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Effects of a 12-Week Exercise Intervention on Joint Kinetics During Curb Negotiation in Cancer Survivors

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EFFECTS OF A 12-WEEK EXERCISE INTERVENTION ON JOINT KINETICS DURING CURB NEGOTIATION IN CANCER SURVIVORS

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ABSTRACT

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Cancer is very prevalent in the United States and many people who live with cancer are older adults. Cancer and cancer treatments can be very difficult on the body causing many symptoms that can increase the survivor's risk of falling. Risk of falling can be even greater when people are required to negotiate obstacles such as curbs or stairs. Research has shown that exercise can reduce symptoms of cancer and cancer treatments and potentially decrease risk of falling. Fourteen cancer survivors, recruited from University of Northern Colorado Cancer Rehabilitation Institute, completed a pre-assessment session followed by a gait assessment while negotiating a curb in a laboratory setting. Walking speed was not significantly different between pre- and post-test sessions. In both the GROUND and CURB legs, toe clearance decreased significantly. Changes in angular velocity were observed post training. Peak plantar flexor moments of both legs also increased post training. There was a significant increase in knee flexion moment for both legs as well as an increased extensor moment for the CURB leg. Changes in hip extensor moments were observed in both legs. Power increased in all three joints in both legs. Positive work increased in both legs at the knee and hip and just in the CURB leg at the ankle, total work increased in the CURB leg at all three joints. The change in power output in the ankle joint could potentially decrease the risk of falling which may potentially improve the quality of life of cancer survivors.

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CHAPTER I

GENERAL INTRODUCTION

Introduction

Cancer is a disease that affects many people and is non-discriminant to age, ethnicity, or gender. In 2017 there will be an estimated 1.7 million people newly diagnosed with cancer, approximately 67% of them will survive with cancer for five years or more (Surveillance, Epidemiology, and End Results program, seer.cancer.gov). About 78% of people diagnosed with cancer are age 55 years or older and just over 50% of newly diagnosed individuals are between the ages of 55 and 74 years (seer.cancer.gov).

Quality of life of those individuals living with cancer is often reduced. Common symptoms that arise with cancer are pain, fatigue, muscle weakness, vision impairments, and balance deficits (Huang, Shilling, Miller, Smith, and LaVictoire, 2015). Chemotherapy and radiation are common cancer treatments; however, these treatments result in various side effects that negatively impact the quality of life of cancer survivors. Some common side effects of chemotherapy include cardiotoxicity and skeletal muscle dysfunction, both of which can severely affect the ability to perform activities of daily living (Hydock, Lien, Jensen, Schneider, & Hayward, 2011). In addition, chemotherapy-induced neuropathy often occurs, which creates greater difficulty with balance and increases the individual's risk of falling (Hydock et al., 2011). Certain cancers have also been found to upset the balance of bone formation and resorption which can lead to advanced osteoporosis (Body et al., 2016).

Both cancer and cancer treatments cause symptoms that increase the risk of falling such as loss of balance, muscle weakness, neuropathy, bone loss, and cardiotoxicity. Given that a majority of new cancer diagnoses will be 55 years or older means that they may also be experiencing age-related gait changes such as slower walking speeds, shorter step lengths, wider base of support, increased double support time, and increased variability in toe clearance (Winter, Patla, Frank & Walt, 1990; Ajisafe, Wu, & Geil, 2017). Combined, these gait changes increase an individual's risk of falling (Chen & Janke, 2013). Research has suggested that once an individual falls, they will most likely fall again (Chen et al., 2013). Falls not only decrease quality of life, but they can be fatal, especially in older adults (Wildes et al., 2015). The potential to fall is increased even more when taking into account obstacle negotiation. Everyday, people have to negotiate curbs, steps, and other changes in elevation which are more demanding than walking across an even surface (Standifird et al., 2016).

Due to the side effects of cancer and cancer treatments, cancer management often focuses on reducing the detrimental effects of cancer and cancer treatments. Recently, exercise has been used in cancer survivors as a way to combat cancer and cancer treatment-related symptoms both over the short-term and long-term; however, there is still a lack of understanding as to how exercise can aid in reducing symptoms of cancer or side effects due to treatments (Stevenson & Fox, 2005). Exercise has been found to increase the quality of life, elevate mood, slow bone loss and preserve bone density, reduce cardiotoxicity, and increase muscle mass (Lien, Jensen, Hydock, & Hayward, 2015; Yeo et al., 2012).

Diabetic patients often exhibit distal neuropathy similar to that experienced in cancer survivors. Individuals who suffer from diabetes who have participated in exercise programs have displayed improvements in postural sway and gait during standing and over ground walking (Handsaker et al., 2016). Improvements in gait and balance, such as walking speed and postural sway, in seniors have also been attributed to participation in exercise programs (Bouaziz et al., 2016). When exercise is prescribed for cancer survivors, it is most effective when individualized to the survivor's needs and supervised as opposed to home-based (Meneses-Echavez, Gonzalez-Jimenez, & Ramirez-Velez, 2015). A systematic review by Bouaziz et al., (2016) suggests that physical activity in seniors should focus on several factors: "moderate-intensity aerobic activity, muscle strengthening, reducing sedentary behavior, and risk management." (Bouaziz et al., 2016, p. 521). The use of multi-modal exercise programs for the elderly have been found to improve VO_{2peak} values, decrease body mass index and fat mass, an increase in fat free mass, and reduced triglycerides and high-density lipoprotein serum levels (Bouaziz, et al., 2016). Further, participation in supervised multi-modal exercise programs by cancer survivors improves cardiopulmonary function, increases muscle strength, improves balance, improves walking ability, and increases flexibility (Bouaziz, et al., 2016; Hsieh et al., 2008).

A specific change that has been suggested to increase the risk of falling in older individuals is a reduction in ankle power generation, which is believed to be due to decreased plantarflexor strength (Kerrigan, Todd, Croce, Lipsitz, & Collins, 1998).

Kerrigan et al., (1998) found that in a group of elderly participants who were considered "fallers" ankle power was consistently lower than that of "non-fallers". (Bouaziz, et al., 2016). However, it is unclear as to whether exercise could benefit gait mechanics in a way that would reduce risk of falling.

The major benefit that exercise interventions can provide by improving gait and balance is reducing the risk of falling which could in turn improve overall quality of life. Age and disease can alter gait and older adults with cancer are more likely to experience a fall than an older adult without cancer (Spoelstra et al., 2013; Viswanathan & Sudarsky, 2012). Many of the gait changes that are experienced as people age are due to a loss of balance, which can lead to falls and fear of falling. In the elderly, there are many changes across many different systems that affect the ability to maintain balance during locomotion. These changes can include both sensory and motor function, specifically changes in vision, the vestibular system, sensory integration, strength, reaction time, and mobility performance (Sturnieks, St George, & Lord, 2008). Falls cause many problems among the elderly, including injuries, loss of mobility, and even death (Winter et al., 1990). Winter et al. (1990) found that while many studies addressed upright balancing tasks and tried to link them to falls, locomotion and the balance required during locomotion was actually a better predictor of falls. It is also important to take into account the ability to negotiate obstacles safely during locomotion as most people will encounter curbs, steps, or stairs during their daily activities. When compared to younger adults, older adults made more mistakes when adapting to an unknown change, and take smaller steps prior to negotiating an obstacle (Caetano et al., 2016). Caetano et al. (2016) also found that older adults had shorter step lengths, decreased step velocity and increased double support time when compared to younger adults asked to do the same task. Another important factor when negotiating obstacles is toe clearance. Older adults tend to have greater variability in toe clearance, which has been linked to increased risk of falling (Ajisafe et al., 2017; Mills, Barrett, & Morrison, 2008).

Therefore, the purpose of this study was to investigate the effects of a 12-week exercise intervention on joint kinetics during curb negotiation in cancer survivors. Since exercise has been shown to improve gait and muscle strength, it is hypothesized that:

H1 Joint moments and powers would increase post training in both GROUND and CURB legs.

H2 Joint work would increase post training in both GROUND and CURB legs.

H3 Toe clearance variability would decrease in both GROUND and CURB legs post training.

CHAPTER II

REVIEW OF LITERATURE

Cancer

Cancer is a disease that causes the body's cells to divide and grow at a rapid rate developing tumors which can cause many symptoms that can decrease quality of life. (Surveillance, Epidemiology, and End Results program, SEER, seer.cancer.gov). It was estimated that for the year 2017 there would be 1,688,780 new cases of cancer in the United States and just under 600 thousand people are expected to die from cancer. Based on research done by SEER from 2006 to 2012 only 66.9 percent of people living with cancer will survive for 5 years or more.

