Spring 2018

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Exercise and Cancer: A Summary of Therapeutic Intervention

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Abstract

Background: There is strong evidence to support the benefits of exercise for cancer patients. However, there are few literature reviews that summarize exercise as it plays a role in all aspects of the cancer diagnosis including during cancer prevention, prehabilitation in surgical cancer patients, cancer treatment, and cancer recovery. This review serves to provide a comprehensive resource for students and health care professionals for research based findings related to the interactions between exercise and cancer.

Purpose: To summarize the current research findings involving the relationship between cancer and exercise.

Data Sources: ZipSearch, Google Scholar, and MEDLINE; 2008-2018

Methods: All data sources were searched for scholarly articles relating to exercise and cancer. One researcher evaluated the abstracts of all relevant articles and then selected those that seemed most relevant based on the content of the abstract. The selected articles were considered in their entirety, relevant findings were documented and reference lists were evaluated to provide an exhaustive review of the topic.

Results: Twenty unique searches were conducted across the databases. Eighty-three abstracts were reviewed while 35 relevant articles selected and analyzed in the systematic review.

Conclusion: It is clear that exercise provides several benefits to cancer patients regardless of stage or cancer of type. It is important that health care professionals are aware of the benefits exercise can provide as primary, secondary, and tertiary prevention and treatment of cancer.
Introduction

Cancer is a condition marked by the uncontrolled division of abnormal cells in the body. Typically, this rapid cell production induces a tumor to form which can spread and affect several parts of the body (Kelly 2016). About 25% of cancer cases globally are due to excess weight and a sedentary lifestyle. Physical activity may decrease risk for various cancers by several mechanisms, including decreasing sex hormones, metabolic hormones and inflammation, and improving immune function (Hojman, Christensen, Pedersen, & Gehl 2017). It is important that health care professionals and cancer patients be aware of the positive effects that exercise can have during the course of a cancer diagnosis and in its prevention. This review aims to summarize the current research and findings relating to the interaction of exercise and cancer diagnosis. Therapeutic benefits have been reported when exercise is conducted during and after cancer treatment. Exercise will be discussed as it plays a role in cancer prevention, prehabilitation, treatment, and recovery.

Methods

A comprehensive literature search was conducted between the dates of December 30, 2017 and January 18, 2018. The databases searched were ZipSearch (2008 to 2018), a compilation of all of the databases offered through the University of Akron library system, MEDLINE (2008 to 2018) and Google Scholar (2008 to 2018). Reference lists of appropriate articles were also reviewed for relevant articles to be used. One reviewer evaluated the abstract of peer reviewed articles relevant to the search and selected articles to undergo a full text review based on the contents of the abstract. No studies were eliminated from the search based on design of study. The database searches were limited to information relevant to exercise as it relates to and plays a role in cancer prevention, prehabilitation prior to surgical intervention in cancer patients, cancer treatment, and
cancer recovery. Following the completion of 20 unique searches across the two databases selected, 83 abstracts were reviewed while 35 relevant articles were selected and analyzed in their entirety to be included in the systematic review. The unique keywords utilized in the conducted searches were as follows:

- Exercise and cancer
- Resistance training in cancer patients
- Endurance training in cancer patients
- Exercise and cancer prevention
- Physical activity as a means of cancer prevention
- Reducing cancer risk among adults
- Molecular mechanisms cancer prevention
- Prehabilitation in cancer patients
- Exercise and cancer prehabilitation
- The role of physical activity in cancer prehabilitation
- Prehabilitation for surgical cancer procedures
- Minimizing recovery time in surgical cancer patients
- Exercise and cancer treatment
- Cancer treatment and physical activity
- Effect of exercise on cancer treatments
- Chemotherapy and exercise
- Exercise and cancer recovery
- The role of physical activity in cancer recovery
- Exercise program for cancer survivors
- Exercise among cancer survivors

Following the completion of 20 unique searches across the three databases selected, 83 abstracts were reviewed while 38 relevant articles were selected and analyzed in their entirety to be included in the systematic review. The inclusion criteria based on the abstracts reviewed were studies which focused on cancer holistically rather than a specific type of cancer, with the exception of prehabilitation studies, and studies which were conducted within the last ten years. Additionally, these inclusion criteria were ignored in the case of an article that was referenced in an initially selected study. The article referenced in the study was deemed relevant based upon its information cited in the original study, which led to its further review in order to ensure proper interpretation prior to including it in this literature review.
Review of Literature

Physical and Physiological Complications of Cancer

Cancer is defined as a condition marked by an overgrowth of abnormal cells. This rapid increase in abnormal cells throughout the body eventually overcrowds the normal cells that initially existed there. Ultimately, this prevents the body from functioning properly. In certain cancer types, this rapid cellular division can cause a tumor to form, or a lump. However, this is not characteristic of all cancer types as leukemia patients do not experience tumor growth. Cancerous tumors are referred to as malignant. While this overgrowth of abnormal cells typically originates in one area of the body in particular, cancer cells are able to spread to other unaffected body areas. This concept is also known as metastasis (American Cancer Society 2018). There are a multitude of signs and symptoms that are indicative of cancer such as pain, fatigue, unexplained weight loss, loss of appetite, and fever. The overgrowth of cancer cells inhibits the body from functioning properly (Cancer Council Victoria 2018; American Cancer Society 2018).

