. The papers identified in the search strategy were screened, first by title and then by abstract using the eligibility criteria. If the methods were unclear, the full article was screened. All articles were reviewed by two authors (CZ and BI). A pilot-tested abstraction form was used for each full-text paper including information regarding the strength-training program, cardiovascular test and participants. The abstraction form also included the Cochrane Collaboration's tool for assessing risk of bias, which was used to determine the quality of each study. This assessment tool evaluates the methodological quality of key domains of randomized controlled trials such as blinding, random sequence generation, and selective outcome reporting (Higgins et al., 2011). After the abstraction forms were completed, they were compared and any discrepancies that could not be resolved through discussion by the two reviewers (CZ and BI) were resolved by a third, unbiased reviewer.

Results

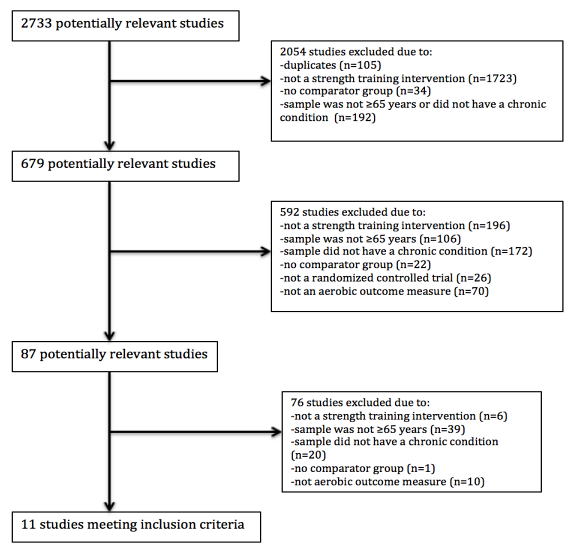
Studies retrieved

A total of 2,733 articles were identified through the search strategy (see Figure 1). Studies included are presented in Table 1.

Study Quality Assessment

A summary of the studies' quality assessments is presented in Table 2. In general, there was a high risk of bias across the studies, mostly related to lack of blinding of participants and investigators, and insufficient information on randomization sequence generation. Studies were rated as high risk of bias for not: i) using a random sequence generator; ii) employing allocation concealment; and iii) blinding of the assessors. The majority of studies were not registered with the National Institute of Health clinical trials database, nor were protocols available to confirm whether selective reporting had occurred. Although some studies did blind the outcome assessors, pragmatically there is a challenge to blinding participants in an exercise intervention. Seven studies did not perform an intention-to-treat analysis (Ades et al., 2003; Brochu et al., 2002; Hiatt et al., 1994; Seynnes et al., 2004; Simpson et al., 1992; Wortley et al., 2013; Zambom-Ferraresi et al., 2015).

Figure 1: Figure 1: Flow chart of study inclusion



Cohort Characteristics

A summary of the cohort characteristics is presented in Table 2.

*Sample size***.** Overall sample size ranged from 22-438 (Ades et al., 2003; Brochu et al., 2002; Cormie et al., 2013; Hiatt et al., 1994; Mudge et al., 2009; O'Shea et al., 2007; Penninx et al., 2002; Seynnes et al., 2004; Simpson et al., 1992; Wortley et al., 2013; Zambom-Ferraresi et al., 2015).

Age. The exercise groups averaged 71.6 yr and control groups 71.7 yr, with 66.9 yr being the youngest population (O'Shea et al., 2007), and 83.3 yr the oldest population (Seynnes et al., 2004).

Sex. Sex was reported in nine (Ades et al., 2003; Brochu et al., 2002; Cormie et al., 2013; Hiatt et al., 1994; Mudge et al., 2009; O'Shea et al., 2007; Simpson et al., 1992; Wortley et al., 2013; Zambom-Ferraresi et al., 2015) of the eleven studies. Across these studies there were a total of 169 males and 170 females.