Many symptoms of cancer are also symptoms of cancer treatments. Symptoms experienced from the disease and/or treatment are "pain, fatigue, muscle weakness, vision and cognitive impairments, difficulty with balance and walking". (Huang et al., 2015, p. 1497). Problems with balance and walking can develop during treatment or right after and can linger for years after treatment has been completed (Huang, Miller, Smith, Fredrickson and Shilling, 2016). This difficulty with balance and walking can lead to an increased risk of falling especially in an aging population which can inadvertently lead to a decrease in quality of life (Huang et al., 2016).

Cancer Treatments

Of the many treatments for cancer, chemotherapy and radiation are commonly used. There are three types of radiation therapy, internal, external and systemic radiation (American Cancer Society, cancer.org). When a patient is treated with external radiation a machine is used to precisely aim a beam of radiation at the cancer. During internal radiation, a source of radiation is implanted inside the body, either intracavitary or interstitially using a pellet, capsule, wire, etc. (American Cancer Society, cancer.org). Systemic radiation therapy uses radioactive drugs given by mouth or intravenously so that they travel through the body and pool around the location of the cancer cells (American Cancer Society, cancer.org). Radiation therapy takes several days or weeks of treatment before it begins to destroy the cancer cells; however, these cancer cells usually continue to die for several months after treatment has stopped (National Cancer Institute, Cancer.gov). While the goal of radiation is to kill or slow the growth of cancer cells, it often affects the surrounding healthy cells as well. The death of these healthy cells can cause some unwanted side effects such as fatigue (cancer.org).

Chemotherapy, similar to radiation, is used to slow or stop the growth of cancer cells. Chemotherapy can be delivered orally, intravenously, intrathecal, intracavitary, intra-arterial, or topical (cancer.org). The type of chemotherapy that a person receives is dependent on cancer type, and whether it will be used to kill the cancer, control its growth or ease symptoms. Chemotherapy is often given in cycles, meaning that there are periods of rest after receiving chemotherapy for a certain amount of time. Doxorubicin (DOX), is a chemotherapy drug that is used to manage a variety of cancers (Chicco, Schneider, and Hayward, 2006). One major side-effect of DOX is cardiotoxicity.

Cardiotoxicity can be acute or chronic and usually presents similar to cardiomyopathy or congestive heart failure (Hydock, Lien, Jensen, Schneider, and Hayward, 2011). Chemotherapy can also kill or slow the growth of healthy cells in addition to the cancer cells that it is targeting, which can cause side effects including fatigue, anemia, appetite loss, pain, peripheral neuropathy, cardiotoxicity, bone loss, and many more (Huang, et al., 2015; Hydock, et al., 2011).

Cancer Symptoms and Aging

Cancer and cancer therapies can cause changes in body movement due to their effects of the neurologic and musculoskeletal systems (Hojan, 2012). About 20% of cancer patients deal with neurological complications during their illness; nerves can be the target of cancer cells or nerves can be compressed by a tumor. Radiation and chemotherapy can cause fibrosis, neurotoxicity and peripheral neuropathy (Hojan, 2012). Loss of sensation, especially in the periphery can predispose people to falls, some researchers have suggested that aging and loss of innervation can cause changes at the muscle spindle which contributes further to decreased proprioception and balance (Sturnieks, St. George, & Lord, 2008). The musculoskeletal effects that cancer and cancer treatments can cause include atrophy, decreased range of motion, myopathy, and osteoporosis. Many of the listed musculoskeletal effects can lead to other serious complications, such as osteoporosis and decreased mineral content in bones leading to an increased risk of fractures especially in high weight bearing bones such as the femur (Hojan, 2012). The majority of people who are estimated to be diagnosed with cancer in 2017 will be over the age of 55 (seer.cancer.gov). Thus, a majority of cancer survivors are older adults who may be beginning to experience age related gait changes. Many of these changes are due to loss of balance, which can cause falls and increase the incidence of injuries such as fractures or head injuries (Wildes et al., 2015). Older cancer survivors may be at a higher than normal risk of falling because the treatment for cancer has impacts on the entire body, not just cancer cells.

As a person ages they progressively lose lean body mass, specifically there tends to be a notable loss of fast twitch fibers (Sturnieks et al., 2008). This loss of muscle causes a loss of strength, especially in the legs. Reduced hip knee and ankle torques while performing a single step balance recovery task, which made it more difficult to recover from a trip or perturbed balance and is believed to increase the risk of injury have been reported (Sturnieks et al., 2008). Kerrigan et al. (2000) found that there was a decrease in hip extension and adduction moments, hip power absorption and generation at pre-swing, knee flexion moment at mid-stance and pre-swing, knee power absorption at pre-swing and ankle power generation and an increase in hip flexion moment at stance between fallers and non-fallers at comfortable walking speeds. Some of these differences were speculated to be caused by a decrease in stride length causing the swing limb to be closer to the center of mass, where the reductions observed at the knee could indicate increased stiffness at the knee joint during walking (Kerrigan et al., 2000). Increased stiffness at the knee could increase the risk of falling because knee flexion is needed during the swing phase to aid in adequate toe clearance. Other gait changes that may be experienced are an increased stance time, decreased step length, and increased step width (Brach, Studenski, Perera, VanSwearingen, & Newman, 2008; Kerrigan et al., 2000). Kerrigan et al. (2000) also found that in a group of elderly adults with a history of falling comfortable and fast walking speed was slower than non-fallers. Many of these changes are due to the loss of balance which can cause falls and increase incidence of injuries such as fractures or head injuries (Wildes et al., 2015). Older cancer survivors may be at a higher than normal risk of falling because the treatment for cancer causes both acute and chronic changes to the entire body that can affect balance and gait negatively. Changes that are often seen in older adults are slower walking speeds, shorter step lengths, and a wider base of support which all aid with increasing the amount of time spent in double support. Double support is the most stable phase during walking. (Winter et al., 1990). These age related changes can be exacerbated by the symptoms of cancer and cancer treatments, which is why it is important to research this and find a way to account for these during cancer treatment and rehabilitation.

Exercise for Symptom Relief

Cancer treatments have detrimental effects on the whole body and body systems and, in some cases, can be overwhelming, which might discourage patients from continuing treatment. Cancer treatments and aging can lead to a loss of muscle mass, decreased peripheral sensation, loss of balance, decreased stride length, and increased stance time and step width. (Brach et al., 2008; Kerrigan et al., 2000). Exercise defined as a “planned, structured, and repetitive body movement” (Yeo et al., 2012, p. 464) has been found to increase the quality of life in many populations and can aid in decreasing cancer and cancer treatment symptoms in general. One study showed that a combination of endurance, resistance and balance training aided in increasing muscle mass, decreasing fat mass, decreasing triglycerides and high-density lipoprotein levels, while improving balance, walking ability, flexibility, cognitive performance and quality of life in aging adults (Bouaziz et al., 2016). Preconditioning exercise training can also be beneficial in protecting against myocardial oxidative stress as shown in a rat model (Hydock et al., 2011). Other studies (Body et al., 2016) have shown that exercise can aid in reducing bone deterioration and preserving bone density, which is also important in an aging population since bone density tends to decrease as one gets older. Exercise increases muscle mass, promotes flexibility, and elevates overall mood, all of which help improve activities of daily living and quality of life. (Yeo et al., 2012). Exercise also reduces the negative emotions that often accompany people who have been diagnosed with a long term and/or fatal illness. (Zheng et al., 2010).

A systematic review by Meneses-Echavez et al. (2015), found that the most effective exercise programs were very individualized to the patient’s symptoms, treatments, and types of cancer, these programs usually lasted at least 12 weeks and supervised although a home exercise program can be successful if the patient is motivated effectively. While there are both short- and long-term benefits to participating in exercise for patients undergoing cancer treatments, very few actually report participating in exercise during their treatment. (Meneses-Echavez et al., 2015; Stevenson & Fox, 2005). The reasoning behind cancer patients not participating in exercise may be due to the lack of education about how exercise can help with cancer and lack of knowledge about exercise programs or classes available to the patient. (Stevenson & Fox, 2005).

Obstacle Negotiation

While several studies have looked into the risk of falling and gait changes associated with falling, most of these studies focus on walking on level ground. While walking safely across level ground is important, the world is not flat and people constantly encounter obstacles that are more demanding than over ground walking (Standifird et al., 2016). Many people have steps to their front door or multiple levels in their house, raised thresholds, etc. that they must be able to navigate safely every day. Failure to negotiate this type of obstacle can result in a fall, potentially reducing the person's quality of life. Not only can falls alter a person's quality of life, but they can potentially be fatal.

