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Chapter I

Physical Activity and Cancer

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Abstract

It is widely accepted that physical activity is important for physical functioning and well-being, and as such the promotion of active lifestyles is becoming increasingly significant in public health policy both in the UK and worldwide. Sedentary lifestyles have been associated with increased risk of obesity and preventable disease including diabetes, coronary heart disease and some cancers. With regards cancer specifically, this chapter will provide a brief overview on current opinions on the link between physical activity and cancer prevention.

The published evidence focuses both on primary and secondary prevention. More recent evidence has investigated the use of physical activity in secondary prevention for those who have been diagnosed with cancer and proposed a link between physical activity, morbidity and mortality in those with cancer. The evidence-base for secondary prevention is more limited. Nevertheless, studies to date have indicated that physical activity can improve both physical functioning and psychological outcomes in cancer survivors, and significantly improve quality of life.

The exact nature of those interventions which confer the most positive effects is less well-established, and there is a current lack of consensus on the most appropriate type, intensity and duration of activity for people with cancer. It has not yet been well-established as to which stage of the treatment programme physical activity should be encouraged (during or following treatment) or the most appropriate length of time during which structured physical activity interventions should be delivered to achieve beneficial results.

These factors will be discussed in this chapter, and barriers to engaging in physical activity for those with a diagnosis of cancer will be considered. The chapter will conclude with a summary of key findings and the potential for further research.

Introduction to Physical Activity and Health

As our understanding of the functioning of the human body increases, we are constantly searching for ways to improve our general health, prevent or delay disease, and to slow the effects of, or cure, disease once it occurs. With the rising prevalence of chronic disease it is now widely accepted that physical activity is important for both physical functioning and psychological well-being. As such, the promotion of active lifestyles is becoming increasingly significant in public health policy both in the UK (Department of Health, 2011) and worldwide (World Health Organisation, 2004a).

The effects of physical inactivity have a public as well as a private impact. Physical inactivity is associated with high healthcare costs since sedentary behaviours are known to be an important contributor to overweight and obesity, diabetes, hypertension, heart disease, colon cancer, breast cancer, and even premature death. In fact, it is estimated that physical inactivity costs a European nation around 150-300 Euros per citizen per year (WHO, 2006), and is responsible for around 6% of deaths worldwide (WHO, 2009), making it the fourth greatest risk factor for global mortality.

The preventative and curative link between physical activity and physical health is better understood when relating to diseases with a clearer etiology. Physical activity is known to decrease the risk of more than 20 chronic conditions, including coronary heart disease (Shaper et al 1991; Oguma & Shinoda-Tagawa, 2004), stroke (Liang et al, 2009) and type 2 diabetes (Gill & Cooper, 2008). Physical activity is also important in the management of long-term conditions such as type 1 diabetes (Chimen et al, 2012); it helps to maintain healthy bones, muscles, and joints and prevents falls among older people. Being active can independently reduce adiposity and body weight (Ekelund et al, 2011; Jakicic & Davis, 2011) which is important due to the significant health risks associated with overweight and obesity (Field et al, 2001). Regular physical activity also has known benefits for psychological health and being active can reduce feelings of stress, depression and anxiety, and promotes overall psychological wellbeing (Hassmén et al, 2000).

Whilst a sufficient level of physical activity is known to reduce the risk of some diseases, an inactive lifestyle or ‘sedentariness’ is often associated with an increased risk of disease. Although the terms are often used inter-changeably in the literature, physical activity is not necessarily synonymous with exercise; exercise is a type of planned and structured physical activity which is undertaken with the aim to improve or maintain one or more aspects of physical fitness. On the other hand, physical activity has been defined as “any bodily movement produced by skeletal muscles that results in energy expenditure” (Caspersen et al, 1985). Due to changes in our modern lifestyles, physical activity rates have declined globally, and only a small proportion of the general population are active enough to benefit their health (Brownson et al, 2005; Dias-da-Costa et al, 2005; James, 2008). With an increasing number of inactive or insufficiently active individuals in recent years, physical activity promotion is arguably more important than ever. A report from the National Audit Office stated that 50 years ago in the UK, people were significantly more physically active in their day-to-day life; so much so that compared with today, the extra activity was equivalent to running a marathon each week (NAO, 2001). Walking and cycling are becoming less commonplace as individuals become more dependent on motorised transport, there are more sedentary occupations, and the popularity of more sedentary leisure activities, such as television viewing, has increased (House of Commons Health Committee, 2004).

Physical activity can be classified as mild, moderate or vigorous in intensity. Mild physical activity requires minimal effort; moderate physical activity raises the heart rate and produces perspiration; vigorous activity results in heavy perspiration and a rapid heart-beat (examples are slow/steady walking, fast walking and jogging/running respectively). There are certain health benefits which may be achieved more quickly and/or to a greater extent through moderate-to-vigorous activity. The evidence suggests that there may be a greater risk reduction for some diseases (such as type 2 diabetes and cardiovascular disease) with increased intensity and duration of physical activity (Gill & Cooper, 2008; Kohl, 2001), and WHO (2010) recommend that adults increase their weekly moderate-intensity aerobic activity to 300 minutes to gain additional health benefits. Although the majority of day-to-day physical activity is light-to-moderate in intensity, engaging in any level of activity and limiting the proportion of time spend in sedentary activities is still of vital importance. Sedentary behaviour is known to have a negative impact on health and this can be irrespective of the level of physical activity an individual engages in altogether. For example, regardless of how much physical activity or exercise an individual undertakes in general, sedentary behaviour (such as time spent watching television or sitting at a desk) has been clearly associated with risk of obesity, type 2 diabetes and cardiovascular disease (Hu et al, 2003; Warren et al, 2010). The relationship between physical activity and health is therefore complex; nevertheless, there is a general consensus that a sufficient level of physical activity is required to maintain health (the current recommendations are 150 minutes of moderate physical activity a week), and in addition, higher levels of physical activity and exercise can further improve health and have added benefits in reducing known disease risk factors.

Introduction to Cancer and Physical Activity

Worldwide, cancer prevalence rates are high and are predicted to further increase by 50% to 15 million new cases in the year 2020. However, the evidence clearly demonstrates that healthy lifestyles and public health action by governments and health practitioners could restrain this trend. There are many reasons for the increasing burden of cancer worldwide although some key explanations include population growth and trends, an ageing population, and an increase in detrimental lifestyle habits (DeSantis et al, 2011; Jemal et al, 2011). The influence of physical activity is becoming increasingly apparent; it is thought that a significant proportion of cancer cases could be prevented, and estimated that in 2010 more than 5% of colon cancer cases (Wolin et al, 2011), 4% of uterine cancer cases, and more than 3% of breast cancer cases (Parkin, 2011) were linked to individuals failing to meet the recommended guidelines of 150 minutes of moderate-intensity physical activity per week (WHO, 2010). Whereas the exact etiology of many cancers is still unclear (Thun, 2007), physical activity has been identified as an important lifestyle behaviour which may exert an influence on prevention and recurrence of some cancers and on the management of symptoms although the *extent* of this influence is uncertain due to the complexity of the condition and its treatment.

Lifestyle Factors and Cancer

Smoking, alcohol consumption and dietary factors are known to affect cancer risk. Smoking is the single biggest cause of cancer worldwide and is responsible for around a third of all cancer deaths (IARC, 2004; Sasco et al, 2004). Smoking significantly increases the risk of lung cancer, mouth cancer, bladder cancer, kidney cancer, oesophageal cancer, pancreatic cancer and stomach cancer (Brennan et al, 2000; Iodice et al, 2008; Johnson, 2001; Parkin et al, 2011). Alcohol consumption can significantly increase the risk of mouth cancer, liver cancer, oesophageal cancer, breast cancer, laryngeal cancer and colorectal cancer (Bagnardi et al, 2001; Blot, 1992; Key et al, 2006). The effect of diet is less clear, and few specific foods have been shown to increase or decrease cancer risk per se. However, there is some evidence that a healthy diet is beneficial; eating sufficient amounts of fruit and vegetables decreases the risk of some cancers, particularly cancers of the mouth, oesophagus and stomach (Benetou et al, 2008; González et al, 2006; IARC 2003); eating sufficient fibre can reduce the risk of colorectal cancer (Nomura et al, 2007). Conversely, excessive consumption of red meat or processed meat can increase the risk of pancreatic cancer, colorectal cancer and stomach cancer (Larsson et al, 2006a; Larsson et al, 2006b; Larsson & Wolk, 2006), and consuming excessive amounts of saturated fat can increase the risk of breast cancer (Thiébaut et al, 2007). Knowledge about the relationship between lifestyle factors and cancer is important since the evidence suggests that health behaviours often ‘cluster’ together in individuals, and those individuals who are physically active may be more likely to adopt a healthy lifestyle in general. For example, there is some evidence to suggest that physically active individuals are more likely to opt for a low fat diet (Martinez et al 1997) and be non-smokers (Leitzmann et al 2009c; McTiernan et al 1998a). Therefore encouraging healthy lifestyle behaviours overall would seem an obvious approach to improving general health. Nevertheless, although a strong association between health behaviours has often been proposed, physical activity remains one of the most important lifestyle factors in cancer prevention since studies which have controlled for lifestyle factors such as diet, smoking, and alcohol use have found an independent relationship between physical activity and cancer risk (Giovannucci et al 1995; McTiernan et al 1996; Wannamethee, Shaper & Walker, 2001). Researchers have considered the relationship between obesity and physical activity in the prevention of cancer. It is already known that obesity increases the risk of some cancers (notably cancers of the colon, breast in post-menopausal women, endometrium and kidney - IARC 2002) and also that a sedentary lifestyle increases the risk of obesity (Hu et al, 2003). It could therefore be theorised that that physical activity may serve to reduce the risk of cancer through helping to prevent or manage obesity. However, studies that have controlled for weight/body mass index have continued to demonstrate an independent effect of physical activity on cancer risk (Holmes et al, 2005; Pierce et al, 2007) suggesting that the relationship between physical activity and cancer risk is not simply due to the reductions in obesity and overweight associated with being active.