The most common treatment modalities for cancer patients are chemotherapy, surgery, biotherapy, and radiation. When patients undergo surgery for cancer treatment, this typically involves removal of the cancer and sometimes the areas that have been affected by the cancer. Radiation therapy involves the killing or hindrance of the growth of the cancer cells. This modality is comparative to receiving an X-ray. Chemotherapy consists of the killing of cancer cells through the use of medications. These medications can be delivered intravenously or orally, and are most useful for patients who are victim of a cancer that has spread throughout the body. Biotherapy serves to stimulate the immune system to fight off the cancerous cells. This treatment
can involve administration of synthetic proteins that serve as a functional component of the immune system. The goal of this type of treatment is to assist the immune system in recognizing cancer cells and increasing its strength in attacking them (American Cancer Society 2018).

While treatments are proved useful in fighting off cancer, these treatment modalities often show side effects among cancer patients. When recovering from cancer surgery, patients most often experience pain and loss of appetite following the surgical intervention. Surgical intervention may also cause natural bodily functions to be altered, such as bowel movements and other complications. Pain can be limiting following a surgical intervention, although movement is encouraged as soon as possible during the recovery process. Radiation therapy is often associated with fatigue and irritation of the skin. The most limiting side effect of radiation therapy, fatigue, can inhibit cancer patients from being able to perform their activities of daily living in an efficient manner. Chemotherapy involves the spreading of medications throughout the body. These medications are capable of damaging not only the cancerous cells within the body, but the normal functioning cells as well. Moreover, chemotherapy has a multitude of side effects that vary from patient to patient. These side effects include fatigue, hair loss as a result of damage to the hair follicle cells, anemia as a result of damage to the red blood cells, malnutrition, loss of appetite, and cachexia, or weakness experienced throughout the body (American Cancer Society 2018). All of the side effects mentioned above can be debilitating to a cancer patient. They may experience muscle atrophy as a result of the inability to function normally and in some cases patients can experience bone loss. It is important for patients to seek strategies which will help to combat these side effects and minimize their influence on the body.
Exercise and its role in the prevention of cancer

According to the World Health Organization, physical inactivity was the fourth ranked risk factor for death by all causes in 2014 (Hoffman 2016). According to medical community, individuals who engage in regular physical activity are less likely to be at risk for 13 different types of cancer (Repka et al. 2014; Kelly 2016). Lack of participation in regular exercise is a risk factor for cancer and should be considered equivalent to other risk factors such as smoking. Individuals are more likely to be diagnosed with cancer as they increase in age, which could be due to internal damage that accumulates as a result of toxins in the body such as carcinogens and viruses that cause damaged cells to proliferate and eventually induce the development of cancer. Typically, the aging process is accompanied by a decrease in the functionality of the immune system, a concept also known as immunosenescence (Bigley, Spielmann, LaVov, & Simpson 2013). This concept is important in that in 2016, 86% of all cancer was diagnosed in patients over the age of 50 (Hoffman 2016).

Research purports that exercise acts as a possible means of delaying the onset of immunosenescence. Exercise places strain on the body which poses a threat to homeostasis, therefore, inducing cellular adaptations in the body (Hojman 2017). In order to better understand the role of the immune system in cancer diagnosis, the underlying mechanisms must be analyzed. In the innate immune response, natural killer cells are responsible for identifying the difference between healthy and infected cells within the body and causes tumors to shrink in size (Bigley et al. 2013; Kelly 2016). Exercise has also been shown to increase the number and effectiveness of monocytes and macrophages, which contribute to the inhibition of cancer growth. In the adaptive immune response, exercise contributes to increased circulation of T cells which function in the killing of cells that are affected by cancer (Bigley et al. 2013). Patients with higher counts of
circulating cytotoxic T cells and natural killer cells have a better prognosis when compared to those with decreased counts. Additionally, the release of myokines from muscles when performance exercise, regulates the activity of immune cells (Hojman 2017). The effects of exercise on the immune system in cancer patients are further illustrated by Figure 1.
Figure 1. The effect of exercise on the immune system. This figure illustrates effects exercise has on the immune system and inflammation associated with a cancer diagnosis. Exercise functions to regulate systemic inflammation, mobilize immune cells, and triggers inflammatory signaling in cancer patients. Hojman, P. (2017). Exercise protects from cancer through regulation of immune function and decreasing inflammation. *Biochemical Society Transactions*, 45905-911.

The endocrine system also comes into play when considering how exercise impacts cancer prevention. During exercise, epinephrine is released which helps to circulate natural killer cells. The endocrine system also plays a role in reducing the insulin and leptin levels in the body.
Lowering the leptin levels can help to limit the growth and metastasis of certain types of cancers (Kelly 2016).

Inflammation influences the development of cancer. Patients who exhibit chronic inflammation induce tumor growth by supplying growth factors and enzymes that promote metastasis, or the spreading of cancer throughout the body. The effects of exercise on cancer associated inflammation can be seen in Figure 1 (Hojman 2017). Cancer is known to stimulate an increase in C-reactive protein, interleukin 6, and tumor necrosis factor which are all known to induce inflammation. There is a correlation between physical activity and reduced systemic inflammation in cancer patients; however, the relationship has not proven to be causal. More research needs to be done to prove the direct link between exercise, inflammation, and cancer prevention (McTiernan 2008).

It is clear that exercise is effective in lowering the risk of developing different cancers; however, further research is needed to determine the dose response necessary as primary prevention of cancer. There is evidence that there is a link between exercise early in life and the prevention of later cancer diagnosis. Research points to early exercise being more effective in cancer prevention than exercise that is limited to late adulthood as a preventative measure (Kelly 2016). A study conducted in China showed that women, who participated in 70 minutes of exercise per week during their teenage years, decreased their risk of developing breast cancer by 16% (Nechuta et al. 2015). In a systematic review of clinical trials which aimed to compare primary exercise interventions in patients with one risk factor for cancer, the results showed that exercise intensity appears to play a role in cancer prevention. The only trial that did not produce significant effects on the blood biomarkers and did not showcase any improvements in adiposity was the intervention that utilized a low intensity exercise program (Brooke, David, Marina, &
Jennifer 2011). This may suggest that high intensity exercise is linked to a greater reduction of cancer risk.