Several studies suggest that the minimum toe clearance variability can be an indication of an increase in risk of falling when negotiating curbs or stairs (Karmakar, Khandoker, Begg, & Palaniswami, 2011). As defined by Karmakar et al. (2011) minimum toe clearance "is the minimum vertical distance between the front part of the foot (shoe) and the ground" (Karamakar et al., 2011, p. 554). One study suggested that the there was no increase in toe clearance between young and older groups of men although there did seem to be a decreased ability to recover from a disturbance of gait, such as a trip or stumble (Mills et al., 2008). A Hamel, Okita, Bus and Cavanagh (2005) stated that older adults might have greater stiffness when stepping down from a height. Greater lower limb stiffness can result in difficulty attenuating forces and might lead to other issues such as arthritis, but landing on a stiff leg on a potentially slippery surface can also increase the chance of falling and causing serious injury. It is important to individualize the exercise program to the patient so that the deficits that they may be experiencing are being addressed. There is also a difference between over ground and curb negotiation or stair ascent. Handsaker et al. (2016) suggested that during stair ascent moments are generated more quickly during weight acceptance to help absorb forces and to control the flexion of the ankle and knee which allowed for more stability earlier on in the stride. Exercise programs should be designed so that they are addressing the needs of the individual and addressing the deficits they are experiencing Exercises that have been identified to potentially aid in obstacle negotiation and stair negotiation are: step ups and step downs, which are easy to progress and regress as needed; lunges, short hurdle tasks, balance tasks on solid and compliant surfaces and on both or one leg. It is important to investigate the potential changes in gait that occur because of cancer treatments and how they might affect obstacle negotiation to help design an exercise program that can target the changes.

CHAPTER III

JOURNAL ARTICLE

Introduction

In 2017 there will be an estimated 1.7 million people newly diagnosed with cancer, approximately 67% of them will survive with cancer for five years or more (Surveillance, Epidemiology, and End Results program, seer.cancer.gov). About 78% of individuals diagnosed with cancer are 55 years or older and just over 50% of newly diagnosed individuals are between the ages of 55 and 74 years (seer.cancer.gov).

Quality of life of those individuals living with cancer is often reduced. Common symptoms that arise with cancer are pain, fatigue, muscle weakness, vision impairments, and balance deficits (Huang, Shilling, Miller, Smith, and LaVictoire, 2015). Chemotherapy and radiation are common cancer treatments; however, these treatments result in various side effects that negatively impact the quality of life of cancer survivors. Common side effects of chemotherapy include cardiotoxicity and skeletal muscle dysfunction, both of which can severely affect the ability to perform activities of daily living (Hydock, Lien, Jensen, Schneider, & Hayward, 2011). In addition, chemotherapy-induced neuropathy often occurs, which creates greater difficulty with balance and increases the individual's risk of falling (Wildes et al., 2015). Certain cancers have also been found to upset the balance of bone formation and resorption which can lead to advanced osteoporosis (Body et al., 2016).

Wildes et al. (2015), reported results from several studies that suggested the risk of falling was generally increased in older adults with cancer when compared to older adults without cancer. Previous research also found that there was a significant increase in the numbers of falls that produced injuries in individuals with cancer over the age of 80 and with individuals who had longer hospital stays (Wildes et al., 2015). Both cancer and cancer treatments cause symptoms that increase the risk of falling such as loss of balance, muscle weakness, neuropathy, bone loss, and cardiotoxicity. Given that a majority of new cancer diagnoses will be 55 years of age or older means that they may also be experiencing age-related gait changes such as slower walking speeds, shorter step lengths, wider base of support, increased double support time, and increased variability in toe clearance (Winter, Patia, Frank & Walt, 1990; Ajisafe, Wu, & Geil, 2017). Combined, these gait changes can increase an individuals risk of falling (Chen & Janke, 2013). Research has suggested that once an individual falls, they will most likely fall again (Chen et al., 2013). Falls not only decrease quality of life, but they can be fatal, especially in older adults (Wildes et al., 2015). The potential to fall is increased even more when taking into account obstacle negotiation. Everyday, people have to negotiate curbs, steps, and other changes in elevation which are more demanding than walking across an even surface (Standifird et al., 2016).

Due to the side effects of cancer and cancer treatments, a lot of cancer management often focuses on reducing the detrimental effects of cancer and cancer treatment-related symptoms Recently, exercise has been used in cancer survivors as a way to combat cancer treatment-related symptoms both over the short-term and long-term; however, there is a lack of understanding as to how exercise can aid in reducing symptoms of cancer or side effects due to treatments (Stevenson & Fox, 2005). Exercise has been found to increase the quality of life, elevate mood, slow bone loss and preserve bone density, reduce cardiotoxicity, and increase muscle mass (Lien, Jensen, Hydock, & Hayward, 2015; Yeo et al., 2012).

Diabetic patients often exhibit distal neuropathy similar to that experienced in cancer survivors. Individuals who suffer from diabetes who have participated in exercise programs have displayed improvements in postural sway and gait during standing and over ground walking respectively (Handsaker et al., 2016). Improvements in gait and balance, such as walking speed and postural sway, in seniors have also been attributed to participation in exercise programs (Bouaziz et al., 2016). When exercise is prescribed for cancer survivors, it is most effective when individualized to the survivor's needs and supervised as opposed to home-based (Meneses-Echavez, Gonzalez-Jimenez, & Ramirez-Velez, 2015). A systematic review by Bouaziz et al. (2016) suggests that physical activity in seniors should focus on several factors: "moderate-intensity aerobic activity, muscle strengthening, reducing sedentary behavior, and risk management." (Bouaziz et al., 2016, p. 521). The use of multi-modal exercise programs for the elderly have been found to improve VO_{2peak} values, decrease body mass index and fat mass, an increase in fat free mass, and reduced triglycerides and high-density lipoprotein serum levels (Bouaziz, et al., 2016). Further, participation in supervised multi-modal exercise programs by cancer survivors improves cardiopulmonary function, increases muscle strength, improves balance, improves walking ability, and increases flexibility (Bouaziz, et al., 2016; Hsieh et al., 2008).

A specific change that has been suggested to increase the risk of falling in older individuals is a reduction in ankle power generation, which is believed to be due to decreased plantarflexor strength (Kerrigan, Todd, Croce, Lipsitz, & Collins, 1998). Kerrigan et al. (1998) found that in a group of elderly participants who were considered “fallers” ankle power was consistently lower than that of “non-fallers”. However, it is unclear as to whether exercise could benefit gait mechanics in a way that would reduce risk of falling.

The major benefit that exercise interventions can provide by improving gait and balance is reducing the risk of falling which could in turn improve overall quality of life. Age and disease can alter gait and older adults with cancer are more likely to experience a fall than an older adult without cancer (Spoelstra et al., 2013; Viswanathan & Sudarsky, 2012). Many of the gait changes that are experienced as people age are due to a loss of balance, which can lead to falls and fear of falling. In the elderly, there are many changes across many different systems that affect the ability to maintain balance during locomotion. These changes can include both sensory and motor function, specifically changes in vision, the vestibular system, sensory integration, strength, reaction time, and mobility performance (Sturnieks, St George, & Lord, 2008). Falls cause many problems among the elderly, including injuries, loss of mobility, and even death (Winter et al., 1990). Winter et al., (1990) found that while many studies addressed upright balancing tasks and tried to link them to falls, locomotion and the balance required during locomotion was actually a better predictor of falls. It is also important to take into account the ability to negotiate obstacles safely during locomotion as most people will encounter curbs, steps, or stairs during their daily activities. When compared to younger adults, older adults made more mistakes when adapting to an unknown change, and took smaller steps prior to negotiating an obstacle (Caetano et al., 2016). Caetano et al. (2016) also found that older adults had shorter step lengths, decreased step velocity and increased double support time when compared to younger adults asked to do the same task. Another important factor when negotiating obstacles is toe clearance. Older adults tend to have greater variability in toe clearance, which has been linked to increased risk of falling (Ajisafe et al., 2017; Mills, Barrett, & Morrison, 2008).

Therefore, the purpose of this study was to investigate the effects of a 12-week exercise intervention on joint kinetics during curb negotiation in cancer survivors. Since exercise has been shown to improve gait and muscle strength, it is hypothesized that we will see an increase in joint moments and joint powers post training and a decrease in toe clearance variability. With the increase in joint power, we also hypothesize to see an increase in joint work post training.

Methods

Participants

Fourteen cancer survivors with an average age of 64 ± 9 years participated in this study. Average height of the participants was 1.71 ± .08 m and average mass of the group was 79.7 ± 26 kg (see Table 3.1). The most common cancer type in this group was breast cancer (n = 5) and other cancer types included: multiple myeloma (n = 1), malignant melanoma (n = 1), chronic lymphatic leukemia (n = 1), B-cell lymphoma (n = 1), Merkel cell carcinoma (n = 1), left lung adenocarcinoma (n = 1), lobular carcinoma (n = 1), and esophageal cancer (n = 1). Of the 14 participants three received chemotherapy alone, four received chemotherapy and surgery, two received radiation and surgery, and five received chemotherapy, radiation, and surgery. Four participants were still receiving treatment during their assessments, six participants were less than six months since their last treatment, and four participants had received their last treatments 10 to 16 months prior to participation. All participants were recruited from the University of Northern Colorado Cancer Rehabilitation Institute. The university's Institutional Review Board approved the study protocol and participants provided a verbal and written informed consent prior to any data collection.