Hormones and Cancer

Hormonal factors are known to be involved in breast and endometrial cancers (Lipworth, 1995; Grady et al, 1995; Olsen et al, 2007), and it is thought that physical activity may reduce the risk of these cancers by altering levels of sex and metabolic hormones (McTiernan et al, 1998b; McTiernan et al, 2008). Physical activity lowers the level of serum sex hormones in women (McTiernan et al, 2004) which reduces the risk of breast and gynaecologic cancers, and improves insulin sensitivity, which has been linked to a decreased risk of breast, pancreatic, colon and endometrial cancers (Kaaks & Lukanova, 2001; PAGAC, 2008).

The Immune System and Cancer

The effect of physical activity on cancer risk has also been attributed to the mediating effect of physical activity on the immune system. The immune system is thought to have a role both in cancer prevention (Jakóbisiak et al, 2003) and cancer survival (Chen et al, 2011) by identifying and eliminating abnormal cells. Moderate physical activity has been shown to have a protective effect on the immune system (Brolinson & Elliott, 2007; Nieman & Pedersen, 1999), although the current evidence is inconclusive.

Although the nature of the relationship between physical activity and cancer is ambiguous, there is nonetheless evidence that such a relationship exists. This chapter will first discuss how physical activity has been linked to primary prevention (the prevention of an initial cancer occurrence), before looking at secondary prevention (the prevention of a reoccurrence of cancer following treatment, and the prevention or delay of cancer-related mortality) and quality of life in cancer survivors.

Primary Prevention

There are very few known modifiable risk factors for cancer. Therefore the risk factors that *are* known, and ameniable to change, are of paramount importance. Established risk factors include age, gender, race, family history, genetic susceptibility, age at menarche and menopause, diet, obesity, smoking and alcohol use (American Cancer Society, 2012; Antoniou et al, 2003; IARC, 2004; NCIN & CRU, 2009; WHO, 2009).

There is evidence that physical activity can reduce the risk of cancer, although the epidemiologic evidence varies by cancer site. There is currently strong evidence for an association between physical activity and colon and breast cancers, and growing evidence for an association with endometrial and lung cancers. The evidence for a relationship between physical activity and prostate cancer is inconsistent, and the evidence base for other types of cancer is presently too limited to determine a clear connection with physical activity.

Colon Cancer and Breast Cancer

There is *consistent and convincing* evidence that physical activity reduces colon cancer risk (IARC, 2002; Wolin & Tuchman, 2011) and *probable* evidence that physical activity reduces breast cancer risk (Lynch et al, 2011). It is estimated that the risk is reduced by 30% for colon cancer and 20% for breast cancer as a result of daily physical activity (DHHS, 2008).

Studies have reported a reduced risk of colon cancer with even low intensity exercise (Howard et al, 2008), and walking alone appears sufficient to reduce the risk of both colon and breast cancers (McTiernan et al, 2003; Wolin et al, 2007). This is encouraging since the vast majority of individuals will have the physical capacity to engage in the level of physical activity which is necessary to reap these benefits.

One potential mechanism at work with regards to colon cancer is colon motility, which is affected by physical activity (McTiernan et al, 1998b). It is thought that a shorter bowel transit time may reduce colonic exposure to cancer-causing chemicals (IARC, 2002). In addition there are several study findings which lend themselves as evidence to theories (discussed above) about the nature of the relationship between physical activity and cancer risk, and how this relationship may be mediated. Firstly, family disease history is known to play a role in breast and colon cancers, with a significant increase in risk for those individuals who have a first-degree relative with the disease (Butterworth et al, 2006; Pharoah et al, 1997). This increased risk is by no means condemning; only around 15% of women who have a first-degree relative with breast cancer will develop the disease themselves (CGHFBC, 2001). However, there is some evidence that physical activity has a greater effect on colon and breast cancer risk in women who do not have a family history of these cancers compared with those who do (Lynch et al, 2011; Slattery et al, 1997).

Another factor is hormone levels. High oestrogen levels are associated with increased risk of breast cancer in post-menopausal women (Key et al, 2002). Oestrogen levels have been found to decrease as a result of physical activity (Chan et al, 2007) though studies which have adjusted for hormone levels have still found an independent effect of physical activity on cancer risk (DHHS, 2008). Conversely, physical activity has been found to have no effect on oestrogen metabolism in pre-menopausal women (Campbell et al, 2007). It has been suggested that oestrogen levels may also play a role in colon cancer risk (Hoffmeister et al, 2007; Slattery et al, 2003) but the evidence for this is inconclusive.

Body weight and adiposity also appear to mediate the relationship between physical activity and cancer risk, as well as the relationship between hormone levels and cancer risk. Obesity is strongly associated with a higher risk of colon cancer (Hou et al, 2004) and also a higher risk of breast cancer, though for the latter this is seemingly only in post-menopausal woman (WCRF & AICR, 2007). Physical activity has been found to have a greater effect on breast cancer risk in women who are lean compared with overweight or obese women (Lahmann et al, 2007; McTiernan et al, 2003); while PA has been found to have an effect independently of other lifestyle behaviours and of body weight, it is also possible that the beneficial effects of PA may be offset by the negative effects of being overweight. For example, findings from a randomised controlled trial showed that whilst physical activity independently lowered oestrogen levels, this effect was amplified if body fat levels were also lowered (McTiernan et al, 2004).

In general, findings show that there is a stronger relationship between physical activity and risk of breast cancer in post-menopausal compared to pre-menopausal women (Lahmann et al, 2007; Lee et al, 2001; Lynch et al 2011). The difference in risk reduction reported by some studies is quite striking; for example, Awatef et al (2011) found no association at all between breast cancer risk and physical activity in premenopausal women, whereas a risk reduction of 56% was observed for postmenopausal women. The evidence for breast cancer risk in pre-menopausal women is less consistent, and concepts of how biological mechanisms are at work in this population remain largely theoretical. For example, exercise has been linked to delayed menarche which may reduce the risk of breast cancer, although it is likely that a very high level of exercise would be necessary to have a significant effect (Bernstein, 2009). There have been findings showing a stronger link between insulin related factors and breast cancer in *pre*-menopausal women (Fletcher et al, 2002) although the evidence is still inconsistent.

Endometrial Cancer and Ovarian Cancer

Endometrial cancer is the most common form of gynaecologic cancer, and there is growing evidence for an association with physical activity. Around half of the 20 available studies reviewed by Cust (2011) reported a statistically significant or borderline significant dose-response relationship between physical activity and endometrial cancer risk. Further, a "best evidence" review by Voskuil et al (2007) of 10 high-quality studies showed that 80% found risk reductions of more than 20% which were associated with physical activity.

The risk of endometrial cancer is strongly associated with obesity. It is estimated that around half of all endometrial cancer cases in Europe and the United States are caused by excess body weight (Calle and Kaaks, 2004). An association between endometrial cancer and physical activity may therefore be related to the effects of physical activity on adiposity, although studies still show an independent effect of physical activity on endometrial cancer risk after controlling for body mass index (PAGAC, 2008). Endometrial cancer risk has also been associated with unopposed oestrogen therapy, which increases the cancer risk, and combination oral contraceptives which decrease the cancer risk (Key & Pike, 1988), supporting the influence of hormone levels on endometrial cancer epidemiology.

Hormonal factors and adiposity are also theorised to affect the risk of ovarian cancer, although the independent role of physical activity is still unclear and the limited number of studies in the published literature show contradictory results. Cust (2011) reviewed 20 studies, nine of which reported a decreased risk of ovarian cancer with increasing levels of physical activity. In ten studies there was no association between physical activity and cancer risk, and one study reported an *increased* risk with higher levels of activity. Even after controlling for factors such as family history, menopausal status, body mass index and energy intake, the results are unclear, with some studies showing moderate associations and others showing no association at all (Tavani et al, 2010; Leitzmann et al, 2009c).

In contrast to the finding that physical activity has a stronger protective effect against breast cancer in lean than overweight women, Pan et al (2005) observed the reverse with regards to ovarian cancer risk, in that a stronger effect was identified in overweight and obese, compared to lean, women. It may be that overweight and obesity exert a stronger influence on ovarian cancer than on breast cancer. A pooled analysis of cohort studies suggests that the risk of ovarian cancer increases by around 75% in those who are obese compared with normal-weight women although this was only found in pre-menopausal women (Schouten et al, 2008).

Nevertheless, there have been findings that obesity increases the risk of ovarian cancer also in post-menopausal women (Lahmann et al, 2010; Rodriguez et al, 2002). Indeed, Leitzmann et al (2009a) found that obesity increased the risk of ovarian cancer by nearly 80% in post-menopausal women who had *not* used menopausal hormonal therapy, but found no such association for those who had.