Current research and evidence discussing exercise and its link to cancer prevention is convincing. There are multiple mechanisms by which exercise can reduce the risk of cancer such as decreased adiposity, decreased tumor growth factors, reduction of systemic inflammation, changes in hormone levels, and improved immune function (Kruk & Czerniak 2013). While there is not a one size fits all approach for the exercise prescription that will be the most effective in preventing cancer, the current research shows that there are undeniable benefits to exercising regularly in order to reduce cancer risk.

*Exercise as prehabilitation for surgical cancer patients.*

The goal of prehabilitation is to prepare patients for upcoming medical stressors as a means of limiting the adverse effects and reactions to such stressors. The definition of cancer prehabilitation is as follows:

A process on the cancer continuum of care that occurs between the time of cancer diagnosis and the beginning of acute treatment and includes physical and psychological assessments that establish a baseline function level, identify impairments, and provide interventions that promote physical and psychological health to reduce the incidence and/or severity of future impairments. (Silver 2014)

The typical duration of the prehabilitation period is between 4 and 8 weeks (Carli, Gillis, & Scheede-Bergdahl 2017). In relation to cancer patients, prehabilitation is best discussed in preparation for a surgical intervention (Silver 2014). Prehabilitation is something that is not frequently studied in comparison to its later counterpart known as rehabilitation, however, there
is strong evidence that prehabilitation prior to a surgical intervention in cancer patients will provide a wide range of benefits including reduced complications post-surgery, reducing hospital costs, and a shorter recovery period as shown in Figure 2.


Rochefort and Tomlinson found that the rate of readmission following an oncologic surgical procedure was between 53% and 66% one year after surgery in the United States which is associated with poor survival outcomes (Silver 2014; Rochefort & Tomlinson 2012). The risk of readmission and/or a prolonged stay at the hospital is affected by patient age, comorbidities, type of cancer, type of procedure, and what type of care they will receive following discharge. It
EXERCISE AND CANCER

is inferred that the greatest predictor of readmission is the condition of the patient prior to undergoing the surgical procedure, with frailty being the most predictive characteristic (Silver 2014; Carli, Gillis, & Scheede-Bergdahl 2017). Prehabilitation aimed at improving functional capacity prior to the surgical intervention reduces the likelihood of readmission and further complications following surgery. More specifically, engaging in exercise activity prior to surgery helps to combat fatigue and improves the overall quality of life for the patient (Silver 2014).

It is recommended that patients perform aerobic exercise in combination with strength training as a means of improving their strength and stamina prior to undergoing surgery which could leave the muscles feeling weaker and other debilitating effects on the body (Silver 2014; “Prehabilitation can improve cancer treatment outcomes,” 2014). When prescribing exercise as a means of prehabilitation, it is imperative for the clinician to avoid surpassing the capabilities of the patient in regards to their functional abilities and fitness level (Carli et al. 2017). Evidence not only supports the use of general exercise in prehabilitation for surgical cancer patients, but also specific exercises with specific outcome goals in mind. For instance, patients who previously underwent surgery to treat cancer of the neck and head are frequently prescribed swallowing exercises aimed at improving their functional capacity in that area. Optimal prehabilitation should employ a holistic approach including not only physical activity interventions, but also psychological and nutritional elements which are currently being studied comprehensively. Studies show that a multidisciplinary approach is best for maximizing the benefits of prehabilitation (Silver 2014). The psychological benefits of physical activity in prehabilitation include stress relief and allowing the patient to feel in control of their body (“Prehabilitation can improve cancer treatment outcomes,” 2014). Typically, patients diagnosed with colorectal, lung, and breast cancer are the most likely to undergo a surgical procedure.
Moreover, these are the types of cancer that are best studied in regards to the effect of prehabilitation on the postoperative condition of the patient (Silver 2014).

A study conducted by Nilsson et al. (2016), further analyzes the relationship between pre-surgical physical activity engagement and post-operative recovery in breast cancer patients. The researchers measured the post-operative recovery period by recording the length of stay in the hospital following completion of the surgery. In this particular study, physical activity was self-reported via questionnaires by patients scheduled to undergo breast cancer surgery. Patients were asked to rank themselves as physically inactive, engaging in slight physical activity, engaging in regular physical activity, or engaging in hard physical activity for competitive sports. Following their surgical procedure, patients were then asked to assess their physical and mental recovery 3 weeks post-surgery and then again at 6 weeks post-surgery. The results of the study showed that patients who considered themselves to be physically inactive prior to breast cancer surgery had an increased BMI as well as increased prevalence of comorbidities. At 3 weeks post-surgery, there was a significant difference seen in patients who engaged in physical activity prior to their surgery. Signs of recovery were evaluated as length of hospital stay, length of sick leave, and self-reported physical and mental recovery. These patients showed better signs of recovery at 3 weeks after their surgery. However, at 6 weeks post-surgery there was no significant difference between the physically active and inactive groups in regards to their recovery status (Nilsson et al. 2016).