Table 3.1.

Demographics

Subject	Gender	Age (yrs)	Height (cm)	Mass (kg)	Cancer Type	Cancer Stage	Cancer Treatment		
							Chemotherapy	Radiation	Surgery
1	M	55	178	61.6	Multiple Myeloma	Unstaged (IV)	*+		*
2	F	46	163	75	Breast	II	*		*
3	M	61	179	90	Malignant Melanoma	IIIB	*		*
4	F	66	170	75	Breast	II	*		*
5	M	65	180	109.5	Chronic Lymphatic Leukemia (CLL)	II	*		
8	M	73	180	87.3	B-Cell Lymphoma	IV	*		
9	M	51	179	76.3	Throat	IIIB	*	*	
12	M	65	183	143.6	Merkel Cell Carcinoma	IIIB	*	*	*
15	F	84	166	65.9	Breast	I		*	*
19	F	69	164	61.8	Left Lung Adenocarcinoma	IV	*+		
20	F	56	170	55.5	Lobular Carcinoma	IIIC	*+	*	*
22	M	77	180	77.2	Esophageal	IIB	*	*	*
24	F	63	164	56.7	Breast	I		*+	*
25	F	60	166	72.7	Breast	III	*	*	*

Note: for Cancer Treatment * indicates the treatment received. *+ indicates treatment was current at the time of assessment.

Experimental Protocol

Each participant completed a pre-assessment session in which medical histories, a treadmill VO_{2peak} test, and a one-repetition max test were done to obtain baselines. These data were then used to design an individualized 12-week exercise intervention for each participant, and baseline measures were used to determine the intensity of the program and the rate of progression. The 12-week exercise intervention included aerobic, strength/resistance, balance and flexibility training 2 to 3 times per week. Each session lasted approximately one hour with 20 minutes designated for cardiovascular exercise, 30 minutes for resistance exercise, and 10 minutes for flexibility training. In the aerobic exercise portion of each session the participant could use a treadmill, cycle ergometer, NuStep, Auquaciser (underwater treadmill), or they could perform outdoor walking or jogging. Resistance exercises targeted muscles in the chest, back, lower extremities, and core. Three sets of 10 repetitions were performed for each resistance exercise and equipment that could be used for these exercises included: Cybex resistance machines, therabands, dumbbells, medicine balls, body weight, and resistance tubing. All muscles that were exercised during the training session were also targeted during the flexibility portion. In order to aid in the efficacy of the stretching, participants had access to rope pulleys, range of motion wheels, and ropes.

Prior to and immediately following the 12-week training intervention, each participant's gait was assessed while negotiating a curb. To recreate a curb in the laboratory, two force plates embedded in tandem in the floor and a third force plate mounted on a steel frame was placed in line with the other two force plates. By using this design we were able to collect a step on the ground (GROUND) prior to the curb and a step up to the curb (CURB) (See Figure 3.1). The top of the curb plate was 16 cm higher than the ground plates and a wooden walkway was placed around the curb plate which extended 3 m beyond the curb plate to provide a level walking space. This simulated a curb similar to what someone would have to navigate on a daily basis. Typical curb heights can range from 10 cm to 22.5 cm (U.S. Department of Transportation, 2014).

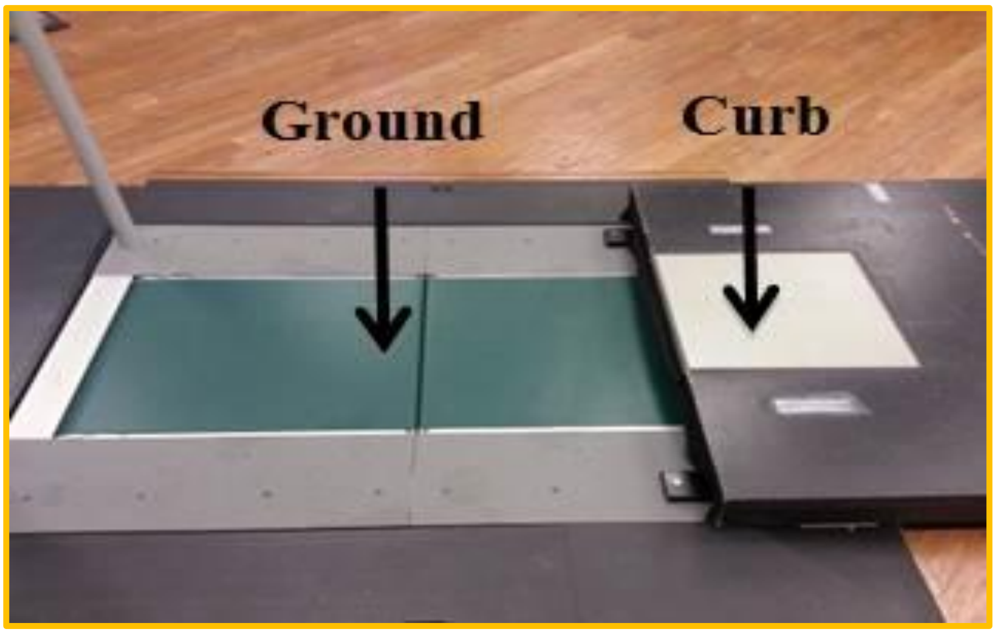

Figure 3.1. Image of the curb design.

Prior to data collection, participants were asked to change into tight fitting clothing in order to minimize marker motions relative to underlying anatomical landmarks during movement trials. Anthropometrics were then measured and used as inputs for the biomechanical model of the person during post-processing. Anthropometric measures included segment lengths and widths as well as whole body height and mass. Retroreflective markers were placed bilaterally on various anatomical according to guidelines for VICON's plug-in-gait model (VICON, Englewood, CO). Motion data were collected using a 10-camera motion capture system (100 Hz, VICON, Englewood. CO). Ground reaction forces were also measured (2000 Hz, AMTI, Watertown, MA). Participants were asked to walk at a self-selected speed up the curb. Participants were allowed to practice walking up the curb prior to data collection to ensure comfort in completing the task safely. The participant's starting position was adjusted to ensure successful foot strikes on the GROUND and CURB. Data were collected until at least three successful trials were captured. A successful trial was defined as when complete contact was made with the ground force plate and the curb force plate. Walking velocity was measured using a timing system spanning a distance of 5 m and centered on the curb.

Data Analysis

CURB and GROUND legs were analyzed separately. Marker coordinates (Fc = 6 Hz) and ground reaction forces (Fc = 50 Hz) were filtered in Visual 3D (C-Motion) using a recursive Butterworth digital filter. Peaks for joint angular velocities, moments, and powers at the ankle, knee, and hip were estimated using Visual 3D (C-Motion). Toe clearance was calculated as the smallest resultant distance between the toe marker and the curb plate as the leg approached and crossed the curb plate (Cho et al., 2013). Work was calculated as the integral of joint power time series to identify the individual joint contributions to the curb negotiation task. To calculate work, positive and negative joint power phases were identified and then integrated to express positive and negative work. Total work was calculated by rectifying the joint power then integrating the entire joint power time series.

Statistical Analysis

A t-test was used to test for significant differences in center of mass velocities between pre- and post-test conditions. Dependent variables were log-transformed if a normal distribution was not present in the raw data prior to statistical analysis. A series of ANOVAs with repeated measures (PRE vs POST) were used to identify differences between pre- and post-test measures ($\alpha = .05$) for the ground and curb leg. Statistical significance was determined at $p<.05$. Given the small sample size, meaningfulness of any differences were further characterized by computing effect size. Effect sizes (ES) were computed based on Cohen's d (Thomas, Nelson, & Silverman, 2015)

$$\text{ES} = \frac{M_1 - M_2}{Sp} \tag{1}$$

where M_1 is the mean for the pre-condition and M_2 is the mean at the post-condition. Effect sizes that were greater than or equal to 0.8 were considered to be large, effect sizes around 0.5 were considered to be moderate, and effect sizes equal to or less than 0.2 were considered to be small. Pooled standard deviation (S_p) was computed as:

$$S_p = \sqrt{\frac{S_1 + S_2}{2}} \tag{2}$$

where S_1 and S_2 are the standard deviations of the pre and post conditions respectively.

Results

All participants were able to negotiate the curb safely. Walking speed was not significantly different between pre- and post-test sessions (1.28 ± 0.15 m/s Pre vs. 1.34 ± 0.16 m/s Post; p =0.094). In both the GROUND ($F(1, 13) = 9265.4$, $p < .001$) and CURB ($F(1, 13) = 11.4$, $p = .005$) legs, toe clearance was significantly decreased after training (Table 3.2, 3.3) however, toe clearance variability was not significantly changed.

