Title Page

Authors

1. Fiona Cramp PhD BSc Hons MCSP
2. Abigail James BSc Hons MCSP
3. Jessica Lambert BSc Hons MCSP

Title: The effects of resistance training on quality of life in cancer: a systematic literature review and meta-analysis

Author affiliations:

1. Fiona Cramp PhD BSc Hons MCSP, Principal Lecturer in Physiotherapy, Department of Allied Health Professions, Faculty of Health and Life Sciences, Glenside Campus, University of the West of England, Blackberry Hill, Bristol, BS16 1DD.
2. Abigail James BSc Hons MCSP, Physiotherapist, Barking, Dagenham and Redbridge NHS Trust, Romford, Essex, RM7 1GN
3. Jessica Lambert BSc Hons MCSP, Physiotherapist, Physiotherapy Department, Hereford Hospitals NHS Trust, The County Hospital, Union Walk, Hereford, HR1 2RE

Corresponding author: Fiona Cramp PhD BSc Hons MCSP, Principal Lecturer in Physiotherapy, Department of Allied Health Professions, Faculty of Health and Life Sciences, Glenside Campus, University of the West of England, Blackberry Hill, Bristol, BS16 1DD. Telephone: +44 (0)117 3288501 Fax: +44 (0)117 3288404 email: [Fiona.cramp@uwe.ac.uk](mailto:Fiona.cramp@uwe.ac.uk)

**Abstract**

**Purpose:** To carry out a systematic review and meta-analysis to evaluate the effect of resistance training upon quality of life (QoL) in cancer.

**Methods: Search strategy:** A wide range of electronic databases were searched from inception to October 2009 using relevant key words. Reference lists of all studies identified for inclusion and relevant reviews were also searched. Relevant journals were hand searched and experts in the field contacted.   **Selection criteria**: Randomized controlled trials that investigated the specific effect of resistance training on QoL in adult cancer survivors were included.   **Data collection & analysis:** Two review authors independently assessed methodological quality and extracted data based upon predefined criteria. A meta-analysis was performed for QoL using a random-effects model.

**Results:** Six studies were identified for inclusion. Two studies demonstrated a significantly beneficial effect of resistance training on QoL compared to usual care. Post-test means +/- SD were available for all comparisons providing data for 278 participants who received a resistance training intervention and 270 control participants. The results of the meta-analysis demonstrated that at the end of the intervention period resistance training was statistically more effective than the control intervention (SMD -0.17, 95% CIs -0.34 to -0.00).  Overall there was heterogeneity between studies in relation to tumor type, stage of cancer treatment, type of cancer treatment and duration of the intervention.

**Conclusions:** Existing evidence suggests that strength training programs for cancer survivors have marginal benefit. Further fully powered studies are required to determine the optimal type, intensity and timing of resistance training.

**Keywords:** Resistance training; quality of life; cancer; systematic review; meta-analysis.

**Introduction**

Psychological, behavioral and physiological disruptions generally occur as a consequence of cancer and its diagnosis. In addition cancer treatment can produce negative short term and some longer term physiological and psychological effects [32] leading to pain, fatigue and reduced QoL [40]. Advances in the treatment of cancer have lead to an increase in the number of cancer survivors [3] and an increased need to focus upon quality of life (QoL). There is evidence to support the positive role of physical exercise in the rehabilitation of cancer survivors [16]. Potential benefits include positive psychological adjustments [38, 26], improved physical functioning [22] and reduced fatigue [5] all potentially leading to improved QoL [30, 25].

Research has shown that following a cancer diagnosis individuals tend to reduce their levels of physical activity [23]. This leads to muscle wasting as well as a reduction in aerobic fitness [2]. It has been suggested that this reduction in activity is likely to contribute to the increased fatigue and reduced function and QoL that is frequently reported in cancer survivors [23] as well as contributing to osteoporosis [35] and increased rates of mortality [14, 15]. Previous research has demonstrated numerous benefits of aerobic exercise in cancer [8, 9, 34, 38] with the benefits of resistance training mainly limited to improvements in muscle strength and function in people with prostate cancer [11].

Resistance training works to increase muscle strength and anaerobic endurance with the execution of relatively few repetitive exercises performed against a relatively high resistance, utilizing weight or body resistance [1, 12, 27]. Resistance training can provide functional benefits and improvements in overall health and well-being including increased bone, muscle, tendon and ligament strength, improved joint function, reduced probability of injury and improved cardiac function [43]. Therefore, resistance training may have beneficial effects in terms of reducing muscle wasting or regaining lost muscle as well as improving muscle movement in cancer patients. In turn, this may lead to reduced fatigue levels, improved functional ability and an overall improvement in QoL [7].