Regarding prehabilitation and lung cancer, Michaels (2016) hypothesized that an exercise program prior to curative lung surgery could have immense benefits for patients in the surgical recovery period. During the prehabilitation period, this study suggested that lung cancer patients should first perform breathing exercises in order to improve their endurance and overall
functional capacity to perform their activities of daily life. This review detailed three preoperative exercise interventions for lung cancer patients. Diaphragmatic breathing, being the first intervention, is said to reduce the stress and anxiety levels of a lung cancer patient by strengthening the abdominal muscles and the diaphragm. The second intervention involves stretching of the upper body which is said to hold benefit in improving chest and back mobility. Increased mobility in these patients will allow for the lungs and diaphragm to move more freely throughout the thoracic and abdominal cavities. Stretching also increases muscle elasticity, blood flow to the muscles, and reduces inflammation, all of which are beneficial to lung cancer patients prior to their surgery. Strength training is also recommended as a means of combatting fatigue which is associated with lung cancer patients who exhibit reduced breathing capacity as a result of weak abdominal muscles. Exercise prior to surgery in lung cancer patients exhibits improved pulmonary capacity, and increased endurance and strength. These benefits in turn reduce the likelihood of postoperative complications as well as improve the overall quality of life of the patient post-surgery (Michaels 2016).

A current ongoing study will examine the effects of prehabilitation in patients undergoing colorectal surgery. The study will compare the effects of a combination of pre and post-operative physical activity interventions with patients who only receive interventions post-surgery. Preoperative exercise interventions will consist of 30 minutes of moderate intensity aerobic activity daily in addition to their normal exercise routine, while the patients in the group lacking preoperative exercise intervention will be advised to continue engaging in their normal exercise routines. The preoperative exercise group will also engage in inspiratory muscle training. The subjects will be asked to report their physical recovery status four weeks post-surgery. While the results of this study have yet to be published, it highlights the direction prehabilitation research is
headed in regards to colorectal surgery and the types of interventions that may be used to improve function and quality of life in colorectal cancer patients (Onerup et al. 2017).

Strides have been made examining the relationship between prehabilitation and surgical cancer patients; however more research is needed in the following areas. First, studies should seek more information about the effects prehabilitation has on treatment options. If a cancer patient engages in physical activity following cancer diagnosis, physicians may be able to consider different treatment options that the patient may have not been fit for prior to gaining better physical fitness. Another area of study should also involve high risk patients. At diagnosis, patients considered high risk are typically in poor health. However, after undergoing exercise as a form of prehabilitation, will improved fitness demonstrate improvements in surgical recovery? Will the health improvements gained as a result of prehabilitation result in developing healthier lifestyles than were present prior to cancer diagnosis (Silver 2014)? Further research into the practice of prehabilitation prior to surgery in cancer patients and its beneficial effects may increase prehabilitation exercise prescriptions and hopefully mitigate excessive lengths of stay as well as increased hospital costs due to post-surgery complications.

*Exercise during cancer treatment.*

When prescribing cancer treatment regimens, exercise is rarely considered a mode of treatment. Evidence shows that there are many psychological, physical, and functional benefits to current cancer patients who perform regular exercise regardless of the stage and cancer diagnosis (Stout, Baima, Swisher, Winters-Stone, & Welsh 2017; Fernandez et al. 2015). Current research shows that only 30-50% of cancer patients meet weekly exercise recommendations. The weekly recommendations for cancer patients, similar to healthy individuals for general health
benefits, are at least 150 minutes of moderate intensity aerobic exercise, flexibility exercises of major muscles and tendons on exercise days, and two sessions of resistance exercise of the same intensity targeting all major muscle groups (Cormie et al. 2017; Haskell et al. 2007).

Cancer-related fatigue (CRF) is regarded as one of the most common side effects associated with individuals undergoing cancer treatment, being that it is reported by nearly 90% of cancer patients being treated. CRF cannot be cured by resting and is defined as follows:

“the perception of unusual tiredness that varies in pattern of severity and has negative impacts on the ability to function in people who have or have had cancer” (Wang & Woodruff 2015).

CRF is marked by an increase in serotonin produced and reduced production of cortisol. Research has established that exercise can significantly reduce CRF, most notably with aerobic endurance and musculoskeletal improvements. While many physicians recommend rest to combat CRF, physical inactivity causes detraining which only contributes to the fatigue and causes an inability to efficiently perform activities of daily living (McMillan & Newhouse 2011). A current randomized controlled trial is being conducted, which aims to examine the effects of exercise on CRF and the quality of life in cancer patients undergoing treatment. The study began in September of 2014 and will follow cancer patients over a 10-year period. The patients included were actively undergoing treatment and randomly assigned to either a low-intensity exercise group or a high-intensity exercise group. The effects of the exercise interventions were monitored at 3 months, 6 months, 1 year, 2 years, 5 years, and 10 years after its completion. The outcome measures were evaluated by self-report in regards to fatigue and quality of life. The final measurement and results of the study will be obtained in 2024. (Bernsten et al. 2017).
Exercise also appears to have a positive effect on the overall health related quality of life of cancer patients currently undergoing treatment. A study conducted by Mishra, Scherer, Snyder, Geigle, & Gotay (2015) demonstrates that patients who participated in regular moderate-to-vigorous intensity exercise showed significant improvements in their health related quality of life. Resistance training also consistently showed a significant increase in quality of life over fifteen research studies conducted on patients engaging in resistance training during active cancer treatment (Segal et al. 2017). When the effects of resistance training and aerobic training were compared against one another in patients being actively treated for cancer, there were no significant differences between the improvements in quality of life achieved by both modes of exercise (Santa Mina et al. 2013).

Regular exercise is also accompanied by hyperthermia, which has been shown to induce vasodilation of the blood vessels. This vasodilation contributes to increased circulation of immune cells which can then more efficaciously infiltrate tumors when compared to inactive individuals (Hojman et al. 2017). Exercise has also been shown to reduce tumor hypoxia by 50% and double the blood flow to tumors thereby increasing the delivery of chemotherapy drugs (Vaccarezza & Vitale 2015).