The rest of the results will be presented in two main sections, first GROUND leg results followed by CURB leg results.

GROUND Step Results

At the ankle there was a significant increase in plantarflexion velocity during pre-swing (F (1, 13) = 5.364, $p = .038$; Table 3.2) and there was a significant decrease in plantarflexor moment in late stance phase post training (F (1, 13) = 679.310, $p < .001$; Table 3.2). In addition, the ankle generated significantly more power during late stance in the post-session (F (1, 13) = 122.300, $p < .001$; Figure 3.2, Table 3.2).

At the knee, flexion velocity increased (Figure 3.2) during the loading response after training (F (1, 13) = 146.629, $p < .001$). There was also a significant increase in knee flexion moment at mid-stance (F (1, 13) = 57.373, $p < .001$) and at about mid-swing (F (1, 13) = 707.722, $p < .001$; Table 3.2). Power generation (Figure 3.2) also increased in the knee joint at heel strike (F (1, 13) = 190.523, $p < .001$), mid-stance (F (1, 13) = 81.263, $p < .001$), and early swing phase (F (1, 13) = 152.323, $p < .001$) of the gait cycle post training. There was also an increase in negative work at the knee (F (1, 13) = 110.761, $p < .001$).

At the hip, extension velocity (Table 3.2) increased during mid-stance post training (F (1, 13) = 344.977, $p < .001$). A significant decrease in extensor moment at the hip during terminal swing phase was also observed (F (1, 13) = 6.142, $p = .031$). Further, power generation (Table 3.2) at the hip joint at about mid-stance (F (1, 13) = 39.207, $p < .001$) and mid-swing phase (F (1, 13) = 133.147, $p < .001$) increased significantly, and power absorption increased significantly (Table 3.2) during heel off (F (1, 13) = 25.522, *p*

< .001). Positive work at the hip also increased significantly post training (F (1, 13) = 108.110, *p* < .001).

Table 3.2

Mean, Standard deviations, P values, and effect sizes for the GROUND leg

Ground Leg					
	Dependent Variable	**Pre Mean ± SD**	**Post Mean ± SD**	**P Value**	**Effect Size**
Angular Velocity (m/s)	Ankle Peak 50-70%*	-249.23±32.49	-296.63±70.22	.038	0.87
	Ankle Peak 65-75%	189.67±74.72	222.89±74.96	.146	-0.44
	Knee Peak 0-15%*	-131.36±32.06	-131.709±41.87	<.001	0.01
	Knee Peak 50-70%	-373.14±93.26	-399.25±97.96	.431	0.27
	Hip Peak 15-35%*	-116.04±24.04	-121.96±30.46	<.001	0.22
	Hip Peak 80-100%	-55.17±25.95	-61.06±21.96	.225	0.24
Joint Moment (Nm/kg)	Ankle Peak 45-60%*	1.72±0.37	1.69±0.21	<.001	0.08
	Ankle Peak 60-75%	-0.02±0.00	-0.02±0.01	.280	0.19
	Knee Peak 0-10%	-0.39±0.15	-0.43±0.21	.236	0.19
	Knee Peak 40-60%	-0.34±0.27	-0.23±0.20	.206	-0.47
	Knee Peak 60-75%*	0.14±0.05	0.15±0.04	<.001	-0.13
	Knee Peak 90-100%	-0.33±0.07	-0.34±0.06	.794	0.12
	Hip Peak 0-15%	9.89±16.21	7.07±10.71	.630	0.21
	Hip Peak 85-95%*	-3.17±6.93	-0.27±0.59	.031	-0.59
	Hip Peak 90-100%	8.04±15.32	4.94±7.41	.480	0.26
Joint Power (W/kg)	Ankle Peak 35-55%	-0.61±0.63	-0.71±0.76	.661	0.14
	Ankle Peak 50-65%*	4.76±1.35	4.94±1.51	<.001	-0.12
	Knee Peak 0-10%*	0.62±0.22	0.72±0.44	<.001	-0.28
	Knee Peak 15-30%*	0.50±0.39	0.59±0.56	<.001	-0.19
	Knee Peak 35-45%	-0.23±0.19	-0.28±0.26	.372	0.22
	Knee Peak 55-70%	-0.52±0.23	-0.58±0.24	.623	0.22
	Knee Peak 70-85%*	0.21±0.11	0.23±0.17	<.001	-0.14
	Hip Peak 0-5%	0.84±0.82	0.79±0.61	.855	0.06
	Hip Peak 10-25%*	0.25±0.47	0.56±0.59	<.001	-0.58
	Hip Peak 40-55%*	-1.31±0.72	-1.25±0.61	<.001	-0.09
	Hip Peak 60-80%*	0.86±0.34	0.87±0.38	<.001	-0.02
Toe Clearance (cm)	resultant as toe crosses plate*	10.21±1.14	10.12±0.88	<.001	0.08
Work (J)	Ankle Positive	0.52±0.11	0.45±0.20	.221	0.09
	Ankle Negative	-0.13±0.09	-0.15±0.10	.176	0.20
	Ankle Total	0.66±0.17	0.67±0.13	.667	-0.07
	Knee Positive	0.17±0.06	0.19±0.09	.484	-0.19
	Knee Negative*	-0.21±0.07	-0.22±0.08	<.001	0.06
	Knee Total	0.38±0.12	0.40±0.16	.798	-0.13
	Hip Positive*	0.20±0.09	0.25±0.11	<.001	-0.41
	Hip Negative	-0.22±0.12	-0.22±0.11	.885	-0.04
	Hip Total	0.43±0.15	0.47±0.13	.248	-0.26

Note: *indicates significant difference.

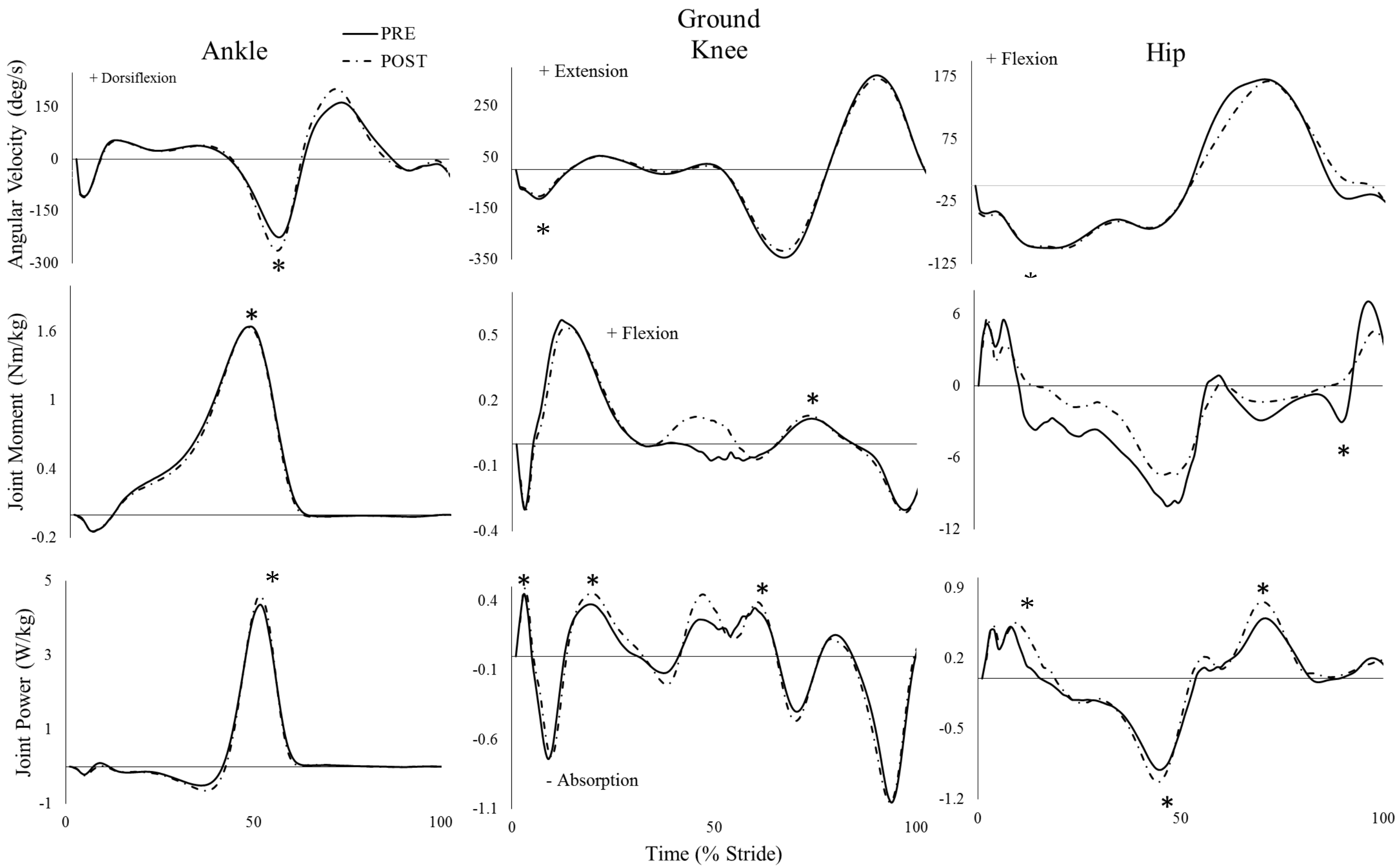

Figure 3.2. Average graphs of angular velocity, joint moment, and joint power over percent stride of the GROUND leg. * indicated significant difference.