Previous systematic reviews have examined aerobic physical activity interventions for cancer survivors suggesting that there are benefits in relation to quality of life [18] when activities are undertaken either during or following cancer treatment [16, 20, 25, 33]. It is important to understand the effects of different exercise regimes on QoL in cancer survivors at each stage of the disease process. Previous reviews have not investigated the specific effects of resistance training upon QoL in cancer.

Therefore the primary purpose of this review was to evaluate the effect of resistance training upon QoL both during and after cancer treatment. A secondary objective, subject to available data, was to explore the effect of resistance training in different types of cancer populations. Groupings were determined based on tumor type, type of cancer treatment received and stage of cancer treatment, that is, either during or after treatment.

**Methods**

**Types of studies**

We considered only randomized controlled trials (RCT) published in English for inclusion.

**Types of participants**

We included studies that evaluated the effect of resistance training on QoL in adults of any age, regardless of gender, tumor type, tumor stage and type of cancer treatment. Participants may have been actively receiving treatment, be in long-term follow-up, or receiving palliative care.

**Types of interventions**

Included studies needed to evaluate and report the effect of resistance training on QoL. The studies should compare resistance training with no exercise, a usual care group (i.e. no specific exercise program prescribed) or an alternative treatment or exercise regime for QoL associated with cancer. The intervention could take place in any setting and be delivered to a group or individual participant. All types of resistance training were considered for inclusion.

**Types of outcome measures**

The primary outcome of interest was patient-reported QoL measured using a reliable and valid assessment tool. Other outcomes of interest were fatigue, anxiety and depression, self-efficacy to exercise, body composition, muscle function and tumor specific outcomes. Additional information was collected in relation to maintenance of resistance training, study attrition and adverse effects associated with the resistance training.

**Search methods for identification of studies**

**Electronic searches**

See Figure I for search strategy. The Cochrane Controlled Trials Register (Central/CCTR); MEDLINE (1966 to October 2009); EMBASE (1980 to October 2009); CINAHL (1982 to October 2009); and AMED (1985 to October 2009) databases were searched in order to identify relevant studies for the review.

**Searching other resources**

Reference lists of all included articles were checked for additional studies and three experts in the field were contacted. In addition, Cancer, Clinical Oncology, and Acta Oncologica were hand searched from 2000-2009.

**Data collection and analysis**

All studies in which the abstract made reference to a resistance training trial in a population of cancer participants were retrieved in full. Where abstracts were not available and the study could not be excluded based upon the title alone the full text was retrieved. For a study to be included it must include QoL as an outcome measure and at least one treatment arm must be resistance exercise. Two independent review authors screened all the retrieved full text articles for inclusion criteria. Discrepancies were resolved through discussion with a third reviewer.

Data from included studies were extracted by two independent review authors. Disagreements were resolved through consensus with a third review author. The methodological quality of each study was assessed using the Critical Appraisal Skills Programme (CASP) methodological criteria adapted from Guyatt et al [13] and recommended by the Public Health Resource Unit [28].

In addition, for each trial data on the number of participants in each arm and the type of control group were extracted. Details of the demographic characteristics of participants including, age and gender were also collected. In relation to cancer detail of the type(s) of cancer as well as the type and stage of treatment were extracted from each study. For the resistance training group(s) information was collected regarding the resistance training undertaken, the duration of the intervention, intensity and total number of training sessions. Finally, the outcome measures employed, including means and standard deviations as well as the duration of follow-up was recorded for each study.

**Measures of treatment effect**

QoL outcomes were likely to be reported in different ways in the identified trials. It was therefore difficult to predict what data would be available to be combined. If the data were available, and it was appropriate to do so, it was proposed that the studies would be combined in a meta-analysis. We proposed to calculate the mean difference in QoL between resistance training and control groups including usual care and alternative treatment groups. Subgroup analysis would also be conducted if the data were available. Separate analysis would be implemented according to tumor type, for example breast cancer participants; treatment received, for example chemotherapy or radiotherapy; and the stage of treatment the participant was at when the resistance training program was administered, that is either during or after cancer treatment. If heterogeneity between studies was suspected, the possibility of utilizing a random effects model of meta-analysis would be considered.

**Results**

Through a comprehensive literature search including screening of titles and abstracts (where available) 30 full text references were retrieved for further evaluation. From these, 24 publications were excluded and six identified as appropriate for inclusion in the current review. See Table for a summary of included studies.

**Excluded studies**

The 24 publications retrieved and subsequently excluded did not meet the review inclusion criteria as they were either not a randomized controlled trial; did not report QoL as an outcome measure; or did not include resistance training as an intervention in isolation.