A study performed on rodents revealed that voluntary wheel running reduced the tumor growth by 50%. This reduction in tumor growth was promoted by the release of increased numbers of natural killer cells and immune cells surrounding the tumor by means of the hormone epinephrine (Pedersen et al. 2016). Additionally, this reduction in tumor growth promoted by exercise is not specific to any one type of cancer (Hojman et al. 2017). In vitro studies have been conducted to assess the ability of exercise to reduce the efficiency of tumor growth. A study which incubated cancer cells with exercise-conditioned serum showed an 80% reduction in
colony formation among the cancerous cells (Kurgan et al. 2017). Tumors typically favor aerobic glycolysis as a mechanism for obtaining the energy needed to survive and grow. Tumors are not living as separate entities in the human body; energy utilized for exercise is going to put added stress on to the tumor and limit its ability to grow. The utilization of aerobic metabolism in tumors causes lactate to build up in the surrounding tissue, which contributes to the inhibition of cytotoxic T cells. However, exercise opposes this effect in that it is able to decrease lactate levels within the body (Hojman et al. 2017). Lactate increases in the blood as a byproduct of the glycolytic cycle which is utilized by the body for rapid energy production. Exercise can increase lactate clearance by causing oxidation or the conversion of lactate to glucose which provides energy.

It is clear that exercise provides several positive benefits for cancer patients; however, there are no specific guidelines to prescribe the proper frequency, mode, intensity, and duration of exercise for cancer patients undergoing active treatment. This allows autonomy for cancer patients to choose exercises and activities that meet their goals and abilities, but makes it difficult to determine the optimal exercise prescription (Stout, Baima, Swisher, Winters-Stone, & Welsh 2017). The general consensus is that vigorous intensity exercise, 60-90% of a patient’s heart rate reserve, is more effective than moderate, 40-60% of a patient’s heart rate reserve, and lower intensity, 30-40% of a patient’s heart rate reserve. However, lower intensity exercise has been shown to induce improvements in individuals who were previously inactive and deconditioned (Stout et al. 2017). Vigorous exercise has been shown to increase blood flow and the production of mitochondria which means that there is more oxygen and immune cells circulating throughout the body. In a study conducted by Courneya et al. (2013), it was found that aerobic exercise performed in bouts of 50-60 minutes was more effective in slowing cancer progression than were
bouts of 25-30 minutes and a combination routine incorporating resistance and aerobic exercise for 50-60 minutes. Additionally, a review conducted by Segal et al. (2017) revealed that increasing intensity maximizes benefits, while increasing duration of each individual exercise bout shows no significant increase in benefits. Exercise interventions that are performed regularly for a longer period of time, typically greater than eighteen weeks, also allow for maximization of the quality of life and fitness benefits which can be obtained by exercising cancer patients (Segal et al. 2017). It is important for cancer patients to maintain an active lifestyle during and beyond their cancer diagnosis and treatment.

When creating an exercise prescription for a cancer patient, it is important that the plan be individualized based on each patient’s cancer type, treatment paths, individual side effects, and risks. Supervised exercise training sessions has also been shown to maximize training benefits as a result of better control over technique, effort, and total work capacity/performance (Stout et al. 2017). Performing exercise under supervised conditions also allows for an educational component to be incorporated into the exercise regimen. Proper education of form and technique, especially in resistance training exercises, allows for optimum safety to be achieved (Segal et al. 2017). While supervision has proven to be important, the end goal of an initial exercise prescription should be to make the program feasible on an independent basis (Stout et al. 2017; Segal et al. 2017). The exercise program should allow for performance within the home of the patient or in a facility to which they have easy access in order to increase adherence. There also needs to be further investigation into what screening needs to take place prior to exercise clearance. Patients need to be examined for potential side effects, toxicities, and functional deficiencies that can occur as a result of their treatment modalities (Stout et al. 2017).
This will allow the exercise prescription be personalized to improve efficacy and ensure the safety of the patient.

A variety of factors may prevent a cancer patient undergoing active treatment from participating in exercise. First, the patient’s self-efficacy must be assessed along with their motivation level (Bernsten et al. 2017). Second, cancer patients report joint stiffness, fatigue, and pain as barriers to becoming and remaining physically active. Third, cancer patients affirm that the lack of education regarding the benefits of exercise during and after treatment prevents their regular engagement (Fernandez et al. 2015). A study conducted by Fernandez et al. (2015), utilized a survey to determine exercise frequency and intensity in cancer patients, as well as their perceived barriers. After 30 cancer patients were surveyed, it was revealed that 66.7% of them engaged in regular physical activity during active cancer treatment. However, these patients did show a decreased frequency in physical activity when compared to their activity level prior to cancer diagnosis. Only four of the study participants reported that they had previously received education regarding the benefits of exercise (Fernandez et al. 2015). Another study demonstrated that a fear of exercise is common among breast cancer patients as a result of the lack of education they received in regards to the safety and efficacy of exercise during cancer treatment (Sander, Wilson, Izzo, Mountford, & Hayes 2012). These findings demonstrate the need for evaluation and assessment of barriers to physical activity for cancer patients prior to creating reasonable exercise prescriptions as well as adherence and relapse prevention strategies.
Exercise during cancer recovery.