Chronic Conditions. Participants were enrolled in the studies with chronic obstructive pulmonary disease (O'Shea et al., 2007; Simpson et al., 1992; Zambom-Ferraresi et al., 2015), peripheral artery disease (Hiatt et al., 1994), coronary heart disease (Ades et al., 2003; Brochu et al., 2002), frailty (Seynnes et al., 2004), bone metastatic disease secondary to prostate cancer (Cormie et al., 2013), knee osteoarthritis (Penninx et al., 2002; Wortley et al., 2013) and stroke (Mudge et al., 2009) (Table 2).

Exercise interventions. A summary of the exercise interventions is in Table 3, including exercise volume and intensity, program frequency, exercise duration and program length. Exercise volume and intensity were generally monitored through sets and repetitions of exercises. All studies reported program length, ranging from 4 to 24 weeks. A description of the equipment used was reported in 10 (Ades et al., 2003; Brochu et al., 2002; Hiatt et al., 1994; Mudge et al., 2009; O'Shea et al., 2007; Penninx et al., 2002; Seynnes et al., 2004; Simpson et al., 1992; Wortley et al., 2013; Zambom-Ferraresi et al., 2015) of the studies, which included: ankle/cuff weights, resistance bands, universal/free weights, dumbbells, resistance machines and body weight. All studies included a control group.

Exercise modality. Eight studies (Ades et al., 2003; Brochu et al., 2002; Cormie et al., 2013; Penninx et al., 2002; Seynnes et al., 2004; Simpson et al., 1992; Zambom-Ferraresi et al., 2015) employed a progressive resistance training program for the intervention groups. Two studies (Hiatt et al., 1994; Mudge et al., 2009) employed circuit-based programs, while one study (Wortley et al., 2013) had an open-kinetic chain resistance training program (Table 3). Open-kinetic chain exercises are performed wherein the foot is free to move. For example, in Wortley et al., (2013) participants performed seated leg extension, standing hamstring curl, straight leg raise, standing hip abduction and adduction, standing hip flexion and calf raises.

Dropout and Adherence. Dropouts were reported in all of the studies (Table 3). Adherence rates ranged from 57-99%, and drop out rates ranged from 16-33% across all groups (Table 3).

Outcome Measures

A summary of the cardiovascular outcomes measured is presented in Table 4.

Cardiovascular Tests & Frequency of Measurement. The 6MWT was the most commonly used cardiovascular test, used in eight of the eleven articles. Of the studies using the 6MWT as the cardiovascular test, most (five) used only the 6MWT as the functional test whereas three of the eight studies used additional cardiovascular tests including peak oxygen consumption (VO_2peak) (Ades et al., 2003; Brochu et al., 2002) and the 400-m walk test (Cormie et al., 2013). Additional outcome assessments used in individual studies included a graded and constant-load treadmill test, (Hiatt et al., 1994) and a progressive braked cycle ergometer test (Simpson et al., 1992; Zambom-Ferraresi et al., 2015) (Table 4).

Table 1: Results of Assessing Risk of Bias.

Citation	Study Design	Random Sequence Generation	Allocation Concealment	Blinding of Participants and Personnel	Blinding of Outcome Assessment	Incomplete Outcome Data	Selective Reporting	Other Sources of Bias
O'Shea et al., 2007	RCT	Low	Low	High	Low	Low	Unclear	Unclear
Hiatt et al., 1994	RCT	High	High	High	Unclear	Low	Unclear	Unclear
Simpson et al., 1992	RCT	Low	High	High	High	Low	Unclear	Unclear
Ades et al., 2003	RCT	Low	Unclear	Low	Unclear	High	High	Unclear
Seynnes et al., 2004	RCT	Low	Low	Low	Unclear	Low	Unclear	Unclear
Cormie et al., 2013	RCT	Low	Low	High	Low	Low	Low	Unclear
Brochu et al., 2002	RCT	Low	Unclear	Low	Unclear	Low	Unclear	Unclear
Penninx et al., 2002	RCT	Low	High	High	High	Low	Unclear	Unclear
Wortley et al., 2013	RCT	High	Low	Unclear	Low	Low	Unclear	Unclear
Zambom-Ferraresi et al., 2015	RCT	High	High	High	Low	Low	Unclear	Unclear
Mudge et al., 2009	RCT	High	Low	High	Low	Low	Low	Unclear

RCT, randomized controlled trial.