CURB step results

For the CURB leg there were significant changes (Table 3.3 and Figure 3.3) noted across all joints in angular velocity, joint moment, joint power, toe clearance, and joint work. There was a significant reduction in dorsiflexion velocity during mid-swing (F (1, 13) = 4.624, $p < .001$) after completing the exercise intervention. At the ankle there was also a significant increase in plantar flexor moment (Table 3.3) during pre-swing (F (1, 13) = 473.958, $p < .001$). Both power generation (F(1,13) = 6.402,$p = .025$) and power absorption (F(1,13) = 8.610, $p = .012$) increased significantly after training (Table 3.3), where power absorption increased during pre-swing and generation increased at toe off (Figure 3.3). Positive (F (1, 13) = 1831.179, $p < .001$), negative (F (1, 13) = 9.719, $p = .008$), and total work (F (1, 13) = 957.903, $p < .001$) at the ankle increased significantly after training.

At the knee there was a decrease in flexion velocity (Table 3.3) during the loading response (F (1, 13) = 48.215, $p < .001$) and at toe off (F (1, 13) = 1202.412, $p < .001$). There was also an increase in extensor moment (Table 3.3) at heel strike (F (1, 13) = 24.007, $p < .001$), towards the end of terminal stance (F (1, 13) = 24.705, $p < .001$) and during terminal swing phase (F (1, 13) = 124.007, $p < .001$) after completing the exercise program. An increase in flexor moment (Table 3.3) was found at toe off (F (1, 13) = 260.389, $p < .001$) in the knee after training. Power generation increased significantly at heel strike (F (1, 13) = 70.287, $p < .001$) and decreased at about mid-stance (F (1, 13) = 31.256, $p < .001$). While power absorption at the knee also significantly increased late in the stance phase (F (1, 13) = 29.955, $p < .001$) and toe off (F (1, 13) = 348.278, $p < .001$).

Negative (F (1, 13) = 227.509, $p < .001$) and total (F (1, 13) = 309.978, $p < .001$) work at the knee significantly increased after training.

At the hip, an increase in extensor moment was found at heel strike following training (F (1, 13) = 10.887, $p < .001$). There was also an increase in power generation at the hip post training at heel strike (F (1, 13) = 87.862, $p < .001$) and toe off (F (1, 13) = 138.596, $p < .001$). Positive (F (1, 13) = 338.404, $p < .001$) and total (F (1, 13) = 1603.309, $p < .001$) work at the hip joint increased significantly.

Table 3.3

Mean, Standard deviations, P values, and effect sizes for the CURB leg.

Curb Leg					
	Dependent Variable	**Pre Mean ± SD**	**Post Mean ± SD**	**P Value**	**Effect Size**
Angular Velocity (m/s)	Ankle Peak 50-70%	-271.97±80.20	-303.52±64.82	.051	0.43
	Ankle Peak 65-75%*	176.99±84.88	167.84±69.82	<.001	0.12
	Knee Peak 0-15%*	-73.68±46.64	-70.39±39.49	<.001	-0.08
	Knee Peak 50-70%*	-359.86±36.17	-345.12±37.77	<.001	-0.42
	Hip Peak 15-35%	-169.55±21.35	-171.21±26.18	.786	0.07
	Hip Peak 80-100%	-40.32±33.42	-48.63±27.53	.056	0.27
Joint Moment (Nm/kg)	Ankle Peak 45-60%*	1.48±0.23	1.61±0.28	<.001	-0.52
	Ankle Peak 60-75%	-0.03±0.00	-0.03±0.00	.139	0.40
	Knee Peak 0-10%*	-0.29±0.18	-0.33±0.15	<.001	0.27
	Knee Peak 40-60%*	-0.24±0.27	-0.28±0.25	<.001	0.15
	Knee Peak 60-75%*	0.21±0.05	0.26±0.11	<.001	-0.53
	Knee Peak 90-100%*	-0.35±0.05	-0.39±0.06	<.001	0.85
	Hip Peak 0-15%*	12.02±20.32	15.50±17.43	.006	-0.18
	Hip Peak 85-95%	-0.42±2.46	-2.33±3.30	.712	0.66
	Hip Peak 90-100%	8.46±14.45	14.68±20.26	.060	-0.35
Joint Power (W/kg)	Ankle Peak 35-55%*	#DIV/0!	-0.61±0.66	.012	0.55
	Ankle Peak 50-65%*	3.73±0.87	4.50±0.98	.025	-0.83
	Knee Peak 0-10%*	0.50±0.42	0.51±0.42	<.001	0.00
	Knee Peak 15-30%*	1.40±0.94	1.33±0.98	<.001	0.07
	Knee Peak 35-45%*	-0.16±0.33	-0.25±0.33	<.001	0.27
	Knee Peak 55-70%*	-1.17±0.27	-1.27±0.33	<.001	0.33
	Knee Peak 70-85%	0.05±0.03	0.05±0.03	.597	-0.16
	Hip Peak 0-5%*	0.71±0.43	0.82±0.52	<.001	-0.23
	Hip Peak 10-25%	1.71±0.61	2.01±0.95	.189	-0.37
	Hip Peak 40-55%	-1.07±0.30	-1.10±0.42	.738	0.09
	Hip Peak 60-80%*	1.18±0.28	1.24±0.41	<.001	-0.18
Toe Clearance (cm)	resultant as toe crosses *plate	13.16±1.28	12.22±0.98	.005	0.78
Work (J)	Ankle Positive*	0.37±0.11	0.40±0.12	<.001	0.36
	Ankle Negative*	-0.06±0.04	-0.10±0.10	.008	-0.34
	Ankle Total*	0.43±0.11	0.50±0.14	<.001	-0.54
	Knee Positive	0.31±0.20	0.30±0.20	.883	0.08
	Knee Negative*	-0.25±0.06	-0.26±0.07	<.001	0.15
	Knee Total*	0.56±0.22	0.56±0.21	<.001	-0.02
	Hip Positive*	0.50±0.13	0.57±0.25	<.001	0.04
	Hip Negative	-0.18±0.07	-0.19±0.10	.752	-0.83
	Hip Total*	0.67±0.10	0.75±0.19	<.001	-0.52

Note: * indicates significant difference.