Although the evidence is limited it does suggest that obesity may increase ovarian cancer risk through its effect on oestrogen levels (Leitzmann et al, 2009c); a protective effect of physical activity may therefore exert itself in an ability to reduce oestrogen levels.

Prostate Cancer

In a recent review of 39 studies investigating the effect of physical activity on prostate cancer risk, 29 showed an inverse relationship between physical activity and prostate cancer, 11 of which were statistically significant showing an association between lower levels of physical activity and increased risk of prostate cancer (Leitzmann, 2011). However, four studies also reported a *positive* relationship (two of which were statistically significant) showing an association between higher levels of physical activity and greater risk for prostate cancer. The strength of the relationship varied greatly between studies, ranging from a 75% decrease in risk (Wannamethee et al 2001) to an 11.6% increase in risk (Sung et al 1999), with an overall estimated effect of physical activity on prostate cancer risk being a 9% decrease.

Subgroup effects have not been consistently identified, but one review found an average 15% decreased risk among younger men (under the age of 65 years) but an average 12% *increased* risk among older men (Leitzmann, 2011). Leitzmann also found a greater increase in risk of prostate cancer associated with high levels of physical activity among Black men than among White men, and a greater decrease in risk among Asian men than among White men. In contrast to the research evidence for colon and breast cancer, one study found that high levels of physical activity significantly decreased the risk for men who *did* have a family history of prostate cancer, but not for those without (Friedenreich et al, 2004).

Overall, based on the available evidence, an inverse association between physical activity and prostate cancer risk is considered to be *possible* (Leitzmann, 2011).

Lung Cancer

An estimated 80-90% of lung cancer is attributable to smoking (U.S. Department of Health and Human Services, 2004; Parkin et al, 2011) and as such, the biologic mechanisms through which physical activity may affect cancer risk are much clearer than for other forms of cancer. Smoking is known to decrease cardiorespiratory function and suppress the immune system (Rodriguez et al, 2010; Sopori, 2002), whereas physical activity increases respiratory function and is thought to reduce the concentration of carcinogenic agents in the lungs, and have a protective effect on the immune system (Brolinson & Elliott, 2007; Emaus & Thune, 2011).

Although the WCRF and AICR concluded in 2007 that the evidence for a protective effect of physical activity on lung cancer risk was “limited”, it is a growing field. Emaus and Thune (2011) reviewed 19 available studies investigating the effect of physical activity on lung cancer risk and found that 11 of these reported a decrease in lung cancer risk for the most active participants, with a suggestion that PA can decrease the risk of lung cancer by 20-50%.

The strongest evidence for a decrease in lung cancer risk with physical activity exists for both current and former smokers compared with people who have never smoked (Leitzmann et al 2009b; Mao et al 2003). Since the majority of lung cancer cases are due to smoking, people who have never smoked already have a lower risk of developing this disease. The association is also stronger in younger people – possibly because the effects of years of smoking are not so easily counteracted by physical activity in older participants.

Despite some promising evidence that physical activity can reduce lung cancer risk in former and current smokers, it must be strongly emphasised that the best protection against lung cancer is to abstain from smoking. The risk of lung cancer decreases once an individual cuts back on, or stops, smoking, and cessation is still likely to have a far greater protective effect than physical activity alone (Godtfredsen et al, 2005; Peto et al, 2000).

Other Cancers

For most other types of cancer there is insufficient research evidence to draw any firm conclusions about the effect of physical activity. One exception is rectal cancer, for which no association with physical activity has been consistently reported (IARC 2002; Spence et al, 2009; Wolin & Tuchman, 2011) and there is considered to be enough evidence to assume that a link between physical activity and rectal cancer is highly improbable. Also, since cervical cancer is known to be caused by infection with subtypes of the human papillomavirus (HPV; Parkin et al, 2005), physical activity is not thought to play a significant role; therefore no studies have been conducted to specifically investigate the relationship between physical activity and this type of cancer risk. HPV is also present in most vaginal and in-situ vulval cancer cases (Bjørge et al, 1997).

Due to the small number of studies there is inconclusive evidence for a link between physical activity and haematological cancer (Pan and Morrison, 2011), bladder, renal cell and testicular cancer (Leitzmann, 2011), and gastric cancer (Wolin & Tuchman, 2011); there is a significant lack of evidence for a link between physical activity and all other forms of cancer.

How Active Do You Need to Be to Reduce the Risk?

For those cancers for which there exists sufficient evidence of a relationship with physical activity (currently colon, breast and endometrial cancer) there is some evidence for this being a dose-response relationship (Cust et al, 2007; Thune & Furberg, 2001). In other words, the more active a person is, the lower their chances of developing cancer. The dose-response can relate to either the *intensity* of activity performed, the *amount* of activity performed, or a combination of the two. Lynch et al (2011) found that the amount of physical activity undertaken made a greater difference to breast cancer risk than the intensity level of that activity. For example, a slightly greater risk reduction has been associated with vigorous compared with moderate activity (18% versus 15%); however, participation in 6.5 hours of activity per week has been shown to reduce the risk by 30% compared to only a 9% risk reduction for 2-3 hours per week. Duration of physical activity has also been found to be more important than intensity of activity for both weight loss and improved cardiovascular fitness in a sample of overweight women (Chambliss, 2005), both of which can be associated with cancer risk. This is consistent with the general evidence suggesting that limiting the time spent inactive (sedentary time) is just as important as meeting the minimum moderate-to-vigorous physical activity recommendations.

However, different studies have found different risk reductions associated with increased intensity and duration of activity, and there is no clear indication of the magnitude of additional risk reductions with each increment of activity level. Further, it is not clear what level of physical activity is the minimum amount that must be performed in order to reap of the rewards of risk reduction. Study findings are contradictory as to whether low intensity exercise provides any significant benefits regarding cancer risk (Cust et al, 2007; Gierach et al, 2009; Howard et al, 2008; Wannamethee, Shaper and Walker, 2001). The reported minimum amount of activity which provides protective effects varies greatly, from 60 minutes to over 35 hours of activity a week (Rockhill et al, 1999; Slattery, 2004). Overall, the evidence suggests that 30-60 minutes of moderate physical activity each day is necessary to significantly reduce the risk of colon, breast, lung and endometrial cancers (DHHS, 2008).

Problems with Primary Prevention Research

Most primary prevention studies rely on participants' self-reports of physical activity levels, and these levels are often over- and under-reported. Studies find disagreement between self-reported levels of physical activity and levels measured using other methods such as accelerometers, pedometers, heart rate monitors, and direct observation, and usually find that physical activity levels are over-reported and sedentary activities are under-reported (DOH, 2010; Prince et al, 2008; Sims et al, 1999). This may be due to inaccurate recall, or due to social desirability bias, where respondents report levels of activity which will be seen as more favourable (Adams et al, 2005).

In primary prevention research, participants are also usually asked to report not only their current level of activity, but also their lifetime activity. These reports are likely to be best estimates and historical recall may be somewhat inaccurate. In addition to the problem of general recall, the same type of activity may have a different physiological effect on different individuals, and what is classed as 'moderate' or 'vigorous' activity may be highly dependent on an individual's sex, age, fitness levels and physical limitations. Asking people what kind of activity they have engaged in, and for how long, does not necessarily provide a comprehensive picture of a person's energy expenditure if fitness levels and factors such as body weight and physical injuries are not taken into account. However, such factors may also change over time, past characteristics may also be inaccurately recalled, and asking people to comment on the intensity of their activities risks attaining highly subjective results. The level of detail in questionnaires also differs greatly between studies (Shephard, 2003), and this may undermine data comparisons. Shephard notes the need for standardisation of measurement and definition of physical activity using self-reports, and of the interpretation of self-reported data.

Despite their limitations, self-reports remain the easiest, cheapest, and in some cases the only viable, way to conduct primary prevention studies. Physical activity levels can only be directly observed or measured for primary prevention purposes by conducting longitudinal studies spanning many decades, and such studies are resource-intensive and so not always feasible. Further, accelerometers, pedometers and heart rate monitors are subject to their own flaws as methods of measurement. Pedometers, for example, only count the number of steps a person takes and do not measure the intensity of exercise. There are also certain types of exercise which pedometers and accelerometers fail to capture, such as swimming and upper body exercises (Prince et al, 2008). Daily variability in heart rate as well as environmental factors can interfere with the accuracy of heart rate monitors (Achten & Jeukendrup, 2003).

Secondary Prevention

Physical activity has been proposed as an important factor in rehabilitation and recovery from illness for a wider range of conditions (Blake, 2009). The role of physical activity in cancer recurrence and mortality will be highly dependent on the type of cancer an individual has, how advanced the cancer is and therefore which treatment or combination of treatments is received. However, there is only limited research on the role of physical activity in secondary prevention and this has been conducted in relation to only a small number of cancer types, with breast cancer being the most studied cancer type.