More than 70% of recent cancer survivors in 2015 were considered inactive prior to undergoing treatment (Culos-Reed, Williamson, Sellar, & McNeely 2017). The debilitating effects of cancer treatments such as ionizing radiation treatments can be acute or long lasting. These long-term effects can present immediately post treatment or months to years after treatment cessation (Schmitz et al. 2010). These effects typically include fatigue, muscle weakness, pain, emotional stress, elevated blood pressure, and decreased functionality of the body. Exercise has been shown to decrease emotional stress and blood pressure in addition to improving muscular strength, bone mineral density, and balance following cancer treatment. It is important to acknowledge the ability of exercise to restore muscular strength and bone mineral density because chemotherapy can contribute to muscular atrophy and decreases in strength. This occurs as a result of the alteration in the functionality of the sarcoplasmic reticulum and mitochondria in patients who were treated by chemotherapy. These alterations limit the ability of muscles to generate force, which leads to atrophy (Barber 2012). However, muscular hypertrophy achieved via resistance training serves to counteract this effect. Additional research has shown that cancer survivors who engage in regular exercise can reduce their risk of mortality and recurrent cancer by 50% (Denning & Hunter 2017).

During an American College of Sports Medicine (ACSM) round table on exercise guidelines for cancer patients, panel members analyzed research on cancer survivors of breast, colon, prostate, hematologic, and gynecologic cancers. The evidence showed that when creating an exercise prescription for cancer survivors, exercise professionals should consider the patient’s aerobic fitness level prior to the initiation of treatment, their treatment responses and side effects, and their comorbidities. Analysis of these factors allows for the exercise prescription to be
individualized for safe execution and maximal efficacy. The round table designated eight goals of an exercise prescription for cancer survivors as follows:

1. To regain and improve physical function, aerobic capacity, strength and flexibility.
2. To improve body image and quality of life.
3. To improve body composition.
4. To improve cardiorespiratory, endocrine, neurological, muscular, cognitive, and psychosocial outcomes.
5. Potentially, to reduce or delay recurrence or a second primary cancer.
6. To improve the ability to physically and psychologically withstand the ongoing anxiety regarding recurrence or a second primary cancer.
8. To improve the physiologic and psychological ability to withstand any current or future cancer treatments. (Schmitz et al. 2010)

The panel members also acknowledged that it is imperative for cancer survivors to avoid inactivity in order to prevent deconditioning and decrease the potential negative effects that follow cancer treatments (Schmitz et al. 2010).

Research shows that aerobic exercise is helpful in the restoration of the functionality of the autonomic nervous system, a benefit that is most notable in the reduction of resting heart rate variability in cancer survivors. This was further demonstrated in a study in which cancer survivors were assessed before and after an exercise intervention examining maximal oxygen uptake, aerobic capacity, and heart rate recovery. Following the completion of the exercise intervention, participants demonstrated a linear relationship between the improvements in aerobic capacity and heart rate recovery. Patients who were more deconditioned at the initiation
of the exercise program showed the most significant improvements (Niederer, Vogt, Gonzalez-Rivera, Schmidt, & Banzer 2015). Flexibility exercises should also be performed by cancer survivors in order to reduce the risk of lymphedema, fractures, and infections (Schmitz et al. 2010).

It is also important to acknowledge the psychosocial and supportive care needs of cancer survivors when creating an exercise prescription. Further research is needed in order to determine what specifically needs to be done to address the needs (Cavers, Cunningham-Burley, Campbell, & Watson 2017). However, LifeSpring, an exercise and education program for cancer survivors, is being implemented nationally. The program is twelve weeks long and consists of two exercise sessions and one education session per week. Individuals who have completed the program reported decreased fatigue, depression, and sleep disruptions. These individuals also reported improved quality of life (Gerpen & Becker 2013). Additionally, exercise in cancer survivors was evaluated for its effect on psychological stability and physical functioning. While the study was limited to breast cancer survivors, the exercise intervention showed significant improvements in the survivors’ overall quality of life, as is shown by the data illustrated in Figure 3. It is important that the psychological aspect of exercise is acknowledged when working with cancer survivors in order to maximize all of the benefits exercise can provide.
Figure 3. Perceived quality of life scores over time. The graph above shows the perceived quality of life scores for each of six participants in a research study conducted by Wiggins and Simonavice which exposed cancer survivors to an exercise intervention. Wiggins, M. S., & Simonavice, E.S. (2008). Quality of Life Benefits: A 12 Month Exercise & Cancer Recovery Case Study. Kentucky Newsletter For Health, Physical Education, Recreation & Dance, 44(2), 16-19.

In a case study analysis performed by Denning and Hunter (2017), a physiotherapy exercise program was assessed for its effects in cancer survivors. The exercise intervention, which was led over the telephone, utilized by the study showed significant improvements in fatigue, fitness, and treatment related symptoms in participants (Denning & Hunter 2017). Another study conducted by Repka et al. (2014), aimed to show that exercise was beneficial regardless of cancer type. The study utilized an exercise intervention that incorporated
endurance, resistance, balance, and flexibility training three days per week for three consecutive months. The results of the study showed significant improvements in quality of life in patients who had previously been diagnosed with breast cancer, prostate cancer, hematological cancer, and glandular and epithelial neoplasms. The average fatigue ratings also decreased by 17% across all cancer types. Breast cancer and gynecologic cancer patients also showed a significant decrease in systolic blood pressure. Significant improvements in cardiorespiratory endurance were also seen in four groups analyzed. This data suggests that responses to exercise are not specific to cancer types (Repka et al. 2014). More research needs to be conducted in regards to the effects that exercise has on all types of cancers rather than the most common types.