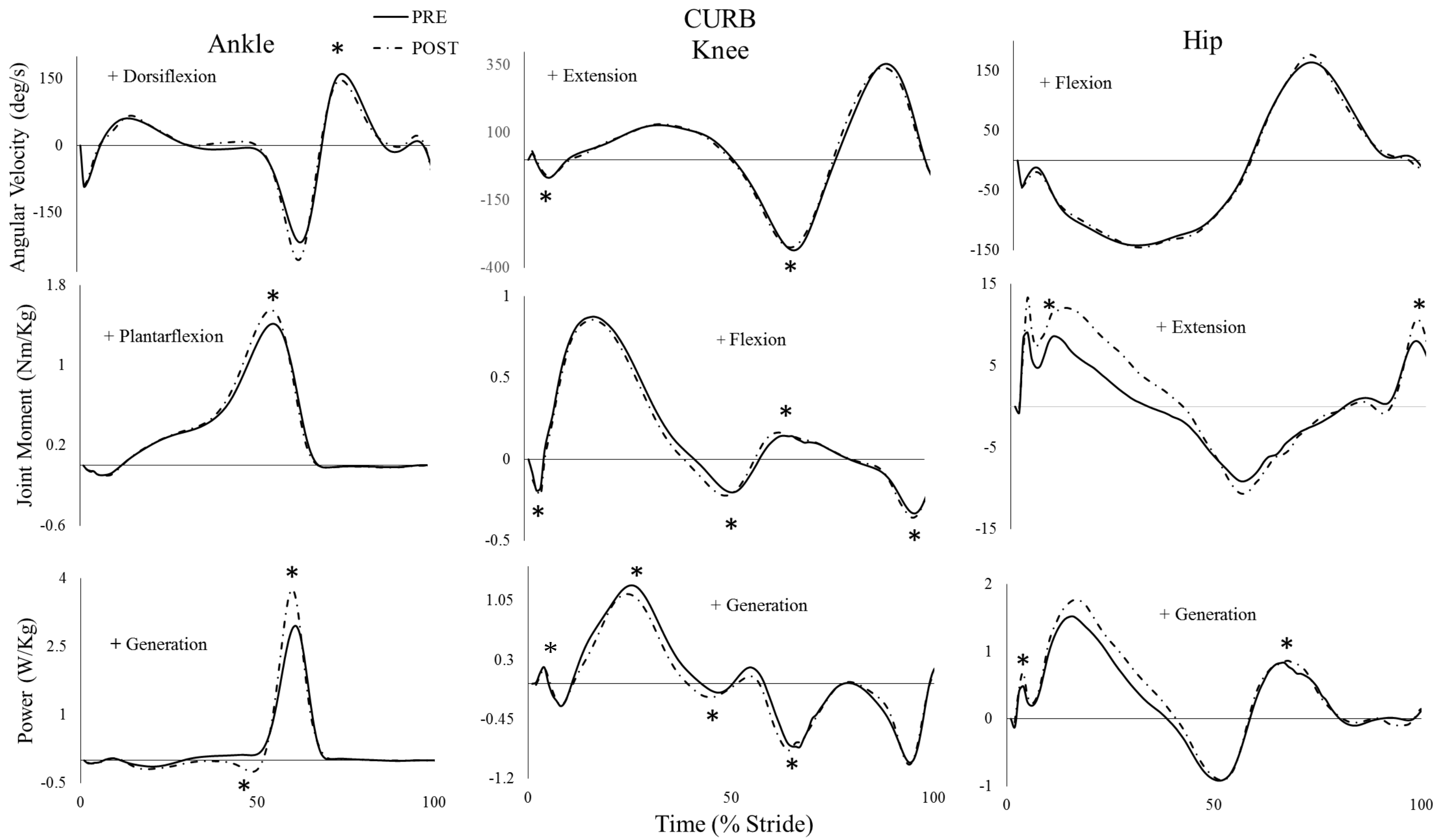

Figure 3.3 Average graphs of angular velocity, joint moment, and joint power over percent stride of the CURB leg. * indicated significant difference

Discussion

The purpose of this study was to determine whether or not there would be biomechanical improvements during curb negotiation in cancer survivors after training. While there were several significant PRE to POST changes in many of the dependent variables and across all joints, several of these findings had very small effect sizes. The data support our hypotheses that joint moments and powers would increase, but does not support the hypothesis that toe clearance variability would decrease in both the CURB and GROUND legs. Our hypothesis that joint work would increase post training in both legs was supported due to the fact that ankle positive joint work decreased in the GROUND leg. Changes from PRE to POST assessments were most likely due to training effects since COM velocity during the task was the same from PRE to POST.

For this task the GROUND and CURB legs were analyzed separately. Angular velocity at the ankle increased during pre-swing in the GROUND leg consistent with findings in negotiating stairs after exercise training (Handsaker et al., 2016). Plantar flexor moments increased at the ankle during late stance/pre-swing phase of the GROUND and CURB legs respectively. Joint power at the ankle had a meaningful significant increase in power absorption (ES = .55) during pre-swing and power generation (ES = -.83) at toe off of the CURB leg. These findings are similar to changes seen in stroke victims after exercise training (Teixeira-Salmela, Nadeau, Mcbride, & Olney, 2001). In the study by Teixeira-Salmela, et al. (2001) they found an increase in plantar flexor moments post training, which is similar to our findings, however they found a decrease in power generation at the ankle. The decrease in power generation was believed to be due to an increase in hip power generation allowing the individual to use their hip and ankle more efficiently during the gait cycle (Teixeira-Salmela et al., 2001). Teixeira-Salmela et al. (2001) noted that a major potential cause of gait dysfunction in stroke survivors is a loss of muscular strength, which is also commonly observed in cancer survivors. For the CURB leg, there was also a significant meaningful increase in positive (ES = .23), negative (ES = .54) and total work (ES = .54) performed at the ankle, which is likely due to the increase in ankle power generation and absorption.

There were also changes at the knee in both the GROUND and CURB legs with more meaningful changes occurring in the CURB leg. Knee flexion velocity increased during the loading response in the GROUND leg, but decreased during loading response in the CURB leg combined with a decreased toe clearance, which is also consistent with findings by Handsaker et al. (2016). Knee flexion moments increased in both GROUND and CURB legs at about mid-swing and toe off, respectively, and in the CURB leg, knee extensor moments at heel strike, terminal stance, and terminal swing phase increased. There was a meaningful increase in knee power generation at heel strike of the GROUND leg, however, at the CURB leg the meaningful differences were increases in knee power absorption in late stance phase and toe off.

Hip extension velocity increased during mid stance in the GROUND leg, but did not significantly change in the CURB leg. Kerrigan et al. (1998) suggested that as people age they reduce the amount of time they spend walking and/or running, which could lead to hip flexor contractures and reduced hip extension. The increase in hip extension velocity could potentially be in response to the flexibility portion of the exercise program allowing for maintained hip extension range of motion coupled with an increase in strength allowing for the hip extensors to be more involved in negotiation the curb. Hip extensor moments decreased in the GROUND leg and increased at toe off in the CURB leg. This change in hip extensor moments could potentially be attributed to an increase in strength at the hip, which would allow for the individual to rely more on the CURB leg to pull them up the curb rather than the GROUND leg to push them up the curb. Hip power generation increased at mid-stance for the GROUND leg and heel strike in the CURB leg. Total work at the hip joint increased post training in the CURB leg. The increase in work for the CURB leg at the hip joint could be in relation to the increase in power output at the joint, which may be indicative e of increased strength in the hip musculature.

Toe clearance significantly decreased in both legs after completing the 12 week exercise intervention. However, toe clearance variability did not significantly change after training. Research that has compared young and older adults found that younger adults had less variability in toe clearance and had an average minimum of 7 cm of toe clearance when transitioning from the ground to stairs (Ajisafe et al., 2017; Mills, Barrett, & Morrison, 2008). Even though minimum toe clearance was greater than 7 cm (12 cm), its decrease post training could be indicative of a more confident gait. More confidence in walking and negotiating obstacles can be translated into more confidence in activities of daily life, which would also increase the overall quality of life.

The most clinically significant changes observed were the increase in ankle and hip power outputs. In a study by Kerrigan et al., (1998) a decrease in plantar flexor strength and hip extensor range were identified as characteristics found in elderly fallers. Kerrigan et al. (1998) suggested that in elderly fallers, a reduction in hip extensor activity could be caused by a strategy to maintain balance during walking. This strategy can also be attributed to the shortened step length and increased double support time often seen in elderly gait (Kerrigan et al., 1998). This is important due the fact that both age and disease can alter gait in a way that can increase the risk of falling (Spoelstra et al., 2013). Previous research found that balance during locomotion is more complex than standing balance and that risk of falling was more closely related with how a person performed during locomotion (Winter, et al., 1990). Therefore, risk of falling would be more likely to be decreased if the focus of interventions was on maintaining balance during locomotion. Thus, increases in ankle power and hip power can potentially reduce the risk of falling, which in turn may improve the quality of life of cancer survivors.

CHAPTER IV

CONCLUSION

Conclusion

Both cancer and cancer treatments cause symptoms that increase the risk of falling such as loss of balance, muscle weakness, neuropathy, bone loss, and cardiotoxicity. This, combined with the fact that a majority of new cancer diagnoses will be age 55 or older means that they may also be experiencing age-related gait changes such as slower walking speeds, shorter step lengths, wider base of support, increased double support time, and increased variability in toe clearance (Winter et al., 1990; Ajisafe et al., 2017). Combined, these gait changes can increase an individual's risk of falling (Chen & Janke, 2013). Some research has found that once an individual falls once they will most likely fall again (Chen et al., 2013). Falls not only decrease quality of life, but they can be fatal, especially in older adults (Wildes et al.,, 2015). The potential to fall is increased even more when you take into account obstacle negotiation. Everyday, people have to negotiate curbs, steps, and other changes in elevation, which are more demanding than walking across an even surface (Standifird et al., 2016).