**Participants**

The total number of participants included in the analysis of the six included studies was 666 with 278 receiving a resistance training intervention, 270 control participants and a further 118 participants receiving an alternative intervention. The latter participants were not included for the purposes of data extraction and meta-analysis. Participants had the following diagnoses: breast [4, 24], prostate [36, 37] and head and neck [19, 21] cancer. Cancer treatments received by participants included various combinations of surgery, radiotherapy, chemotherapy and androgen deprivation therapy. The treatments delivered varied by study as well as within studies. Three of the studies investigated participants during cancer treatment [4, 36, 37]; one study investigated a mixed group of participants with some still receiving radiotherapy [19] and in two studies the participants were considered to have completed cancer treatment [21, 24] although some participants were still receiving hormonal therapy or aromatase inhibitors [24].

The mean age of participants ranged from 49 [4] to 68 [36] years. Two of the studies recruited females only [4, 24], two recruited males only [36, 37] and the remaining two studies recruited a mixed sample of males and females [19, 21].

**Interventions**

Duration of the intervention ranged from 12 weeks [19, 21, 36] to 26 weeks [24]. One intervention was delivered throughout chemotherapy and had a mean duration of 17±4 weeks [4]. Resistance training consisted of up to 10 exercises, with 1-2 sets of 8-15 repetitions per set. Resistance training was undertaken 2-3 times per week. Five of the six studies provided clear information regarding the intensity of the resistance training and any progression in intensity. Only one study provided insufficient detail regarding the intensity of the prescribed training [19].

All studies investigated supervised, institutional-based training programs although in one study the initial 13 weeks of supervised sessions was followed by a further 13-week unsupervised period [24].

**Study Outcomes**

**Quality of Life**

Five of the six studies measured QoL using a disease-specific version of the Functional Assessment of Cancer Therapy (FACT) self-report questionnaire [4, 19, 21, 36, 37]. The remaining study used the Cancer Rehabilitation Evaluation System Short Form (CARES-SF) to assess QoL [24]. Four of the six studies reported no significant benefit of resistance training on global QoL scores [4, 19, 21, 24]. However, Courneya et al [4] and McNeely et al [21] reported trends for improved QoL in the resistance training group compared to the control group. Further to this Ohira et al [24] reported significant benefits of resistance training compared to a control in the CARES-SF subscales for physical QoL (p=0.006) and psychosocial QoL (p=0.02). The remaining two studies reported significant improvements in QoL in the resistance training group compared to controls [36, 37] (p=0.001 and p=0.015 respectively).

A meta-analysis was used to combine the post-test results (see Figure II). Post-test means ± standard deviations were available for all comparisons providing data for 278 participants who received a resistance training intervention and 270 control participants. At the end of the intervention period resistance training was statistically more effective than control (SMD -0.17, 95% CIs -0.34 to -0.00) demonstrating a marginal effect.

**Additional Outcomes**

All studies additionally reported results for a wide range of physiological and psychological variables including lean body mass, body composition, depression, fatigue, anxiety and self esteem.

*Fatigue*

Four of the six studies assessed fatigue as an outcome [4, 21, 36, 37] with two of the four showing no significant benefit of resistance training over usual care [4, 21] and two demonstrating a significant improvement in fatigue in the resistance training group compared to usual care [36, 37].

*Anxiety and Depression*

Only one study assessed anxiety and depression with no significant effects reported for resistance training [4].

*Self-Efficacy*

None of the studies included self-efficacy to exercise as an outcome measure. Self esteem was however assessed in one study and a significant improvement in the resistance training group compared to usual care was demonstrated [4].

*Body Composition*

Two studies assessed lean body mass with both demonstrating a significant benefit of resistance training compared to usual care [4, 24]. Body fat percentage was reported in three studies with two of the studies demonstrating significant benefits of resistance training compared to usual care [24, 37] and the third study showing no significant differences between groups [4]. Two studies also reported body fat weight with no differences identified between resistance training and control groups [4, 24]. Two studies reported findings for body mass index with neither study reporting a difference between the resistance training group and control group [24, 36]. One study assessed the ‘sum of skinfolds’ with no significant differences reported between the resistance training group and control group [36]. Four studies assessed body weight with no differences reported between the resistance training groups and control groups [4, 24, 36, 37]. Finally, waist circumference was assessed in two studies with no significant differences reported between resistance training and control groups [24, 36].

*Muscle Function*

Three of the six studies reported muscle strength as an outcome measure with all three studies reporting significant increases in upper limb and lower limb muscle strength in the resistance training groups compared to usual care groups [4, 21, 37]. Further to this, two studies assessed muscular endurance with both studies reporting significant improvements following resistance training compared to the control groups [21, 36].