While it is evident that exercise has a positive impact on the overall quality of life of cancer survivors, more research and efforts are needed to make exercise a standard of care for cancer patients and survivors (Culos-Reed et al. 2017). Research has shown that non-smoking and low stress individuals are more likely to engage in regular exercise following the cessation of cancer treatment (Kampshoff et al. 2016). It is important that health care professionals be educated on the positive impact of exercise on cancer survivors. This education will allow for referral to exercise professionals to motivate survivors to continue regular exercise and ensure they are receiving appropriate exercise prescriptions. Exercise professionals working with cancer survivors need specialized education regarding the role of exercise in successful cancer recovery. Professionals need to be able to assess the patient’s medical history, perform baseline testing, and create feasible individualized exercise plans for their patients. This may involve addressing psychosocial factors and practical concerns rather than just physical limitations. If all of these things are to take place, it will be possible for cancer survivors to become more regularly engaged in physical activity following the cessation of treatment (Culos-Reed et al. 2017).
Results

Eight relevant peer-reviewed journal articles were analyzed and included in the review based on their assessment of the relationship between exercise and cancer prevention. Each of the eight studies was a literature review conducted within the last ten years. Eight peer-reviewed studies were included in relation to prehabilitation for surgical cancer patients. The studies included discussed exercise as it has an effect on the prehabilitation for surgery in patients diagnosed with lung cancer, colorectal cancer, and breast cancer specifically. There were two studies included that assessed exercise as prehabilitation for several types of cancer rather than one particular type. The study designs included were three randomized controlled trials, five literature reviews, and a cohort study. All of the studies relating to prehabilitation agreed and provided evidence to support that preoperative physical activity in surgical cancer patients contributes to minimizing postsurgical complications, increases functional capacity, as well as decreases the recovery time following surgery. There were eleven articles that looked into the relationship between exercise and cancer treatment. These peer reviewed articles consisted of five systematic literature reviews, a meta-analysis, a series of case studies, a randomized controlled trial, a pragmatic study, and a cross-sectional study. Eleven peer-reviewed journal articles which assessed exercise as it relates to cancer recovery were included in this literature review. The study designs included in the review were one consensus statement, a case study preliminary analysis, a randomized controlled trial, systematic literature reviews, a cross sectional study, a combination of surveys and questionnaires, and a randomized control trial. All of the studies were analyzed and reviewed for their relevance and contributions to the relationship between cancer and exercise.
Table 1

Exercise and Cancer Prevention Resources

<table>
<thead>
<tr>
<th>Article Title</th>
<th>Journal Title</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can exercise-related improvements in immunity influence cancer prevention and prognosis in the elderly?</td>
<td>Maturitas</td>
<td>2013</td>
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<tr>
<td>Physical activity and cancer prevention: a systematic review of clinical trials</td>
<td>Cancer Causes &amp; Control</td>
<td>2011</td>
</tr>
<tr>
<td>The impact of physical activity for cancer prevention: implications for nurses</td>
<td>Seminars In Oncology Nursing</td>
<td>2016</td>
</tr>
<tr>
<td>Exercise protects from cancer through regulation of immune function and inflammation</td>
<td>Biochemical Society Transactions</td>
<td>2017</td>
</tr>
<tr>
<td>Molecular mechanisms linking exercise to cancer prevention and treatment</td>
<td>Cell Metabolism</td>
<td>2017</td>
</tr>
<tr>
<td>Exercise &amp; cancer</td>
<td>IDEA Fitness Journal</td>
<td>2016</td>
</tr>
</tbody>
</table>
Table 2

**Exercise and Cancer Prehabilitation Resources**

<table>
<thead>
<tr>
<th>Article Title</th>
<th>Journal Title</th>
<th>Year</th>
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</thead>
<tbody>
<tr>
<td>Promoting a culture of prehabilitation for the surgical cancer patient</td>
<td><em>Acta Oncologica</em></td>
<td>2017</td>
</tr>
<tr>
<td>Inhibition of human lung cancer cell proliferation and survival by postexercise serum is associated with the inhibition of Akt, mTOR, p70 S6K, and Erk1/2</td>
<td><em>Cancers</em></td>
<td>2017</td>
</tr>
<tr>
<td>The importance of exercise in lung cancer treatment</td>
<td><em>Translational Lung Cancer Research</em></td>
<td>2016</td>
</tr>
<tr>
<td>The effect of pre- and post-operative physical activity on recovery after colorectal cancer surgery (PHYSSURG-C): study protocol for a randomised controlled trial</td>
<td><em>Trials</em></td>
<td>2017</td>
</tr>
<tr>
<td>“Prehabilitation” can improve cancer treatment outcomes</td>
<td><em>Women’s Health Advisor</em></td>
<td>2014</td>
</tr>
<tr>
<td>Unexpected readmissions after major cancer surgery: an evaluation of readmissions as a quality-of-care indicator</td>
<td><em>Surgical Oncology Clinics of North America</em></td>
<td>2012</td>
</tr>
<tr>
<td>Cancer prehabilitation and its role in improving health outcomes and reducing health care costs</td>
<td><em>Seminars in Oncology Nursing</em></td>
<td>2014</td>
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Table 3