Exercise has been found to increase the quality of life, elevate mood, slow bone loss and preserve bone density, reduce cardiotoxicity, and increase muscle mass (Lien, Jensen, Hydock, & Hayward, 2015; Yeo et al., 2012). People who suffer from diabetes who have participated in exercise programs have displayed improvements in postural sway and gait during standing and over ground walking, respectively (Handsaker et al., 2016). Improvements in gait and balance, such as walking speed and postural sway, in seniors have been attributed to participation in exercise programs (Bouaziz et al., 2016). When exercise is prescribed it is most effective when individualized to the survivor's needs and supervised as opposed to home-based (Meneses-Echavez, Gonzalez-Jimenez, & Ramirez-Velez, 2015). A systematic review by Bouaziz et al., (2016) suggests that physical activity in seniors should focus on several factors: "moderate-intensity aerobic activity, muscle strengthening, reducing sedentary behavior, and risk management." (Bouaziz et al., 2016, p. 521). A specific change that has been suggested to increase the risk of falling is a decrease in ankle power generation which is believed to be caused by a decrease in plantarflexor strength (Kerrigan et al., 1998). A study by Kerrigan et al., (1998) found that in their group of elderly participants who were considered "fallers" ankle power was consistently lower than that of "non-fallers". Participation in a supervised multi-modal exercise program has been found to improve cardiopulmonary function and balance, as well as increase muscular strength, walking ability, and flexibility (Bouaziz, et al., 2016; Hsieh et al., 2008).

Prior to and immediately following the 12-week training intervention, each participant's gait was assessed while negotiating a curb. The top of the curb plate was 16 cm higher than the ground plates, which replicated the height of a standard curb. A series of ANOVAs with repeated measures were used to identify differences between pre- and post-test measures ($\alpha = .05$) for the ground and curb leg. There were several significant differences found across all three joint in both the GROUND and CURB legs. Toe clearance was found to have decreased in both legs post training which could suggest more confidence in walking ability. The most significant finding may have been the increase in power output at the ankle joint, considering that a decrease in ankle power, possibly due to a decrease in plantarflexor strength, is indicative of a predisposition to falls among the elderly (Kerrigan et al., 1998). Exercise training clearly improved ankle power output, which could be a key factor in limiting falls in cancer survivors.

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APPENDIX A

INSTITUTIONAL REVIEW BOARD DOCUMENTS

UNIVERSITY of NORTHERN COLORADO

CONSENT FORM FOR HUMAN PARTICIPANTS IN RESEARCH

UNIVERSITY OF NORTHERN COLORADO

Project Title: **Influence of 12-week Training Program on Muscular Fatigue and Functional Performance of Cancer Survivors**

Researcher: Trista Manikowske, M.S., School of Sport & Exercise Science

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Purpose and Description:

The purpose of this study is to determine whether functional activities of daily living, such as walking and rising from a chair, are influenced by a 12-week resistance and aerobic training intervention. Additionally, we are studying whether self-reported psychometric fatigue is related to measured local muscular fatigue. There are two parts to this study. The first part focuses on functional activities such as walking and rising from a chair and the second part focuses on muscular fatigue. You are not required to participate in both portions of the study, but you can participate in both portions. You are being asked to participate in this study because you are a cancer survivor. Many cancer treatments have negative effects on vestibular function and sensorimotor function. Both of these are important contributors to balance and muscle control of movements. Below prior to signing this document you are asked to put you initials next to which portions of the study you are willing to participate in.

Gait Analysis (Portion 1)

For the gait assessment portion of this study, you will be asked to visit the Biomechanics Lab in Gunter Hall on two separate occasions with 12-weeks between each session. Each session will last approximately two and half hours. During the 12-weeks between sessions you will be asked to participate in a 12-week strength, endurance, and flexibility training program that will involve working one-on-one with an exercise specialist in the Rocky Mountain Cancer Rehabilitation Institute. You will be asked to visit RMCRI 3 days per week for 12-weeks following your first visit to the Biomechanics lab.

Functional performance measures

You will be asked to perform walking, stair climbing, and a five times sit-to-stand test.

Questionnaires

You will be asked to complete a set of questionnaires related to general health, physical activity, and balance confidence.

Motion Analysis

Movement patterns will be measured using UNC’s Biomechanics Laboratory’s motion capture system. This test involves wearing reflective markers while performing a series of 10 meter walks and stepping up and down from a 6 inch step. Prior to markers being positioned on your body, you will be asked to change into tight fitting clothing in order to ensure that there is minimal movement between the markers and your skin.

Fatigue Testing (Portion 2)

You will be asked to complete two different fatigue tests. First, you will be asked to complete a series of grip strength tests for each hand using a hand-grip dynamometer. In this task you will squeeze the grip handle as hard as possible multiple times with each hand. For the second fatigue test, you will be positioned in a chair and perform a series of movements with you knee and hip. While performing these movements at the knee and hip your leg will be strapped to a lever arm that will allow us measure the effort of your movements. These seated strength exercises require some training so you will be asked to visit the Biomechanics lab on two separate occasions for this protocol. The first session will last approximately one hour and will be used to familiarize you with the testing protocol. You will be asked to visit the Biomechanics Lab one week after the first session for the experimental testing and this session will also last one hour.

What are the possible discomforts or risks?

Though the testing procedures to which you will be exposed are safe, some participants do report some muscle soreness after muscle strength testing for approximately 2 days after testing. This soreness is similar to the muscle soreness that you may feel if you lift weights or vigorously exercise after a long layoff. Although the force levels to be used in this study pose very little risk for injury, possible injuries include musculoskeletal injury or falls. The risks of a fall are no higher than normal daily life. This study may include risks that are unknown at this time. In the unlikely event of injury, we will contact the appropriate medical authorities.

There are no direct benefits to you for participating in this study. Data from this study, however, are likely to improve our current understanding of how functional activities of daily living are influenced by cancer and cancer treatments. In addition, data will also help researchers understand the effects of a 12-week training program on improving function during activities of daily living.

We will take every precaution in order to protect your anonymity by identifying your data by number only. Only the principal investigator and his assistants will know the name connected with a subject number and when we report data, your name will not be used. Data collected and analyzed for this study will be kept in a locked cabinet in the Biomechanics Lab, which is only accessible to the research team.

Participation is voluntary. You may decide not to participate in this study and if you begin participation you may still decide to stop and withdraw at any time. Your decision will be respected and will not result in loss of benefits to which you are otherwise entitled. Having read the above and having had an opportunity to ask any questions, please sign below if you would like to participate in this research. A copy of this form will be given to you to retain for future reference. If you have any concerns about your selection or treatment as a research participant, please contact the Office of Sponsored Programs, Kepner Hall, University of Northern Colorado Greeley, CO 80639; 970-351-2161.

Please write your initials next to the portions of this study you are willing participate in.

_______ I agree to participate in gait analysis (portion 1)

_______ I agree to participate in fatigue testing (portion 2)

_________________________________ _____________________

Participant’s Signature Date

_________________________________ _____________________

Researcher’s Signature Date

UNIVERSITY OF
NORTHERN COLORADO

Institutional Review Board

DATE:	November 16, 2015
TO:	Trista Manikowske, M.S.
FROM:	University of Northern Colorado (UNCO) IRB
PROJECT TITLE:	[696399-3] Physiological Examinations to Investigate the Negative Side- Effects of Cancer Treatments
SUBMISSION TYPE:	Continuing Review/Progress Report
ACTION:	APPROVED
APPROVAL DATE:	November 16, 2015
EXPIRATION DATE:	December 19, 2016
REVIEW TYPE:	Expedited Review

Thank you for your submission of Continuing Review/Progress Report materials for this project. The University of Northern Colorado (UNCO) IRB has APPROVED your submission. All research must be conducted in accordance with this approved submission.

This submission has received Expedited Review based on applicable federal regulations.

Please remember that informed consent is a process beginning with a description of the project and insurance of participant understanding. Informed consent must continue throughout the project via a dialogue between the researcher and research participant. Federal regulations require that each participant receives a copy of the consent document.

Please note that any revision to previously approved materials must be approved by this committee prior to initiation. Please use the appropriate revision forms for this procedure.

All UNANTICIPATED PROBLEMS involving risks to subjects or others and SERIOUS and UNEXPECTED adverse events must be reported promptly to this office.

All NON-COMPLIANCE issues or COMPLAINTS regarding this project must be reported promptly to this office.

Based on the risks, this project requires continuing review by this committee on an annual basis. Please use the appropriate forms for this procedure. Your documentation for continuing review must be received with sufficient time for review and continued approval before the expiration date of December 19, 2016.

Please note that all research records must be retained for a minimum of three years after the completion of the project.

If you have any questions, please contact Sherry May at 970-351-1910 or Sherry.May@unco.edu. Please include your project title and reference number in all correspondence with this committee.

Trista and colleagues -

Thank you for clear and thorough continuation application materials.

Please update the information for mistreatment as a research participant as follows on the consent form before further use: "If you have any concerns about your selection or treatment as a research participant, please contact Sherry May, IRB Administrator, in the Office of Sponsored Programs, Kepner Hall, University of Northern Colorado Greeley, CO 80639; 970-351-1910."

Best wishes with your continued work on this project.

Sincerely,

Dr. Megan Stellino, UNC IRB Co-Chair

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within University of Northern Colorado (UNCO) IRB's records.