Table 2: Study characteristics.

Citation	Age Resistance Group (yr)	Age Control Group (yr)	Males (n)	Females (n)	n	Main Inclusion Criteria	Main Exclusion Criteria	Chronic Condition	Duration of Condition	Number of co-morbidities
O'Shea et al., 2007	66.9	68.4	22	35	57	People with chronic obstructive pulmonary disease	Respiratory condition other than chronic obstructive pulmonary disease	COPD	Not Reported	2.3
Hiatt et al., 1994	67	67	29	0	29	People with intermittent claudication	Leg pain at rest, ischemic ulceration or gangrene	Peripheral Artery Disease	Stable over 3-month period, but disabling	Not clear
Simpson et al., 1992	73	70	19	15	36	A ratio of forced expiratory volume in one second to vital capacity of less than 0.7	Not Reported	COPD	Not Reported	Not Reported
Ades et al., 2003	73.2	72.2	0	42	42	Physical function score below 85 from the MOS-SF36 health questionnaire	Hospitalization for an acute coronary syndrome within 6 months	Coronary Heart disease	Chronic > 6 months	Not Reported
Seynnes et al., 2004	83.3	80.3	Not Reported	Not Reported	22	At least 70 years of age, and ambulatory	Cognitive impairment	Frailty	Not Reported	2.3
Cormie et al., 2013	73.1	71.2	27	0	27	Histological diagnosis of prostate cancer, established bone metastatic disease	Experienced moderate-severe bone pain that limited activities of daily living	Bone metastatic disease secondary to prostate cancer	3.9 years since cancer diagnosis	1.7
Brochu et al., 2002	70.5	70.7	0	30	30	Physical function score below 85 from the MOS-SF36 health questionnaire	Hospitalization for an acute coronary syndrome within 6 months	Coronary Heart disease	> 6 months	Not Reported

Citation	Age Resistance Group (yr)	Age Control Group (yr)	Males (n)	Females (n)	n	Main Inclusion Criteria	Main Exclusion Criteria	Chronic Condition	Duration of Condition	Number of co-morbidities
Penninx, 2002	69	69	NR	NR	438	60 years of age with knee pain	Presence of a medical condition that precluded safe exercise participation	Knee osteoarthritis	Pain most days of the month	Not clear
Wortley, 2013	69.5	68 Tai Ji; 70.5 control	0	22	22	Between ages 60-85 and have knee osteoarthritis	Received arthroscopic surgery or an intra-articular injection within the past 3 months	Knee osteoarthritis	Not Reported	Not Reported
Zambom-Ferraresi, 2015	68	69	40	0	40	People with stable chronic obstructive pulmonary disease	Declined to participate	COPD	Stage II-III Chronic Lung Disease	Not Reported
Mudge, 2009	76	71	32	26	31 INT, 27 CTRL	One or more strokes more than 6 months earlier	Progressive neurologic disease	Stroke	6 months post stroke	Not Reported

n, participant number; INT, intervention group; CTRL, control group.

Table 3: Intervention Characteristics.