Physical Activity Guidelines for Cancer Survivors

The physical activity guidelines for cancer survivors do not greatly differ from the physical activity guidelines for the general population, which are:

- 150 minutes of moderate-intensity *or* 75 minutes of vigorous-intensity aerobic physical activity per week, in bouts of at least 10 minutes
- Undertake physical activity which improves muscle strength at least 2 days per week
- Minimise the amount of time spent sitting down for extended periods

(WHO, 2010)

Early physical activity intervention studies with cancer survivors concerned themselves not only with the benefits of being active, but also whether or not it was safe for cancer survivors to be as physically active as the general population. Historically, medical recommendations had discouraged high levels of physical activity in those with a diagnosis of cancer, and instead encouraged rest. The benefits of adequate rest and appropriately pacing activities continue to be promoted in those with chronic conditions. However, there is now a consensus that safe and appropriate levels of physical activity should be promoted in most individuals who have cancer, to avoid the decline in physical conditioning and muscle strength that can occur with inactivity, and to promote overall health and wellbeing.

Research has shown that moderate-intensity physical activity interventions can be safe, both during treatment (Dimeo et al 1999; Courneya et al 2007; Schwartz and Winters-Stone 2009) and after treatment (Courneya et al 2003; Herrero et al 2006; Pekmezi & Demark-Wahnefried, 2011). With this knowledge, it is now recommended that cancer survivors undertake 150 minutes of moderate-vigorous activity per week as would be recommended for the general population (ACSM, 2010; Campbell et al, 2011; Doyle et al, 2006).

However, the findings suggest that the majority of cancer survivors are not meeting these guidelines. Low levels of physical activity have not only been identified in those who have cancer, with population figures showing that 58% of adults worldwide do not meet physical activity guidelines (WHO, 2009). Furthermore, the proportion of adults not meeting the current guidelines for physical activity have been shown to be similar across continents, ranging from 54% (South East Asia and the Eastern Mediterranean) to 63% (Europe).

However, low levels of physical activity in cancer survivors is of particular importance, since it has been suggested that activity levels in cancer survivors tend to decrease post-diagnosis (Blanchard et al, 2003a; Kwan et al 2012; Vallance et al 2005). Even five years post-diagnosis, cancer survivors are still more likely to be inactive than those individuals who have no cancer history (Smith et al, 2011).

The extent of a decrease in physical activity levels is in large part due to how difficult cancer survivors find it to be active following a diagnosis, and this is strongly influenced by their health status and their treatment options. For example, Kwan et al (2012) found that the strongest predictors of a post-diagnosis decline in physical activity levels were being treated with chemotherapy, and being overweight or obese. Common side effects of chemotherapy include fatigue, nausea and vomiting, increased risk of infection, anaemia, loss of appetite and sleep problems, so it is unsurprising that physical activity may be perceived as challenging. The barriers to physical activity faced by cancer survivors will be discussed later in this chapter.

Cancer varies from individual to individual; since some cancer treatments make it very difficult for a survivor to exercise at the recommended level, physical activity programmes can be tailored to the individual's needs, by beginning at a lower frequency or intensity level and progressing to 150 minutes of moderate to vigorous activity per week. At the very minimum, cancer survivors should aim to do some activity and avoid being completely sedentary (Campbell et al, 2011).

Recurrence and Mortality

Probably the most desired outcome that could arise from cancer survivors engaging in physical activity is prolonged survival and reduced risk of cancer re-occurrence following successful treatment. Courneya and Friedenreich (2011) note that there are many ways that physical activity could theoretically impact upon cancer survivorship, both prior to, during, and following treatment. For example, before treatment, physical activity may help in the management of the cancer and its symptoms and therefore delay the need for treatment; alternatively it may improve a patient's physical fitness in preparation for, or in order that they may undergo more physically demanding treatments. During treatment, physical activity may help to alleviate side effects and either improve, or prevent a loss of, physical fitness and functioning therefore enabling the treatment to be completed more easily. Post-treatment, physical activity may assist in recovery, reduce the risk of a cancer recurrence, and reduce the risk of co-morbidities.

There is some published evidence to suggest that engaging in physical activity can decrease the risk of cancer recurrence (Meyerhardt et al, 2009b) and cancer-related mortality (Hollick et al, 2008) in certain cancer populations. Four observational studies by Meyerhardt et al (2006a, 2006b, 2009a, 2009b) have all suggested that there is a significant positive relationship between post-diagnosis physical activity levels and survival (both disease-specific and overall) in colorectal cancer survivors. A systematic review of cohort studies observed a trend towards increased cancer-related survival with higher physical activity levels in both breast and colon cancer survivors (Barbaric et al, 2010). Haydon et al (2006) found that although increased waist circumference and body fat also decreased the chances of survival in colorectal cancer survivors, physical activity was associated with survival independently of body composition.

It has been recognised that cancer survivors are at greater risk of developing other chronic diseases (such as diabetes, heart disease and hypertension) compared with those who have no history of cancer (Oeffinger et al, 2006). This is significant since there is a well-established link between physical activity and such diseases (Willett et al, 2006) and as such the relationship between physical activity and both mortality and morbidity in cancer is highly complex. In addition to the known influence of physical activity on *cancer-specific* mortality, the breast cancer literature has shown that physical activity can decrease the risk of *overall* mortality in breast cancer survivors (Irwin et al, 2008; Sternfeld et al, 2009). In terms of the magnitude of the association, a recent meta-analysis by Ibrahim and Al-Homaidh (2011) of six studies found that post-diagnosis physical activity reduced breast cancer recurrence by 24%, cancer-related mortality by 30% and overall mortality by 41%.

Other research identifying a relationship between physical activity and mortality has focused on populations with lung cancer. A significant benefit of engaging in physical activity for lung cancer survivors relates to cardiorespiratory functioning. Lung cancer survivors have significant reductions in aerobic capacity – studies report anywhere between around 25-70% below the capacity of age-matches controls following a pneumonectomy (DeGraff et al, 1965; Loewe et al, 2007). Aerobic capacity is a strong predictor of surgical complications (Loewen et al, 2007) and has been shown to be the most important predictor of mortality (Myers et al, 2002). Studies have shown that physical activity interventions can significantly increase aerobic capacity in lung cancer survivors both pre-surgery (Bobbio et al, 2008; Jones et al, 2007b) and post-surgery (Spruit et al, 2006; Jones et al, 2008), and therefore improve chances of survival. Unfortunately, around 75% of diagnosed lung cancer cases are advanced and inoperable. The treatment for these cases is aggressive and further decreases the individual’s capacity for exercise. However, studies have suggested that there is value in those with lung cancer maintaining a certain level of physical activity. Pertinently, cancer symptoms have been shown to significantly decrease in inoperable lung cancer patients after just eight weeks of physical activity, which also prevented a decrease in cardiovascular fitness (Temel et al, 2009).

The Effect of Obesity

As we have seen, obesity is a significant risk factor for many cancers, and obesity continues to be a predictor of survival and quality of life after cancer diagnosis (Zhang et al, 2005). Worldwide, there are now more deaths resulting from being overweight or obese than from being underweight (WHO, 2009). With regards cancer mortality, obesity has been found to be an independent predictor of cancer-specific and overall survival in colon cancer (Sinicrope et al, 2010), breast cancer (von Drygalski et al, 2011), ovarian cancer (Pavelka et al, 2006) and endometrial cancer survivors (Calle et al, 2003), and is associated with higher level tumours and higher recurrence rates in men treated for prostate cancer (Amling et al, 2004). Obesity is known to increase the risk of illnesses such as heart disease, stroke, and type 2 diabetes (Field et al, 2001; Mokdad et al, 2003), and as such has significant influence on morbidity in the general population, although this carries added risks for cancer survivors who may also suffer from an already lowered immune system as a result of the cancer or the cancer treatment. Although a cancer diagnosis and treatment in itself may impact negatively on quality of life (Carlsson et al, 2000; Gomella et al, 2009; Kayl & Meyers, 2006), obesity has independently been associated with a decline in quality of life (Courneya et al, 2005b), and worryingly, as levels of overweight and obesity have markedly risen in the general population, a significant proportion of cancer survivors are now overweight or obese (Courneya et al, 2005b, 2008b; Irwin et al, 2004).

Physical activity can independently alter body composition in adults without a cancer history (Slentz et al, 2004; Shaw et al 2006). Whilst the evidence is limited, in general it would seem that this relationship has also been demonstrated in populations of cancer survivors. A review of randomised controlled trials examining the effect of physical activity on body composition in breast cancer survivors found that over half of the studies (conducted both during and post-treatment) showed significant improvements in one or more body composition variable [such as body weight, percentage body fat and lean body mass] (Schmitz, 2011). There is also some evidence from controlled interventions showing positive effects of physical activity on body composition in those with endometrial cancer (von Gruenigen et al, 2008) and also in prostate cancer survivors (Segal et al, 2009). However, research across the board suggests that the effect of physical activity on body weight and body fat is limited without simultaneous caloric reduction (PAGAC, 2008). Further, physical activity is known to have positive effects on survival independent of changes in body composition (Haydon et al, 2006).

Quality of Life

Research has not focused solely on preventing cancer recurrence or mortality. It has been estimated that there are over 24.5 million cancer survivors in the world (Parkin & Fernandez, 2006), and as the proportion of cancer patients reaching the five, seven, and ten year survival markers increases, there is growing importance attached to cancer survivors' quality of life post-diagnosis. Further, cancer survivors' ability to engage in some form of physical activity is improved as the side effects of treatment become more manageable.