*Tumor Specific Outcomes*

Both studies that investigated the effects of resistance training in people with head and neck cancer reported beneficial effect on shoulder function [19, 21]. Resistance training resulted in significant improvements in the global shoulder pain and disability index score compared to the control group for both studies. Some improvements in shoulder range of movement were also identified following resistance training.

Both studies that recruited participants with prostate cancer reported no significant differences between the resistance training group and the control group in terms of testosterone levels [36, 37]. In one study prostate specific antigen was reported to be significantly less reduced following resistance training compared to the control group [37] with no differences reported in the other study [36]. Only one study assessed hemoglobin levels with no significant difference reported between resistance training and the control condition [37]. Segal et al [37] reported a significant decrease in triglycerides in the resistance training group compared to the control group. However, no significant differences were reported for cholesterol levels [37].

*Maintenance*

All studies reported maintenance as percentage attendance at the resistance training sessions. Attendance at supervised sessions was reported as 68% [4]; 88% [37]; 89% [36]; 92% [24]; 93% [19]; and 95% [21]. All studies carried out statistical analysis on an intention to treat basis.

Three studies did not report any attempt to monitor or control resistance training in the control group [19, 24, 36]. In two studies participants in the control group were asked not to initiate an exercise program during the study period, however, this was not monitored [4, 37]. In the remaining study the comparison group carried out a lower level of therapeutic supervised exercise. Attendance at the sessions was reported as 87% in comparison to 95% in the experimental group [21].

For analysis purposes all studies considered participants in the group to which they had been assigned, regardless of adherence, hence the estimated benefit of resistance training did not take into consideration whether or not the participants adhered to the prescribed activity.

*Attrition*

Attrition rates were reported for all studies, ranging from 7.4% [37] to 15% [19]. Reasons for attrition were reported in full for three of the included studies [19, 21, 24]. The main reasons for loss to follow-up were cancer recurrence, complications associated with cancer treatment and lack of interest. The remaining three studies either failed to report the reasons for loss to follow-up [36, 37] or did not report reasons in full [4]. Participants who dropped out of the studies were not included in the analyses.

*Adverse Effects*

No serious adverse effects were reported due to resistance training. Adverse effects were reported in five of the six studies with the remaining study failing to report whether any adverse effects occurred [36]. There was only one adverse effect that resulted in the participant withdrawing from the resistance training program. This consisted of a soft tissue injury to the scapula region [21]. The remaining adverse effects that were reported did not prevent continued participation in the resistance training program. The adverse effects were one incidence of nausea that occurred after a training session [19], four participants reported back injuries [24]; and one incidence of chest pain was reported [37]. In the remaining study there were no adverse effects relating to the resistance training but two adverse effects were reported as a result of the maximal treadmill testing [4].

**Risk of bias in included studies**

The included studies were initially assessed for quality using CASP. Following discussion there was 100% agreement in scores between the review authors. All six studies asked a clearly focused research question and were appropriately designed as randomized controlled trials. Eligibility criteria were clearly specified for all studies with adequate randomization procedures also described. Because of the nature of the intervention it was impossible to conceal treatment allocation from participants. However, blinding was considered appropriate if the assessor was unaware of group allocation. This was reported to have occurred in four of the six studies [21, 24, 36, 37] and was unclear in the remaining two studies [4, 19].

Sample size ranged from 20 [19] to 242 [4] recruited participants. Two of the included studies made no attempt to perform sample size calculations [19, 24]. One of these was a feasibility study and the sample size was appropriate for this purpose [19]. The remaining four studies performed sample size calculations based upon the following outcomes; fatigue [36, 37], anemia [4] and shoulder pain and disability [21]. The target sample was achieved or was close to being achieved in each case. However, it is not clear if the sample sizes were adequate to detect statistical differences in QoL.

The primary outcomes were identified, although three of the studies reported more than one primary outcome. QoL was the main outcome in one study [4]; was one of two primary outcomes in three studies [24, 36, 37] and a secondary outcome in the remaining two studies [19, 21]. It was hypothesized in three of the studies that resistance training would improve disease specific quality of life [24, 36, 37].

Follow-up assessment of long-term outcomes was poor with four of the six studies failing to assess outcomes beyond the end of the intervention period [19, 21, 36, 37]. One study followed up participants post intervention (3 months) and at 6 months. However, due to the cross-over of participants from the control group to the intervention at 3 months there were no comparison data available [24]. The remaining study reported a 6 month follow-up but data were not reported in the original publication [4].