Citation	Control Group (n)	Control Group Training	Resistance Training (n)	Resistance Training	Frequency (days per week)	Intensity (sets, reps, % load, RPE)	Duration (min)	Program Length (week)	Drop Out	Adherence
O'Shea et al., 2007	27	No intervention	27	Progressive Resistance Training	3	3 sets 8-12 reps	Not Reported	12	13 total participants withdrew, 15/27 completed in exercise group	Not Reported
Hiatt et al., 1994	10	Maintain usual activities	9	Circuit based	3	3 sets 6 reps	60	12	2 control subjects at 12 weeks, 3 control subjects after 12 weeks	Not Reported
Simpson et al., 1992	14	Control-Nothing	14	Progressive Resistance training	3	3 sets 10 reps, 50-85% of 1-RM	Not Reported	8	3 dropped out, 3 control lost at follow up	90%
Ades et al., 2003	14	3x/ week for 30-40 mins at cardiac rehab for stretching, calisthenics, deep breathing and light yoga	19	Progressive Resistance Training	3	1-2 sets 10 reps, 50-80% 1-RM, 14 on 6-20 Borg RPE scale	Not Reported	6	9 drop out total, 5 intervention, 2 removed for not adhering	75%
Seynnes et al., 2004	8	Weight-free placebo-control training	14	Progressive Resistance Training	3	2 sets 8 reps HI group at 80% 1-RM, LI group at 40% 1-RM	Not Reported	10	5 participants dropped out total	99% in exercise; 89% in control
Cormie et al., 2013	10	Usual Care, offered exercise after intervention	10	Progressive Resistance Training	2	2-4 sets 8-12 reps	60	12	2 participants from exercise group, 3 participants lost to follow up	83%

Citation	Control Group (n)	Control Group Training	Resistance Training (n)	Resistance Training	Frequency (days per week)	Intensity (sets, reps, % load, RPE)	Duration (min)	Program Length (week)	Drop Out	Adherence
Brochu et al., 2002	12	3x/ week for 30-40 min at cardiac rehab for stretching, calisthenics, deep breathing and light yoga	13	Progressive Resistance Training	3	1-2 sets 10 reps, 50-80% 1-RM, 14 on 6-20 Borg RPE scale	40	24	5 participants in total: 2 participants removed from analysis for non compliance to training protocol, 3 for medical problems unrelated to training	75%
Penninx et al., 2002	148	Health education	145	Progressive Resistance Training	3	2 sets 10 reps	60	12	16 % drop out in low depression, 24% drop out in high depression	62% in low depression group; 57% in high depression group
Wortley et al., 2013	9	Tai Ji and control group	15	Osteo-kinetic chain	2	2-3 sets 8-12 reps	60	10	8 dropped out	87% attendance in RT, 82% in Tai Ji
Zambom-Ferraresi et al., 2015	8	Combined aerobic and resistance, control	14	Progressive Resistance Training	2	3-4 sets 6-12 reps	90	12	4 dropped out 1 control, 2 combined, 1 resistance	Not Reported
Mudge et al., 2009	27	Social and educational sessions	23	Circuit based	3	Not Reported	50-60	4	8 dropped out total, 4 exercise 4 control	Not Reported

Table 4: Cardiovascular assessment and outcome after strength training program.