'Quality of life' (QOL) is a term which refers to an individual's entire wellbeing. Quality of life measures typically focus on physical and psychological wellbeing, although the scope can be much wider than this. For example, the WHOQOL-BREF (2004b) measures physical health, psychological health, self-esteem, sexual health, social relationships and environment. Cancer survivors generally report lower QOL scores than matched individuals without cancer (Baker et al, 2003, 2009; Lazovich et al, 2009) and poor quality of life can be long-lasting, since it has been shown that cancer survivors can experience physical and psychological symptoms for more than ten years following their treatment (Harrington et al, 2010). Research therefore has sought, and continues to seek, ways in which quality of life might be improved in this population group. One method of improving quality of life is to encourage those health behaviours which are known to impact on both physical health and psychological wellbeing. For example, a recent review by Pekmezi and Demark-Wahnefried (2011) and meta-analysis by Fong et al (2012) conclude that physical activity can improve cancer survivors' physical functioning, strength, fitness, body composition, psychological wellbeing, and overall quality of life.

Physical Health

Current cancer treatments produce several negative short and long term physical effects. One of the most common and debilitating symptoms experienced by cancer survivors, particularly those who are undergoing, or have undergone, chemotherapy and/or radiotherapy, is fatigue (Armes et al, 2005). Cancer related fatigue (CRF) is defined as "a persistent subjective sense of tiredness related to cancer or cancer treatment that interferes with usual functioning" (Mock et al, 2003) and is thought to affect anywhere between 60-100% of cancer patients (Alberg et al, 2003; Wagner & Cella, 2004). For many patients, this fatigue does not end with the cancer treatment, and has been found to continue for months, or even years, post-treatment (Andryowski et al, 1998; Minton & Stone, 2008).

Although it may be perceived that rest is the best medicine for fatigue, a lack of physical activity over time may have negative effects since it is known to result in a further reduction in cardiopulmonary fitness and decline of the musculoskeletal system (Germain et al, 1995; Ness et al, 2006), which is already weakened by cancer treatments, notably chemotherapy and androgen deprivation therapy (Demark-Wahnefried et al, 2001; Galvão et al, 2010). A reduction in fitness and muscle mass worsens feelings of fatigue (Kilgour et al, 2010). Furthermore, maintaining some degree of physical activity attenuates the loss of, and can even improve, functional capacity (Courneya et al, 2003b; PAGAC, 2008; Segal et al, 2003). Intervention studies with breast cancer survivors have demonstrated that physical activity can significantly decrease fatigue, both during treatment (Courneya et al, 2008a; Mock et al, 2005; Pinto et al, 2000) and after treatment (Burnham & Wilcox, 2003; Granger et al, 2011; Shelton et al, 2009; Wilson et al, 2005). There have been fewer studies conducted with non-breast cancer survivors, although there is some evidence that physical activity also reduces CRF in other cancer survivors, notably those with prostate cancer (Battaglini, 2011; Cramp & Daniel, 2008; Fong et al, 2012; Keogh & MacLeod, 2012; Monga et al, 2007).

Most forms of cancer, but particularly cancers of the breast, gynaecologic and genitourinary regions, can result in sexual dysfunction and lack of sexual interest and satisfaction (Hill et al, 2011; Morreale, 2011; Ofman, 1995). Surgery for gynaecologic cancers may involve the removal of parts of the body involved in sexual arousal (Stead, 2003), and chemotherapy in particular often results in fatigue which affects both sexual functioning and interest (Arora et al, 2001). There is a lack of research into the effects of physical activity in this area with cancer survivors, but Dahn et al (2005) found that sexual functioning was positively associated with PA levels in a sample of prostate cancer survivors who had undergone radiation therapy, and there is also evidence which links physical activity to improved sexual functioning in the general population (Bacon et al, 2003; Hsiao et al, 2012; Laumann et al, 2005).

Cancer treatment to the pelvic region can also result in faecal and urinary incontinence for gynaecologic, colorectal, bladder and prostate cancer survivors, problems which can persist for months or even years after treatment (Dunberger et al, 2011; Erekson et al, 2009;

Hilton & Henderson, 2003; Miller et al, 2005; Nikoletti et al, 2008). Although this is an understudied field in cancer survivorship, pelvic floor exercises have been found to significantly reduce incontinence rates following radical prostatectomy and colorectal cancer surgery (Allgayer et al, 2005; Ribeiro et al, 2010; Van Kampen et al, 2000), and in individuals with non-cancer related incontinence (Borello-France et al, 2006, 2008; Sar & Khorshid, 2009).

Whilst physical activity has been clearly associated with general health, some studies have examined the safety of physical activity for cancer survivors with regards to specific symptoms – notably, lymphedema. Treatment for breast cancer usually involves surgery to remove the tumour (lumpectomy) or the whole breast (mastectomy). It is also usually recommended that some of the underarm lymph nodes be removed to determine whether the cancer has spread, and the amount of lymph nodes which are removed is dependent on cancer stage. This removal can cause damage to the lymph system resulting in swelling of soft tissue in the arm. This is called lymphedema, and can affect over half of breast cancer survivors (Paskett et al, 2007). Lymphedema can also be caused by radiation therapy to the underarm, neck or groin areas, a tumour blockage or infection restricting lymph flow, and may also affect patients with cancers of the prostate, pelvic area, blood and skin. However, most of the research relating to physical activity and lymphedema has focused on the safety of upper-body activity for breast cancer survivors.

Upper body exercise has previously been discouraged for women who have undergone axillary node dissection in order to avoid stressing the affected limb and risk causing or exacerbating lymphedema. However, Schmitz (2011) reviewed 8 studies which measured the effect of upper body exercise on lymphedema and found no evidence of lymphedema onset or worsening as a result of the exercise. One study even found that after a randomised controlled one-year weight training intervention for women who had had at least two lymph nodes removed, the incidence of lymphedema was *lower* in the intervention group compared with the no-exercise control group, and that this difference was significant for women who had had five or more lymph nodes removed (Schmitz et al, 2010). Further, that the evidence suggests that obesity increases the risk of developing lymphedema (Paskett et al, 2007; Ridner et al, 2011; Sagen et al, 2009), and therefore any physical activity which results in weight loss may also have a protective effect against lymphedema onset or progression.

Reviews have also indicated the safety of engaging in physical activity for prostate cancer survivors (Galvao et al, 2011) colon cancer survivors (Sellar & Courneya, 2011), lung cancer survivors (Jones, 2011) and haematological cancer survivors (Battaglini, 2011). However, Gil and von Gruenigen (2011) recommend that further studies examining the safety and feasibility of physical activity are required for gynecologic cancer survivors since this population is less well studied.

Psychological Health

It is commonly understood that a diagnosis of cancer can have a significant impact on an individual's psychological wellbeing as they come to terms with their symptoms, treatment plan, and in some cases, a potentially poor prognosis. Depression is more common amongst cancer survivors than in the general population (Hewitt & Rowland, 2002; Massie, 2004) and many survivors experience anxiety about the future, cancer recurrence and physical health problems (Baker et al, 2005; Deimling et al, 2006). Depression and anxiety have a significant impact on quality of life and can continue to affect cancer survivors for many years after treatment (Meyer & Aspergren, 1989).

Some cancer types are more strongly associated with depression than others – a greater proportion of oropharyngeal, pancreatic, breast, and lung cancer patients receive a diagnosis of depression than colon, gynaecological and lymphoma cancer patients (Massie, 2004). The impact that a cancer diagnosis has on an individual's mental health is no doubt affected by cancer stage and treatment as well as cancer site. For example, depression is more common amongst breast cancer patients who are diagnosed with a malignant compared with a benign tumour (Morris et al, 1977; Goldberg et al, 1992) and more common in those cancer patients who report more severe symptoms and greater physical restrictions (Hopwood & Stephens, 2000; Kurtz et al, 2002). Anxiety increases with the number of health symptoms present during treatment (Deimling et al, 2006). However, even diagnoses of those cancers with increased chances of survival can have a significant negative impact on psychological wellbeing. Mental health has been found to worsen immediately following a prostate cancer diagnosis, despite a promising prognosis, and then to improve following initial treatment (Korfage et al, 2005, 2006).

Shortly after diagnosis, mental wellbeing may also be affected by the sense of control cancer patients feel they have over their treatment. Breast cancer patients who had undergone mastectomy were less likely to report depressive symptoms if they had chosen to have the surgery themselves compared to those who went along with a surgeon's suggestion (Fallowfield et al, 1990). Strong predictive factors of depression and anxiety persisting long-term have been identified, and include previous treatment for psychological illness, maladaptive coping mechanisms, younger age and poor social support and lack of positive social interaction (Boyes et al, 2009; Mehnert & Koch, 2008).

Whilst cancer diagnosis and treatment may have negative effects on psychological wellbeing, studies have been conducted to investigate the possible positive effects of physical activity on mental health. In general population samples, low levels of physical activity have been associated with poorer mental health (Jorm et al 2003; Kull 2002). In cancer survivor populations, studies have found that higher levels of physical activity are associated with fewer depressive symptoms (Humpel & Iverson, 2007; Yeter et al, 2006) and lower levels of anxiety (Stevinson et al, 2009a). The evidence shows positive outcomes for depression and anxiety following a range of physical activity programmes in breast, lung, hematalogic, prostate and gynaecologic cancer survivors (Battaglini et al, 2009; Culos-Reed et al, 2006; Fong et al, 2012; Oldervoll et al, 2006; Schmitz, 2011).