**Discussion**

This review provides some evidence that resistance training can provide benefits in relation to QoL in adults with cancer. Statistically significant improvements in QoL were identified following a resistance training program in adults with cancer. The two studies that independently demonstrated a statistically beneficial effect of resistance training upon QoL were carried out in participants with prostate cancer. This may suggest a variable response to resistance training according to cancer site and warrants further investigation. It also remains to be determined whether the type of cancer treatment or stage of treatment alters the beneficial effect of resistance training on QoL.

**Limitations of the review**

This review has incorporated a diverse range of studies and not all studies were statistically powered to detect changes in QoL. There is a considerable degree of clinical heterogeneity between studies in terms of adjuvant therapy, mode and intensity of resistance training, stage and type of cancer. Despite this statistical heterogeneity was not detected for the QoL meta-analysis (P=0.92; I2 = 0%). The lack of statistical heterogeneity does not however exclude heterogeneity given the small numbers.

For the purpose of inclusion in the review all studies recorded QoL as an outcome, however, the primary purpose of the resistance training interventions varied between studies. The resistance training may therefore have been designed for an alternative purpose resulting in a lack of beneficial effect for QoL.  
  
The results of the review should not be considered in isolation as there are a range of non-pharmacological interventions that may be considered beneficial in the management of QoL. Interventions that may be delivered in conjunction with a resistance training program include, but are not limited to, psychosocial therapies [39], nutrition therapy [17], complementary therapies [e.g. 29, 41, 42] and other physical activity interventions [5].

Limitations of the current review were the exclusion of studies that were not published in the English language.

**Limitations of the included studies**

Quality of the included studies was variable with the more recent studies generally being of better quality. Participants recruited to the included studies were volunteers therefore response to treatment in terms of motivation and participation may differ to the target population [31]. As a result validity is threatened as outcomes are open to selection bias [10, 31]. Few of the included studies provided information about eligible people who refused participation in the trial. It is possible that the included participants differed statistically to those who refused participation, particularly in relation to their attitudes towards resistance training. It is possible that those who declined to participate would not have achieved the same benefits from a resistance training program as those who chose to participate. The more recent studies indicated the main reasons for individuals refusing to participate and these included a lack of interest in the study [4], a refusal or inability to travel [4, 37], being too busy or having other commitments [4, 21, 37], and already active [37].  
  
The types of cancer investigated in the included studies was limited to prostate, breast and head and neck cancers thus limiting generalizability of the results to all cancer groups. Further research in this area needs to include participants with various cancer diagnoses or other specific cancer populations at various stages of disease including those receiving palliative care.  
  
In the majority of studies the control group received less attention than the intervention group which may have resulted in bias due to the Hawthorne effect. This is highlighted in the study that incorporated a control group [21] as although the resistance training group demonstrated greater improvements in QoL this did not reach significance. Further to this, in the two studies that included an aerobic exercise training group [4, 37] there were no significant differences between the intervention groups in relation to quality of life. Despite this it has been suggested that improvements in QoL are likely to have occurred as a result of increased muscular fitness [24, 36] and lean body mass [24]. In contrast to the findings of the studies reviewed, previous research comparing the effects of aerobic training to a placebo exercise group (light body training and stretching) indicated that improvements in QoL due to aerobic training could not be entirely attributable to attention [6]. Participants attended the same number of supervised training sessions with the aerobic group demonstrating significant improvement in QoL compared to the placebo group. To investigate this issue further, future researchers studying the effects of resistance training should consider the inclusion of an attention control group.

Long-term follow-up measures were either not included or not reported in the studies. Further research is therefore required to determine the long term effects of resistance training upon QoL.

The included studies did not compare the effects of different frequency or intensity of resistance training. However, in one study the participants in the control group carried out basic resistance training with light weights [21] which were considered standard care. There were non-significant improvements observed in the resistance training group compared to the control condition. It is possible that the inclusion of light resistance training in the control condition was the reason that the difference did not reach significance. Further studies are therefore required to determine the influence of training duration and intensity requires further investigation to determine optimal parameters.

**Outcome measures**

Although five of the six studies used the FACT the addition of a disease specific domain prevented direct comparisons between studies. Results for the FACT-G were not generally reported which would have allowed comparison. It is positive to note however that data was available for the purpose of meta-analysis for all studies retrieved and identified as suitable.

**Adherence and contamination**

Group contamination has previously been reported in studies investigating exercise. This may occur when the control participants undertake exercise or the exercise group do not adhere to the program. Only one study attempted to monitor exercise participation within the control group [21]. Control participants in this study attended a therapeutic exercise program described as usual care; however, there were no attempts to monitor exercise participation outside of the supervised sessions. Further to this, contamination may occur when participants do not undertake the exercise at the prescribed intensity or for the prescribed duration. However, within the included studies resistance training programs were hospital based and it was therefore possible to monitor participation. Adherence to the programs was high for all the included studies suggesting that resistance training is acceptable to people with cancer.