Citation	Cardiovascular Test	Frequency of Cardiovascular testing	Cardiovascular Adaptation	Was CV improvement seen?
O'Shea et al., 2007	6 MWT	At 0 weeks, 12 weeks, 24 weeks	meters in 6MWT	No, not statistically significant, maybe clinically (4m improvement between groups)
Hiatt et al., 1994	Graded and constant-load treadmill test	At 0 weeks, 12 weeks, 24 weeks	Walking time, Peak VO2, HR, RER	Yes in walking time, No in peak VO2, No in HR, No in peak RER
Simpson et al., 1992	Progressive braked cycle ergometer	At 0 and 8 weeks	Maximal incremental exercise capacity, 6MWT	No significant change in maximal exercise capacity, 6MWT, but significant improvement in endurance to fatigue during cycling at 80% capacity in exercise group but not control
Ades et al., 2003	Peak VO2 and 6MWT	0, 6 months	Treadmill modified Balke protocol	Statistically significant improvement in 6MWT, and an increase in VO2 peak but not statistically significant
Seynnes et al., 2004	6MWT	0 and 10 weeks	meters 6MWT	Statistically significant improvement in 6MWT for HI training and Low training groups but not control
Cormie et al., 2013	400 m Walk, 6-m Walk	0 and 12 weeks	time in 400 m walk	Statistically significant improvement in 400m walk
Brochu et al., 2002	Peak VO2 and 6MWT	0 and 6 months	Treadmill modified Balke protocol	Statistical improvement in 6MWT, non-statistical improvement in VO2 peak
Penninx et al., 2002	6MWT	0, 3, 9, 18 months	meters 6MWT	Not clearly stated but seems as if there was no statistical improvement in walking speed for the resistance training group
Wortley et al., 2013	6MWT	0 and 10 weeks	meters 6MWT	Not statistically significant increase in meters post testing in 6MWT
Zambom-Ferraresi et al., 2015	Progressive braked cycle ergometer	0 and 12 weeks	maximal aerobic power	Not statistically significant increase in aerobic power in resistance group
Mudge et al., 2009	6MWT	3 week prior, 0 and 4 weeks	meters 6MWT	Not statistically significant increase in meters in 6MWT

6MWT, Six minute walk test; VO_2peak, peak oxygen consumption; HR, heart rate.

All studies measured the baseline aerobic capacity of participants as well as at follow-up at intervals ranging from 4 to 12 weeks at the end of intervention. Three studies measured aerobic outcomes midway through the study, (Hiatt et al., 1994; O'Shea et al., 2007; Penninx et al., 2002) and one study measured aerobic outcomes prior to the start of the intervention (Mudge et al., 2009).

Aerobic Adaptation. Of the studies that utilized the 6MWT, four (Ades et al., 2003; Brochu et al., 2002; Cormie et al., 2013; Seynnes et al., 2004) found a statistically significant improvement in meters walked, and four observed no difference after the intervention (Mudge et al., 2009; O'Shea et al., 2007; Penninx et al., 2002; Wortley et al., 2013). One study (Hiatt et al., 1994) found a statistically significant improvement in walking time, but no difference between groups in VO_2peak, heart rate or respiratory exchange ratio. One study (Simpson et al., 1992) demonstrated no significant improvement in maximal exercise capacity or 6MWT, but found a significant improvement in endurance to fatigue during cycling. However, another study (Cormie et al., 2013) did not find a statistically significant improvement in 6MWT, yet found a significant improvement in 400-m walking time. Finally, one study (Zambom-Ferraresi et al., 2015) found no statistically significant difference in maximal aerobic power in the resistance training only group.

Discussion

This literature review suggests that the available evidence regarding the effects of resistance training on aerobic outcomes in older adults with a chronic condition is scarce and largely of low quality. However, a few trials did report some benefit of resistance training to aerobic outcomes. Specifically, results indicated that progressive resistance training using free weights for strength might improve aerobic outcomes. Exercise adherence was generally good (57-99%), indicating resistance training is a feasible treatment option for individuals with a chronic condition. Studies that observed significant improvements in aerobic outcomes were in a variety of a chronic condition (i.e., COPD, peripheral artery disease, coronary heart disease, knee osteoarthritis, and frailty), suggesting that resistance training is a viable option for an assortment of cardiovascular, musculoskeletal, and multi-system chronic conditions.