In addition, cancer survivors often struggle with issues relating to body image. Body image and self-esteem can be greatly affected by mastectomy and breast reconstruction, incontinence following surgery, hair loss resulting from chemotherapy, concern over changes in body composition as a result of treatment, and loss of physical or sexual functioning as a result of fatigue or of gynaecologic or genitourinary surgery (Denlinger & Barsevick, 2009; Fobair et al, 2006; Speer et al, 2005). Both women and men report a difficult period of psychosexual readjustment following breast, gynaecologic and genitourinary surgery (Bokhour et al, 2001; Juraskova et al, 2003; Wilmoth, 2001). Combined with concerns relating to body image, this can affect a person's sexual interest and satisfaction, and as a result, their satisfaction with relationships (Ganz et al, 1999; Holmberg et al, 2001). Whilst physical activity programmes cannot alter the surgical outcome of physical loss, they may influence the common side effects of cancer treatments affecting body weight and muscle mass, factors which may influence mental wellbeing and have knock-on effects for self-esteem (Monga et al, 2007). There is also evidence to support an association between physical activity and improved body image both in cancer survivors (Duijts et al, 2011; Schmitz et al, 2005b; Speck et al, 2010) and in the general population (Campbell & Hausenblas, 2009).

Problems with Secondary Prevention Research

The published evidence on recurrence, mortality and quality of life is restricted to certain cancer populations (and heavily dominated by studies involving breast cancer survivors), and it is not yet clear whether the findings are applicable to other cancer survivors. More research is also needed to investigate the longer term implications of physical activity for these outcomes.

One of the main difficulties with research on physical activity in those who have cancer is that many studies do not account for the participants' physical activity levels before diagnosis. It is still unclear how important pre-diagnosis versus post-diagnosis physical activity levels are for secondary prevention and quality of life, with study findings showing mixed results (Rohan et al, 1995; Ibrahim & Al-Homaidh, 2011). It has been suggested that cancer survivors who maintain or increase their physical activity levels after being diagnosed report a higher quality of life compared with those whose PA levels decrease post-diagnosis (Blanchard et al, 2003b). This suggests that a sense of normality may be an important factor in quality of life and that an awareness of pre-diagnosis activity levels may be of importance. However, in noting pre-diagnosis activity levels one must be aware of the risk of inaccurate recall and social desirability bias in reporting. Further, most physical activity interventions have involved a formal exercise programme and have not accounted for participant's activities levels outside of the structured programme.

Despite these limitations, the growing evidence base for physical activity intervention studies has contributed to our understanding of the benefits of physical activity for those who have, or have had, cancer.

Intervention Studies

As with primary prevention studies, there appears to be no clear indication of exactly *how much* physical activity needs to be performed for a positive effect on cancer survival, cancer symptoms and quality of life (QOL). Controlled intervention studies are important in increasing our understanding of the amount of activity, type and duration of activity which is required to make a difference. Such research is required to understand whether physical activity is best performed during or after treatment, supervised or unsupervised, and individually or in a group setting for most benefit. At present the research focuses primarily on those cancers which are most common (such as breast cancer and prostate cancer) and even here the evidence is limited, which makes it difficult to draw firm conclusions. Nevertheless, the randomised controlled trials (RCTs) available in the published literature have provided an initial indication of potential benefits of physical activity that may inform policy and practice.

Dose

A common consideration when recommending physical activity to cancer survivors is *how* active they should be in order to improve their quality of life, mental health, and prolong their survival. Currently, it is advised that cancer survivors should aim to meet the physical activity guidelines for the general adult population (ACSM, 2010). This is at least 150 minutes of moderate (or 75 minutes of vigorous) intensity aerobic physical activity per week, and to engage in muscle-strengthening activities at least two days each week, in order to improve cardiovascular and muscular fitness, and reduce the risk of non-communicable diseases and depression (WHO, 2010).

However, it may be difficult for some cancer survivors to meet the recommended activity dose immediately, due to cancer disease or treatment symptoms, or current fitness levels. Courneya et al (2005a) found that more colorectal cancer survivors who had received adjuvant therapy, compared to surgery alone, reported that they were progressing towards the recommended amount of activity rather than managing to meet public guidelines. Although the WHO guidelines do not address cancer-specific needs, the recommendations for older adults (aged 65 and above) state that *"when adults of this age group cannot do the recommended amounts of physical activity due to health conditions, they should be as physically active as their abilities and conditions allow"* (WHO, 2010). This guidance is applicable to a significant proportion of cancer survivors, since around 63% of cancer cases are diagnosed in individuals over the age of 65 (Cancer Research UK), although it would also apply to those cancer survivors who experience debilitating physical symptoms which may impact on their activities of daily living. Although most physical activity interventions prescribe a dose of around 150 minutes of moderate intensity activity for the benefit of general health, some benefits may be gained from less than this since improved quality of life in breast cancer survivors has been associated with as little as 60 minutes of moderate physical activity a week (Campbell et al, 2005). Also, Burnham and Wilcox (2002) found no significant difference between low-intensity and moderate-intensity intervention groups in aerobic capacity, body composition, physical functioning or overall QOL after a 10 week programme, although levels improved significantly in both groups compared with controls.

A sizeable number of interventions with breast cancer survivors have therefore prescribed a progressive activity programme which allows cancer survivors to start by engaging in lower-intensity and/or shorter sessions, building up to a higher dose over time as their fitness level and strength increases. This approach has met with some success, demonstrating significant improvements in physical functioning, psychological wellbeing, cancer related fatigue (CRF) and overall QOL (Burnham & Wilcox, 2002; Courneya et al, 2007; Dimeo et al, 1997a; Mustian et al, 2009; Pinto et al, 2005). There is limited evidence also demonstrating positive outcomes for this form of progressive programme in prostate cancer survivors (Galvão et al, 2008, 2010). However, a self-report study by Stevinson et al (2007) found no difference in quality of life for ovarian cancer survivors who were partly active but did not meet the recommended guidelines of 150 minutes of moderate physical activity a week.

In summary, although it would be preferable for cancer survivors to meet general adult physical activity guidelines, findings indicate that lower levels of activity may still be beneficial for breast cancer and prostate cancer survivors, and therefore those individuals who are physically limited should aim to do as much activity as they can safely manage, with a view to increasing their activity levels as fitness and physical symptoms improve. More studies investigating the specific dose-response relationship for physical activity in various cancer populations are required.

Type of Activity

Most physical activity interventions with breast cancer survivors have prescribed aerobic activity, followed by a combination of aerobic and resistance activities (Schmitz et al, 2011). Studies of cancer survivors' preferences have shown that walking is often reported to be their most favoured form of exercise (Brownson et al 2000; Jones et al. 2007a; Rabin et al 2006; Vallance et al, 2006). This was highlighted in a study by Courneya et al (2003b) who found that when participants in their study were given a choice of activity, over 95% chose walking. This preference may be dependent on participants' current level of fitness and engagement with physical activity, since Stevinson et al (2009b) found that preference for walking in ovarian cancer survivors was greatest for those survivors who were not currently meeting physical activity guidelines. Nevertheless, walking has been recognised as an achievable form of activity for most cancer survivors regardless of fitness levels or income (which may affect the resources a person has access to). Walking interventions have met with some success and have been shown to improve fitness, and reduce body fat and fatigue (Dimeo et al, 1997a; Matthews et al, 2007; Mock et al, 2005).

Some research has shown that certain types of activity may be more beneficial in alleviating specific physical symptoms. For example, a programme consisting of pelvic floor exercises can significantly reduce incontinence rates in men who have undergone radical prostatectomy (Van Kampen et al, 2000). Further, aerobic activities have been found to have a greater impact on aerobic capacity than flexibility and resistance activity, and resistance activity has the greatest impact on muscle strength (Courneya et al, 2007; Galvão et al, 2006; Keogh & MacLeod, 2012). One study found that aerobic activity but not flexibility exercises prevented unwanted declines in red blood cell count for breast cancer survivors undergoing radiation treatment (Drouin et al, 2006), although flexibility exercises are important since they have been shown to improve satisfaction with life and decrease fatigue and depressive symptoms in breast cancer survivors (Daley et al, 2007).

Positive effects on CRF and overall QOL in breast cancer survivors have been observed as a result of a range of physical activity interventions involving aerobic, resistance or flexibility activities, or a combination of these elements (Fong et al, 2012; Schmitz, 2011). Courneya et al (2007) found that improvements in aerobic fitness as a result of aerobic conditioning, and in lean body mass as a result of resistance conditioning, were both associated with increased QOL, decreased fatigue and improved mental wellbeing in breast cancer survivors who were undergoing chemotherapy. However, one RCT with prostate cancer survivors receiving androgen deprivation therapy ADT found that while both resistance and aerobic exercise reduced fatigue in the short term, resistance exercise showed greater improvements long-term and produced added benefits for QOL, strength, fitness and lowered body fat (Segal et al, 2009). It is possible that the gender differences for responsiveness to resistance training which have been observed in the general population (Lewis et al, 1986; Tracey et al, 1999; Walts et al, 2008) might explain some of the differences in conditioning responses between breast and prostate cancer survivors. However these differences tend to be small and a greater effect of resistance training in prostate cancer survivors could simply be due to the significant decrease in lean body mass that often occurs as a result of ADT.