It is possible that implementation of any exercise program should be accompanied by a behavioral change intervention to ensure that participants are supported and therefore more likely to continue exercising unsupervised. None of the studies monitored participant’s self-efficacy which may be an important predictor of long-term exercise maintenance.

Previously published exercise guidelines for cancer rehabilitation suggest that an individualized approach is more appropriate [20], however, further research is required to determine the most appropriate recommendations for exercise. Further research to determine the additional benefits of resistance training when carried out in combination with aerobic exercise compared to aerobic exercise in isolation may also be beneficial.

In summary, the research to date suggests that it is possible to increase muscle strength in cancer survivors through a resistance training program. Marginal improvements in QoL are also apparent immediately following a resistance training program. However, further research is required to determine the optimal parameters for resistance training as well as the long term effects of such programs.

**Acknowledgements**

We would like to thank the following individuals for their contributions to this review: Jennifer Campbell, Patrick Cookson and Lauren Wee.

**References**

1. Al-Majid S, McCarthy DO (2001) Cancer-induced fatigue and skeletal muscle wasting: the role of exercise. Biol Res Nurs 2:186-197.
2. Battaglini C, Bottaro M, Dennehy C, Barfoot D, Shields E, Kirk D, Hackney AC (2006) The effects of resistance training on muscular strength and fatigue levels in breast cancer patients. Rev Bras Med Esport 12:139-144.
3. Brown JK, Byers T, Doyle C, Courneya KS, Denmark-Wahnefried W, Kushi LH, McTiernan A Rock CL, Aziz N, Cloch AB, Eldridge B, Hamilton K, Katzin C, Koonce A, Main J, Mobley C, Morra ME, Pierce MS, Sawyer KA (2003) Nutrition and physical activity during and after cancer treatments: an American Cancer Society guide for informed choice. CA: Cancer J Clin 53:268-291.
4. Courneya KS, Segal RJ, Mackey JR, Gelmon K, Reid RD, Friedenreich CM, Ladha AB, Proulx C, Vallance JKH, Lane K, Yasui Y, McKenzie DC (2007) Effects of aerobic and resistance exercise in breast cancer patients receiving adjuvant chemotherapy: a multicenter randomized controlled trial. J Clin Oncol 25:4396-4404.
5. Cramp F, Daniel J (2008) Exercise for the management of cancer-related fatigue in adults. Cochrane Database Syst Rev 16;(2):CD006145.
6. Daley AJ, Crank H, Saxton JM, Mutrie N, Coleman R, Roalfe A (2007) Randomized trial of exercise therapy in women treated for breast cancer. J Cli Oncol 25: 1713-1721.
7. Dimeo FC, Fetscher S, Lange W, Mertelsmann R, Keul J (1997) Effects of aerobic exercise on the physical performance and incidence of treatment-related complications after high-dose chemotherapy. Blood 90:3390-3394.
8. Dimeo F, Rumberger BG, Keul J (1998) Aerobic exercise as therapy for cancer fatigue. Med Sci Sport Exerc 30:475-478.
9. Dimeo FC, Stieglitz RD, Novelli-Fischer U (1999) Effects of physical activity on the fatigue and psychologic status of cancer patients during chemotherapy. Cancer 85:2273-2277.
10. Domholdt E (2000) Physical therapy research: Principles and applications. 2nd edn. WB Saunders, Pennsylvania.
11. Galvao DA, Nosaka K, Taaffe DR, Spry N, Kristjanson LJ, McGuigan MR, Suzuki K, Yamaya K, Newton RU (2006) Resistance training and reduction of treatment side effects in prostate cancer patients. Med Sci Sport Exerc 38:2045-2052.
12. Graves S, Whitehurst M, Findley BW (2006) ACSM’s resource manual for guidelines for exercise testing and prescription. Lippincott, Williams and Wilkins, Philadelphia.
13. Guyatt GH, Sackett DL, Cook DJ (1993) Users’ guide to the medical literature. II. How to use an article about therapy or prevention. J Am Med Assoc 270:2598-2601.
14. Holick CN, Newcomb PA, Trentham-Dietz A, Titus-Ernstoff L, Bersch AJ, Stampfer MJ, Baron JA, Egan KM, Willett WC (2008) Physical activity and survival after diagnosis of invasive breast cancer. Cancer Epidemiol Biomark Prev 17: 379-386.
15. Holmes MD, Chen WY, Feskanich D, Kroenke CH, Colditz GA (2005) Physical activity and survival after breast cancer diagnosis. JAMA 293: 2479-2486.
16. Knols R, Aaronson NK, Uebelhart D, Fransen J, Aufdemkampe G (2005) Physical exercise in cancer patients during and after medical treatment: a systematic review of randomized and controlled trials. J Clin Oncol 23: 3830-3841.
17. Marín Caro MM Laviano A Pichard C (2007) Impact of nutrition on quality of life during cancer. Curr Opin Clin Nutr Metab Care 10: 480-487.