It was hypothesized that resistance training would improve aerobic health in older adults with a chronic condition. However, only five (Ades et al., 2003; Brochu et al., 2002; Cormie et al., 2013; Hiatt et al., 1994; Seynnes et al., 2004) of the 11 studies observed a statistically significant improvement in aerobic health after a resistance training intervention, these studies were of higher quality with lower risk of bias than studies with no significant improvements. Furthermore, a few of the studies that did not observe statistically significant improvements to cardiovascular health may have found clinically meaningful differences although these were not specifically reported. Several studies reported improvements in the 6MWT, ranging from 4-16 m (Mudge et al., 2009; O'Shea et al., 2007; Wortley et al., 2013) in resistance training groups, and minimal or no improvements in the control groups. However, it has been proposed that in geriatric populations a clinically important difference is 50-m (Perera et al., 2006), indicating the improvements in the 6MWT in these studies may not be clinically relevant. Interestingly, one study observed an improvement in cycling endurance to fatigue in the resistance-training group, (Simpson et al., 1992) and not in the controls, suggesting aerobic adaptations to resistance training. Studies that are larger and longer in duration are suggested for future research.

Unfortunately, poor study design and reporting across many trials weaken the conclusions that can be derived and the generalizability of the work to date. The inconclusive findings in many of the studies may have been due to small sample sizes and low methodological rigour. As previously mentioned, ensuring participants are blinded is challenging in exercise interventions unless the control group is participating in an active program. The studies that did not observe statistically significant results had an inactive (non-exercise) control group. Thus, it is possible that individuals in these groups engaged in exercise programs independently, confounding the results of the intervention without an assessment of participants' baseline activity level. Future studies should include objective physical activity measurement (i.e., accelerometry) to evaluate activity levels in a non-exercise control group throughout the intervention.

The present review provides some evidence that resistance training may improve aerobic health for older adults with a spectrum of chronic conditions. Previous work has shown the importance of resistance training to maintain muscle mass, muscle strength and balance (American College of Sports Medicine, 2013). For some chronic conditions, resistance training is advised in preference to aerobic training to reduce the risk of falling, (Giangregorio et al., 2014) and has been shown to improve disease-related symptoms better than aerobic training (Giangregorio et al., 2013). This suggests that resistance training may be beneficial for falls risk reduction and management among older adults with chronic condition(s). Many older adults lack resistance training self-efficacy and therefore minimally engage in it (Boehm et al., 2013), emphasizing aerobic training in their exercise routine instead (e.g., walking). Therefore, clinicians prescribing exercise should consider resistance training as a high priority to older adults with a chronic condition.

It is important to maintain physical endurance to reduce the risk of frailty. Fried and Guralnik (1997) identified that physical endurance is linked to an increased risk of frailty in older adults. Physical endurance is important for maintaining reserve capacity of the cardiovascular system, which also deteriorates with increasing age (Fried and Guralnik, 1997). It has been suggested that exercise is likely the medicine to reverse frailty, or slow the accumulation of functional deficit. (Bray, et al., 2016) Increasing physical endurance through resistance training may target Fried's frailty criteria by increasing muscle mass, and improving independence (Singh et al., 2012). Improving physical endurance through aerobic training, such as walking, is not necessarily feasible in frail older adults. However, Bray et al. (2016) recommend frail adults engage in longer aerobic exercise sessions, and pre-frail individuals engage in resistance training exercise. Arguably, the benefits of resistance training exercise for pre-frail adults would also benefit frail older adults. Low weight, high repetition resistance training would increase muscle endurance, and muscle strength, which are necessary to maintain physical independence and reduce age-related muscle loss. More research needs to be done to determine the feasibility and efficacy of frail older adults engaging in resistance training exercises. Resistance training can gradually build muscular strength and endurance to progress individuals out of the pre-frail and frail categories and towards becoming healthy older adults (Nelson et al., 2007; Tremblay et al., 2011; Bray et al., 2016).

There are a few limitations to this study. Firstly, the criteria for inclusion of all chronic conditions may have been too broad. A narrower search may have provided more supportive evidence to specific chronic conditions that would benefit the most from resistance training program. Alternatively, a secondary analysis of the impact of resistance training on individual body systems (e.g., neuromuscular, musculoskeletal, cardiorespiratory) may help differentiate the role of resistance training on aerobic health among specific chronic condition. However the existing evidence base is limited for such specific analyses at this time.