Whilst a combination of aerobic, resistance and flexibility exercises is likely to be the most beneficial in terms of all-round physical and psychological wellbeing, cancer survivors may need to prioritise certain types of activity if they are in the progression phase of their disease. In this case, it may be beneficial to focus on the particular type of activity which best addresses the most pressing symptoms – for example, resistance exercises for prostate survivors experiencing a significant loss of muscle mass, or aerobic exercises for lung cancer survivors whose aerobic capacity is significantly compromised. These are likely to be different for each individual based on their cancer site, treatment, and previous activity and fitness levels. Therefore, it would seem prudent to ensure that physical activity programmes are tailored to meet individual needs.

Supervised versus Self-Directed

Some studies have reported the outcomes of interventions in which participants have been prescribed a physical activity programme to complete independently. In other interventions, participants have been provided with access to the facilities required to perform the prescribed activity, and supervised them whilst they do so, either for motivational or monitoring purposes.

There is some evidence to suggest that supervised programmes may offer benefits over and above home-based or unsupervised programmes. For example, Shelton et al (2009) conducted an intervention study with haematological cancer survivors comparing supervised with self-directed groups, and found that the supervised group showed a greater decrease in fatigue, although this difference was not statistically significant. Additionally, a meta-analysis of RCTs reported that supervised aerobic programmes were significantly more successful in reducing CRF than home-based aerobic programmes in breast cancer survivors during treatment (Velthius et al, 2010), although there were not enough studies with prostate cancer survivors to draw conclusions for this population.

The positive findings that were found for breast cancer survivors may be in part due to the fact that cancer survivors often express uncertainty about how much activity it is safe for them to engage in (Craike et al, 2011; Robertson et al, 2012), and welcome the supervision of a professional who can assure and monitor them (Blaney et al, 2010). Uncertainty may lead to lower adherence levels (either fewer sessions or lower intensity) and therefore lessen the positive effects of physical activity compared with supervised groups. Despite the potential advantages of supervising cancer survivors during physical activity, supervised programmes are resource-intensive, and therefore are not feasible for delivery in the long-term. Furthermore, Irwin (2008) suggests that home-based interventions which encourage individuals to find ways to fit physical activity into their daily routine may lead to more effective long-term maintenance, and this was supported by Bourke et al (2011) who noted the importance of equipping survivors with the skills and confidence to maintain positive health behaviours independently. Some interventions have involved participants being supervised at the beginning of the programme before leaving them to continue with a physical activity programme individually; alternatively, some interventions have involved both supervised and self-directed approaches with some supervised and some individual sessions each week (e.g. Cadmus et al, 2009; Irwin et al, 2009).

These combined approaches allow initial monitoring, education, and the opportunity for cancer survivors to ask questions and raise concerns, whilst at the same time encouraging them to find ways to be active independently and reducing reliance on professionals in the long-term. Supervised programmes should be handled sensitively towards the end of the programme, since Emslie et al (2007) found that a common complaint among breast cancer survivors was that a supervised intervention stopped too abruptly which led to feelings of abandonment for the participants. This suggests that programmes may be best delivered using a part-supervised approach, for initial support and guidance about safety and individual needs, followed by encouragement of independent physical activity, with the supervised aspect gradually reduced when an individual no longer requires regular professional support.

Individual versus Group Based

An individual's social environment can have an impact on their quality of life; social support can have a positive effect both on mortality (Pinquart & Duberstein, 2010) and psychological health (Godding et al, 1995; Griffiths et al, 2009). Some authors have suggested that group-based interventions may produce added social benefits, through providing social interaction with, and emotional support from, other cancer survivors who have a similar understanding of the problems and experiences associated with the cancer journey. Group psychotherapy programmes have been shown to improve QOL among cancer survivors (Blake-Mortimer et al, 1999); however, breast cancer survivors reported preferring a group physical activity intervention to standard support groups, stating that support groups focussed on the illness and were "depressing", whereas group physical activity gave them a chance to forget about the cancer. Also, they felt that group physical activity provided them with the *option* to talk to other individuals about their disease, rather than this being expected of them, which they felt was the case if they attended support groups (Emslie et al, 2007).

Reviews with breast cancer survivors have concluded that physical activity positively impacts on QOL regardless of whether it takes place in an individual or group setting, with no significant differences between the two conditions (Crank and Daley, 2004; Floyd & Moyer, 2009). However, it should be recognised that in the majority of studies, specific psychosocial outcomes have not been measured, such as feelings of isolation and stigma. Cancer survivors have reported that sharing the experience of physical activity with other cancer survivors helped them to feel less isolated and more accepted (Adamsen et al, 2001; Emslie et al, 2007; Hennessy et al, 2005). This can have long-lasting effects; in one intervention study, social support was found to be such a valued part of a group exercise programme for breast cancer survivors that the participants arranged to exercise together weekly following the completion of the intervention (Campbell et al, 2005). However, studies providing physical activity interventions with breast cancer survivors have not all demonstrated the importance of social support - for example, Taylor et al (2006) found that group physical activity education or cognitive-behavioural sessions relating to physical activity did not improve levels of social support. However, the participants in this group did not engage in actual physical activity together and it may be that the collective action element that cancer survivors appear to desire may play an important role in bolstering this support.

Studies have identified benefits to performing physical activity independently. Naumann et al (2011b) found that compliance rates were slightly higher (though this difference was not statistically significantly) in their independent physical activity compared with group-based physical activity group; the authors suggested that the inflexibility of group-based sessions may prove problematic for some cancer survivors who may wish to reschedule. Another benefit to individual activity is that programmes can be best tailored to meet the needs of the each survivor. Studies have shown that individually tailored written encouragement leads to a greater increase in physical activity and positive health outcomes than generic material (Demark-Wahnefried et al, 2006, 2007), and the same may be true of verbal encouragement.

Studies reporting cancer survivors' preferences for individual versus group-based activity show conflicting results. Some individuals show a strong preference for exercising with other cancer patients, who are of similar fitness levels and understand each other's experiences (Adamsen et al, 2001; Blaney et al, 2010; Turner et al, 2004), while others find no such preference (Karvinen et al, 2006; Stevinson et al, 2009b). Some cancer survivors may also have a preference for exercising individually due to certain side effects of treatment– for example, incontinence amongst prostate and colorectal cancer survivors is likely to result in a strong preference to exercise alone and at home (Blaney et al, 2010). Researchers have also suggested that many cancer survivors experience self-consciousness and low body-image, as a result of treatment which impacts on their physical appearance (Blaney et al, 2010; Denlinger & Barsevick, 2009; Fobair et al, 2006; Speer et al, 2005), and this may discourage them from physical activity which takes place around other people. For example, in an interview study with prostate cancer survivors, one participant revealed that he was embarrassed to go swimming because of a scar resulting from his surgery (Craike et al, 2011). This again demonstrates the need for tailoring physical activity interventions to individual cancer survivor's needs.

The Addition of Education and Psychological Interventions

Some interventions have included an education and/or psychological element (such as counselling, support groups or cognitive-behavioural therapy) either instead of, or in addition to, a prescribed activity programme. Educational intervention such as print-based physical activity promotion has been shown to improve relevant knowledge in patients who have chronic diseases (Cooper et al, 2001). Interventions combining telephone counselling with tailored print materials have been found to significantly increase cancer survivors' self-confidence in their ability to engage in physical activity, and to have positive effects on physical and psychological wellbeing (Demark-Wahnefried et al, 2006; Morey et al, 2009), and it has been shown that tailored print materials alone can lead to a significant increase in cancer survivors' physical activity levels (Demark-Wahnefried et al, 2007). Additionally, research suggests that a significant proportion of cancer survivors report that they would like to receive information about physical activity and/or exercise counselling (Jones et al, 2007a; Jones & Courneya, 2002; Rogers et al, 2009).

However, few studies have assessed the specific benefit of adding health education or psychological counselling for health behaviours into a physical activity intervention. The majority of interventions which have included health education or psychological elements have not included an exercise-only group which would be needed to measure their added effects. One exception is Naumann et al's (2011) study with breast cancer survivors, in which participants were assigned to one of four conditions: usual care, exercise-only, counselling-only, or a combined exercise and counselling group. They found that the group who received both the exercise *and* counselling interventions showed the greatest improvements in fatigue. Both groups involving exercise, (but not the group receiving counselling only), showed significant improvements both in aerobic capacity and depressive feelings.

The success of these supportive interventions is significant since health care providers are unlikely to have the resources to offer all cancer survivors a tailored, supervised physical activity programme over a prolonged period of time to assist with recovery. Motivating cancer survivors to begin or continue their own physical activity programme by educating them about the importance, benefits and safety of PA and helping them to overcome their own individual barriers to PA (which will vary due to cancer type, stage and treatment effects, as well as other factors such as household income, family support and access to facilities) may help to overcome some of the problems commonly found with home-based interventions. The fact that positive outcomes have been demonstrated without the need for face-to-face contact increases the feasibility that such programmes may be offered to a significant number of cancer survivors (Demark-Wahnefried et al, 2006, 2007; Morey et al, 2009).