18. Markes M, Brockow T, Resch KL (2006) Exercise for women receiving adjuvant therapy for breast cancer. Cochrane Database Syst Rev 18;(4):CD005001.
19. McNeely ML, Parliament M, Courneya KS, Seikaly H, Jha N, Scrimger R, Hanson J (2004) A pilot study of a randomized controlled trial to evaluate the effects of progressive resistance exercise training on shoulder dysfunction caused by spinal accessory neurapraxia/neurectomy in head and neck cancer survivors. Head Neck 26:518-530.
20. McNeely ML, Campbell KL, Rowe BH, Klassen TP, Mackey JR, Courneya KS (2006) Effects of exercise on breast cancer patients and survivors: a systematic review and meta-analysis. Can Med Assoc J 175:34-39.
21. McNeely ML, Parliament MB, Seikaly H, Jha N, Magee DJ, Haykowsky MJ, Courneya KS (2008) Effect of exercise on upper extremity pain and dysfunction in head and neck cancer survivors: a randomized controlled trial. Cancer 113:214-222.
22. Mock V, Hassey DK, Meares CJ, Grimm PM, Dienemann JA. Haisfield-Wolfe ME, Quitasol W, Mitchell S, Chakravarthy A, Gage W (1997) Effects of exercise on fatigue, physical functioning, and emotional distress during radiation therapy for breast cancer. Oncol Nurs Forum 24:991-1000.
23. National Comprehensive Cancer Network. Clinical Practice Guidelines in Oncology. Cancer-related fatigue version 1.2010. Available via: www.nccn.org Accessed 1 March 2010.
24. Ohira T, Schmitz KH, Ahmed RL, Yee D (2006) Effects of weight training on quality of life in recent breast cancer survivors. Cancer 106:2076-2083.
25. Oldervoll LM, Kaasa S, Hjermstad MJ, Lund JA, Loge JH (2004) Physical exercise results in the improved subjective well-being of a few or is effective rehabilitation for all cancer patients? Eur J Cancer 40: 951-962.
26. Pinto BM, Maruyama NC (1999) Exercise in the rehabilitation of breast cancer survivors. Psycho-oncology 8:191-206.
27. Powers SK, Howley ET (2006) Exercise Physiology: theory and application to fitness and performance. McGraw Hill Higher Education, Sydney.
28. Public Health Resource Unit (2006) Critical appraisal skills programme (CASP) learning and development. Available via: <http://www.phru.nhs.uk/Pages/PHD/resources.htm> Accessed 15 March 2009.
29. Richardson MM, Babiak-Vazquez AE Frenkel MA (2008) Music therapy in a comprehensive cancer center. J Soc Integr Oncol 6: 76-81.
30. Salmon PG, Swank AM (2002) Exercise-based disease management guidelines for individuals with cancer: potential applications in a high risk mid-southern state. J Exerc Physiol online 5:1-10.
31. Shapiro SH, Weijer C, Freedman B (2000) Reporting the study populations of clinical trials. Clear transmission or static on the line? J Clin Epidemiol 53:973-979.
32. Schmitz KH, Ahmed RL, Hannan PJ, Yee D (2005) Safety and efficacy of weight training in recent breast cancer survivors to alter body composition, insulin, and insulin-like growth factor axis proteins. Cancer Epidemiol Biomark Prev 14:1672-1680.
33. Schmitz KH, Holtzman J, Courneya KS, Masse LC, Duval S, Kane R (2005) Controlled physical activity trials in cancer survivors: a systematic review and meta-analysis. Cancer Epidemiol Biomark Prev 14:1588-1595.
34. Schwartz AL, Mori M, Gao R (2001) Exercise reduces daily fatigue in women with breast cancer receiving chemotherapy. Med Sci Sport Exerc 33:718-723.
35. Schwartz AL (2004) Physical activity after a cancer diagnosis: psychosocial outcomes. Cancer Invest 22: 82-92.
36. Segal RJ, Reid RD, Courneya KS, Malone SC, Parliament MB, Scott CG, Venner PM, Quinney HA, Jones LW, Slovinec D’Angelo ME, Wells GA (2003) Resistance exercise in men receiving androgen deprivation therapy for prostate cancer. J Clin Oncol 21:1653-1659.
37. Segal RS, Reid RD, Courneya KS, Sigal RJ, Kenny GP, Prud’Homme DG, Malone SC, Wells GA, Scott CG, Slovinec D’Angelo ME (2009) Randomized controlled trial of resistance or aerobic exercise in men receiving radiation therapy for prostate cancer. J Clin Oncol 27:344-351.
38. Segar ML, Katch VL, Roth RS, Garcia AW, Portner TI, Glickman SG, Haslanger S, Wilkins EG (1998) The effect of aerobic exercise on self esteem and depressive and anxiety symptoms among breast cancer survivors. Oncol Nurs Forum 25:107-113.
39. Stanton AL (2006) Psychosocial concerns and interventions for cancer survivors. J Clin Oncol 24:5132–7.
40. Twycross R, Wilcock A (2001) Symptom management in advanced cancer. TJ International Ltd, Padstow, United Kingdom.
41. Wilkinson S, Barnes K, Storey L (2008) Massage for symptom relief in patients with cancer: systematic review. J Adv Nurs 63: 430-439.
42. Wilkinson S, Lockhart K, Gambles M, Storey L (2008) Reflexology for symptom relief in patients with cancer. Cancer Nurs 31: 354-360.
43. Wilmore JH, Costill DL (2005) Physiology of sport and exercise. Human Kinetics Europe Ltd, Leeds.