*Exercise and Cancer Treatment Resources*

<table>
<thead>
<tr>
<th>Article Title</th>
<th>Journal Title</th>
<th>Year</th>
</tr>
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<tbody>
<tr>
<td>Design of a randomized controlled trial of physical training and cancer (Phys-Can) the impact of exercise intensity on cancer related fatigue, quality of life and disease outcome</td>
<td><em>Bmc Cancer</em></td>
<td>2017</td>
</tr>
<tr>
<td>Implementing exercise in cancer care: study protocol to evaluate a community-based exercise program for people with cancer</td>
<td><em>BMC Cancer</em></td>
<td>2017</td>
</tr>
<tr>
<td>Physical activity and cancer: a cross-sectional study on the barriers and facilitators to exercise during cancer treatment</td>
<td><em>Canadian Oncology Nursing Journal</em></td>
<td>2015</td>
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<tr>
<td>The effectiveness of exercise interventions for improving health-related quality of life from diagnosis through active cancer treatment</td>
<td><em>Oncology Nursing Forum</em></td>
<td>2015</td>
</tr>
<tr>
<td>Exercise is an effective treatment modality for reducing cancer-related fatigue and improving physical capacity in cancer patients and survivors: a meta-analysis</td>
<td><em>Applied Physiology, Nutrition, And Metabolism</em></td>
<td>2011</td>
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<td>Voluntary running suppresses tumor growth through epinephrine- and IL-6-dependent NK cell mobilization and redistribution</td>
<td><em>Cell Metabolism</em></td>
<td>2016</td>
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<tr>
<td>Cancer type does not affect exercise-mediated improvements in cardiorespiratory function and fatigue</td>
<td><em>Integrative Cancer Therapies</em></td>
<td>2014</td>
</tr>
<tr>
<td>Exercise for people with cancer: a systematic review</td>
<td><em>Current Oncology</em></td>
<td>2017</td>
</tr>
<tr>
<td>Title</td>
<td>Journal</td>
<td>Year</td>
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<tr>
<td>A systematic review of exercise systematic reviews in the cancer literature</td>
<td>PM &amp; R: The Journal of Injury, Function, and Rehabilitation</td>
<td>2017</td>
</tr>
<tr>
<td>Tumor chemosensitation by physical exercise? Insights from an animal model</td>
<td>Future Oncology</td>
<td>2015</td>
</tr>
<tr>
<td>Effects of exercise dose and type during breast cancer chemotherapy: multicenter randomized trial.</td>
<td>Journal of the National Cancer Institute</td>
<td>2013</td>
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</table>
### Table 4: Exercise and Cancer Recovery Resources

<table>
<thead>
<tr>
<th>Article Title</th>
<th>Journal Title</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social support and physical activity engagement by cancer survivors</td>
<td>Clinical Journal Of Oncology Nursing</td>
<td>2012</td>
</tr>
<tr>
<td>Living with and beyond cancer with co-morbid illness: reflecting on a research prioritization exercise</td>
<td>Psycho-Oncology</td>
<td>2017</td>
</tr>
<tr>
<td>Why cancer survivors need to move more: Building an Alberta exercise program</td>
<td>Wellspring</td>
<td>2017</td>
</tr>
<tr>
<td>Cancer recovery and a personalized exercise service: a preliminary analysis</td>
<td>Physiotherapy</td>
<td>2017</td>
</tr>
<tr>
<td>Participation in and adherence to physical exercise after completion of primary cancer treatment</td>
<td>International Journal of Behavioral Nutrition and Physical Activity</td>
<td>2016</td>
</tr>
<tr>
<td>Heart rate recovery and aerobic endurance capacity in cancer survivors: interdependence and exercise-induced improvements</td>
<td>Supportive Care In Cancer: Official Journal Of The Multinational Association Of Supportive Care In Cancer</td>
<td>2015</td>
</tr>
<tr>
<td>Factors that affect decisions about physical activity and exercise in survivors of breast cancer: A qualitative study</td>
<td>Physical Therapy</td>
<td>2012</td>
</tr>
<tr>
<td>A randomized trial of aerobic versus resistance exercise in prostate cancer survivors</td>
<td>Journal of Aging And Physical Activity</td>
<td>2013</td>
</tr>
<tr>
<td>College of Sports Medicine roundtable on exercise guidelines for cancer survivors</td>
<td>Medicine And Science In Sports and Exercise</td>
<td>2010</td>
</tr>
<tr>
<td>Development of an evidence-based exercise and education cancer recovery program</td>
<td>Clinical Journal of Oncology Nursing</td>
<td>2013</td>
</tr>
<tr>
<td>Quality of Life Benefits: A 12 Month Exercise &amp; Cancer Recovery Case Study</td>
<td>Kentucky Newsletter For Health, Physical Education, Recreation &amp; Dance</td>
<td>2008</td>
</tr>
</tbody>
</table>
Summary and Conclusion

Overall, there is a great deal of supporting evidence demonstrating that exercise provides numerous benefits as primary, secondary, and tertiary prevention of cancer. Exercise reduces the risk of cancer and decreases the recovery time and side effects experienced due to a surgical procedure. Research also shows that exercise can slow tumor growth and improve the effects of treatment modalities. Lastly, exercise also provides many psychological benefits, most importantly significant improvements in the overall functional capacity and quality of life in cancer patients and survivors. As research continues to expand, it is clear that cancer patients could benefit from exercise being incorporated into their treatment and recovery plan.

Prior to this research project, I knew very little about the effects of cancer on the body as well as what can be done to prevent them. I have found that exercise provides substantial benefits over the course of cancer treatment as well as in its prevention. However, I feel that this is often overshadowed by the negative side effects associated with cancer. It is important for medical professionals to be aware of the benefits that exercise may provide. Raising medical awareness and patient education that exercise may provide therapeutic benefits during cancer treatment and recovery needs more attention. Going forward in my professional career as a physician assistant, I will continue to emphasize the importance of exercise for cancer patients and seek to educate my colleagues and patients. If patients and medical professionals are aware of the benefits that exercise can provide, they are more likely to minimize the negative effects associated with cancer.
References


http://doi.org/10.1016/j.ygyno.2014.10.013