Similarly, this review included all modes of resistance training (i.e., body weight and free weights), where it is possible that each mode may induce unique aerobic responses. However, since the literature is currently limited, the present study does provide insight into the benefits of resistance training in older adults with a chronic condition. As the evidence base continues to develop, future research may wish to conduct sub-analyses on the effect of resistance training on individual body systems as well as specific resistance training modalities for managing cardiovascular outcomes among individuals with a chronic condition.

Conclusion

To the authors' knowledge, this is the first literature review that has investigated the effects of a resistance training program to improve aerobic fitness and cardiovascular health in an assortment of chronic medical conditions. The results from this literature review suggest that it is feasible for older adults with a chronic medical condition to adhere to a resistance training program and that resistance training can improve components of cardiovascular functions. It is recommended that future studies are longer in duration, using several arms to determine if there is an "ideal" resistance training program to improve aerobic health in older adults with a chronic condition, and consider objective measures of physical activity among intervention and control groups. Such studies may include individual groups for upper extremity training, lower extremity training, whole body training, and control. More evidence is required to understand whether resistance training equipment is necessary, or whether body weight resistance training programs would be sufficient to elicit aerobic improvements. Overall, it is suggested that clinicians prescribe resistance training programs not only for the previously established risk reduction for falls, osteoporosis and cardiovascular disease, but also for improvement of aerobic outcomes, especially among older adults with a chronic condition.

There are no conflicts of interest.

Authors' Qualifications

The authors' qualifications are as follows: Christina Ziebart MSc, R. Kin, CEP; Brittany Intzandt MSc, CEP; Emily Knight PT, PhD, CEP.

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Appendix A: Search Strategy

	Medline	**CINHAL**	**Cochrane**
#1	(weight lifting[tiab] OR weight bearing[tiab] OR strength[tiab] OR resistance[tiab]) AND (training[tiab] OR exercise[tiab]) OR (RT[mesh] OR weight bearing[mesh]) (47892 articles)	("weight lifting" OR "weight bearing" OR "weightlifting" OR strength OR resistance) AND (training OR exercise*) OR (MH "Weight Lifting") OR (MH "Muscle Strengthening+") (24247 articles)	cardio or cardiovascular or aerobic or heart rate or pulse or VO2 or cardiovascular deconditioning or exercise test or physical fitness or oxygen consumption or exercise tolerance or heart rate or pulse
#2	cardio[tiab] OR cardiovascular[tiab] OR aerobic[tiab] OR heart rate[tiab] OR pulse[tiab] OR VO2[tiab] OR cardiovascular deconditioning[mesh] OR exercise test[mesh] OR physical fitness[mesh] OR oxygen consumption[mesh] OR exercise tolerance[mesh] OR heart rate[mesh] OR pulse[mesh] (774321 articles)	S2 cardio OR cardiovascular OR aerobic OR "heart rate" OR pulse OR VO2 OR (MH "Oxygen Consumption+") OR (MH "Heart Rate") OR (MH "Exercise Test") OR (MH "Exercise Tolerance+") OR (MH "Pulse") (108524 articles)	(weight lifting or weight bearing or strength or resistance) and (training or exercise) or (RT or weight bearing)
#3	(old people*[tiab] OR older people*[tiab] OR older adult*[tiab] OR aged[mesh]) (2436655 articles)	S3 "older people*" OR "old people" OR "older adult*" OR "senior*" OR (MH "Aged+") (370909 articles)	old people* or older people* or older adult* or aged
#4	randomized controlled trial[Publication Type] OR random*[tiab] OR RCT[tiab] (889653 articles)	random* OR RCT OR "randomized control trial" OR (MH "Randomized Controlled Trials") (156130 articles)	randomized controlled trial or random* or RCT
	#1 AND #2 AND #3 AND #4	S1 AND S2 AND S3 AND S4	