**Figure I. Search strategy**

The following search strategy was utilised for this review, using text and keyword and MESH terms in each database:

1. Randomized controlled trials.mp. [mp=title, original title, abstract, name of substance word, subject random allocation.mp. heading word]

2. Randomized controlled trial.pt

3. random allocation.mp. [mp=title, original title, abstract, name of substance word, subject heading word]

4. double blind method.mp. [mp=title, original title, abstract, name of substance word, subject heading word]

5. single blind method.mp. [mp=title, original title, abstract, name of substance word, subject heading word]

6. clinical trial.pt

7. Exp clinical trials/

8. or/1-7

9. (clinic$ adj trial$1).tw.

10. ((singl$ or doubl$ or treb$ or tripl$) adj (blind$3 or mask$s)).tw.

11. placebo.mp. [mp=title, original title, abstract, name of substance word, subject heading word]

12. placebo$.tw.

13. randomly allocated.tw.

14. (allocated adj2 random).tw.

15. or/9-14

16. 8 or 15

17. Case report.tw.

18. Letter.pt.

19. historical article.pt.

20. review of reported cases.pt.

21. review, multicase.pt.

22. or/17-21

23. 16 not 22

24. exp NEOPLASMS/

25. exp LEUKEMIA/

26. exp LYMPHOMA/

27. exp RADIOTHERAPY/

28. BONE MARROW TRANSPLANTATION/

29. neoplasm$.mp. [mp=title, original title, abstract, name of substance word, subject heading word]

30. cancer$.mp. [mp=title, original title, abstract, name of substance word, subject heading word]

31. (leukaemi$ or leukemi$).mp. [mp=title, original title, abstract, name of substance word, subject heading word]

32. (tumour$ or tumor$).mp. [mp=title, original title, abstract, name of substance word, subject heading word]

33. malignan$.mp. [mp=title, original title, abstract, name of substance word, subject heading word]

34. neutropeni$.mp. [mp=title, original title, abstract, name of substance word, subject heading word]

35. carcino$.mp. [mp=title, original title, abstract, name of substance word, subject heading word]

36. adenocarcinoma$.mp. [mp=title, original title, abstract, name of substance word, subject heading word]

37. lymphoma$.mp. [mp=title, original title, abstract, name of substance word, subject heading word]

38. (radioth$ or radiat$ or irradiat$ or radiochemo$ or chemotherapy$).mp. [mp=title, original title, abstract, name of substance word, subject heading word]

39. (bone adj marrow adj5 transplant$).mp. [mp=title, original title, abstract, name of substance word, subject heading word]

40. or/24-39

41. (qualit$ of life or qualit$ adjusted life year$ or health status or mental health or well being or qualit$ adjusted survival). mp. [mp=title, original title, abstract, name of substance word, subject heading word]

42. Exp strength training/

43. ((strength$ or resist$) adj (train$ or program$)).mp [mp=title, original title, abstract, name of substance word, subject heading word]

44. resist$ adj (exercise or train$ or program$).mp. [mp=title, original title, abstract, name of substance word, subject heading word]

45. (progressive adj resist$ adj train$).mp. [mp=title, original title, abstract, name of substance word, subject heading word]

46. or/42-45

47. 23 and 40 and 41 and 46

**Figure II: Meta-analysis of QoL post-test means (SD) for resistance exercise compared to control**