Length of Intervention

It would appear that cancer survivors gain some level of benefit fairly rapidly following physical activity programmes. A post-surgery intervention with breast cancer survivors showed that whilst flexibility exercises did not produce any positive effect on strength in the short-term, the exercises produced significant improvements in physical functioning after just 11 days. Two other brief intervention studies (one with breast cancer survivors and one with prostate cancer survivors) have shown that physical activity can have positive effects on overall QOL, fatigue, physical functioning, strength and aerobic capacity after just four weeks (Mustian et al, 2009; Windsor et al, 2004). Immediate short-term benefits are particularly notable in those individuals who were previously more sedentary. One study comparing the effects of a moderate-intensity intervention on both regularly active and previously sedentary breast cancer survivors found that after 12 weeks, those participants who were previously sedentary had decreased the time it took them to walk one mile, and increased their physical activity and self-efficacy for physical activity so much so that baseline between-group differences disappeared (Rabin et al, 2006).

However, since the majority of interventions have been of short duration (less than 6 months), and have not included a follow-up, long-term adherence rates and outcomes for physical activity, health and wellbeing are largely unknown.

Timing

Courneya and Friedenreich (2001) developed the ‘Physical Exercise Across the Cancer Experience’ (PEACE) framework, separating the cancer experience into six stages. Two of these are pre-diagnosis (pre-screening and screening/diagnosis) and four are post-diagnosis (pre-treatment, treatment, post-treatment and resumption). The majority of physical intervention studies with breast cancer survivors have been conducted following the completion of cancer treatment. In general the research has shown that post-treatment physical activity programmes can have positive effects on a wide range of outcomes (Cramp & Daniel, 2008) including quality of life (Carson et al, 2009; Daley et al, 2007), physical functioning (Courneya et al, 2003a; Pinto et al, 2005), aerobic capacity (Burnham & Wilcox, 2002; Milne et al, 2008), and mental wellbeing (Cho et al, 2006; Morey et al, 2009). A recent meta-analysis also found positive effects of physical activity on a wide range of QOL outcomes across different cancer-site survivors, although it should be recognised that 65% of the reviewed studies included breast cancer patients only (Fong et al, 2012).

Cancer survivors report significantly more health-related problems during their treatment (Baker et al, 2005). A smaller number of physical activity intervention studies have been conducted with breast cancer patients during the period of their treatment. Nonetheless, there are a significant number of such studies which provide sufficient evidence that physical activity during chemotherapy and radiotherapy for breast cancer can have positive effects on CRF (Cramp & Daniel, 2008; Velthius et al, 2010), physical functioning (Mutrie et al, 2007; Schwartz et al, 2007) mental wellbeing (Dimeo et al, 1999), aerobic capacity (Courneya et al, 2007) and body weight (Segal et al, 2001) and all studies demonstrated the safety of commencing a physical activity programme during this period.

In contrast to interventions with breast cancer populations, interventions with prostate cancer survivors tend to have been conducted during their treatment period. Galvão et al (2011) reviewed ten such interventions and of these, nine reported significant effects of physical activity on at least one physical or psychological outcome. There remains a significant lack of post-treatment intervention studies with prostate cancer survivors, and while some survey studies point to the benefits of post-treatment physical activity on QOL and physical functioning (Blanchard et al, 2004; Demark-Wahnefried et al, 2004), the benefits of a post-treatment intervention relative to during-treatment are unknown.

The evidence for physical activity intervention with haematological cancer survivors includes RCTs which have been conducted both post- and during treatment. Most have only included a small sample of participants and so the evidence is limited. However, the findings suggest that engaging in physical activity appears to be safe for this population, and have provided some evidence for positive effects on quality of life outcomes through both of these time periods (Battaglini, 2011). The only RCT identified including both those patients who were post-treatment and also those who were currently undergoing treatment was conducted with lymphoma patients. In this study, the authors found that a 12-week aerobic exercise intervention improved participants’ overall QOL, fatigue, cardiovascular fitness, mental health and general physical health, regardless of their treatment stage (Courneya et al, 2009). The evidence does not show consistent findings; a retrospective study by Vallance et al (2005) demonstrated positive effects for meeting physical activity guidelines only during off-treatment periods for lymphoma patients, although this may have been due to the low proportion of participants who reported meeting public health guidelines during treatment (6.5%).

Whilst there is not currently enough evidence to fully determine the stage within an individual's cancer cycle in which physical activity may have the biggest impact. However, there is some evidence from on-treatment studies that physical activity during treatment can help to manage side effects of treatment, decrease hospitalisation times, and may therefore facilitate treatment completion (Battaglini et al, 2008; Campbell et al, 2004; Dimeo et al, 1997). There is a lack of sufficient evidence for physical activity during treatment for other types of cancer, and also a lack of evidence for the efficacy of physical activity during the pre-treatment and resumption stages for all cancers. However, a recent systematic review concluded that it is safe for non-small cell lung cancer patients to engage in physical activity pre-treatment, and that such activity has positive effects on exercise capacity (Granger et al, 2011). In general, more research is needed before physical activity during treatment can be safely advised for cancer survivors diagnosed with cancers other than breast or prostate cancer.

Since the safety of engaging in physical activity during this period has been demonstrated for breast cancer survivors (and evidence of safety is growing for prostate and haematological cancer survivors), it may therefore be advisable for individuals in these populations to initiate a physical activity programme as early as possible after diagnosis (if one is not already in place) in order to benefit from a full range of positive effects which can be maintained and increased following treatment. Nevertheless it remains important to be mindful of the need for assessment of individual need regarding safety for physical activity, and to tailor activities to the needs and abilities of the participant.

Barriers to Physical Activity

Although the general health benefits of physical activity are well-known, studies consistently show only a low proportion of cancer survivors meeting physical activity guidelines (Bellizzi et al, 2005; Blanchard et al, 2008; Courneya et al, 2005b; Smith et al, 2011) and as we have seen, physical activity levels in cancer survivors tend to decline post-diagnosis, during treatment, and/or post-treatment (Blanchard et al, 2003a; Kwan et al 2012; Vallance et al 2005). It is therefore important to better understand the reasons why those cancer survivors who are less active are discouraged from engaging in physical activity.

Although the barriers and determinants of physical activity vary between individuals, there are some barriers which are consistently reported by cancer survivors. These frequently include lack of time or being too busy, nonspecific treatment side effects, fatigue, nausea, diarrhoea, surgical complications, work or family responsibilities, and lack of enjoyment (Courneya et al, 2005a; Ottenbacher et al, 2011; Rogers et al, 2008). Some of these barriers are also often reported in general population samples. Specifically, lack of time, lack of enjoyment, and work or family responsibilities are commonly reported as barriers by individuals with no cancer history (Booth et al, 1997; Luoto et al, 2001; Trost et al, 2002) and are therefore not necessarily cancer-specific. However, some barriers are reported more frequently in cancer populations than in general population samples. Physical limitation and fatigue have been shown to be particularly significant barriers to physical activity. For example, 53% of cancer survivors report that they are physically limited when it comes to exercise, compared with 21% of those with no history of cancer (Ness et al, 2006). One of the most prominent barriers, affecting at least 60% of cancer survivors (Alberg et al, 2003; Wagner & Cella, 2004), is cancer related fatigue (CRF). CRF is a debilitating sense of exhaustion which is disproportionate to energy expenditure (and therefore different from generally experienced tiredness), and is described by sufferers as “a complete shutdown”, “unrelenting” and “uncontrollable” (Blaney et al, 2010). Chambers et al (2009) found that cancer survivors who were fatigued were around 50% more likely to be sedentary or insufficiently active for the benefit of their health. Focus groups with 26 individuals with CRF revealed that half of the participants perceived themselves as “very active” before diagnosis, compared to none of them post-diagnosis. Instead, almost three-quarters of participants felt that they were “not active” or only “a little active” post-diagnosis (Blaney et al, 2010).

Other cancer-related factors which may present as potential barriers to physical activity include nausea, vomiting, diarrhoea, decreased muscle mass and strength, and osteoporosis (Carlsson et al, 2000; Courneya et al, 2008a; Galvão et al, 2009; Partridge et al, 2001; Spry et al, 2006; Smith, 2004). Around 60% of cancer survivors undergo some form of surgery (Courneya, 2003), which carries general surgical risks such as infection, pain, loss of physical sensation, and loss of physical function (Blaney et al, 2010; Bruce et al, 2001; Morii et al, 2012; van Wilgen et al, 2004). Further, surgery for colorectal, prostate, bladder and gynaecologic cancers can affect digestive functioning, and faecal and urinary continence, and this may result in exercising being uncomfortable, difficult or embarrassing (Dunberger et al, 2011; Erekson et al, 2009; Hilton & Henderson, 2003; Miller et al, 2005; Nikoletti et al, 2008). Incontinence has been reported as a significant barrier to physical activity, both for cancer survivors and in the general population (Blaney et al, 2010; Farage et al, 2008; Nygaard et al, 2005).

Courneya et al (2008a) note that some physical barriers can be managed behaviourally; for example, survivors suffering from fatigue are advised to engage in shorter activity sessions and/or to be active when feelings of fatigue are at their lowest. Survivors suffering from incontinence may feel more comfortable performing physical activity alone and in close proximity to toilet facilities. However, other barriers such as nausea may require medical assistance.

Whilst many barriers to physical activity mean that engaging in physical activity may be perceived as difficult, the research is promising and suggests that physical activity is both beneficial and achievable. Intervention studies have shown that it is possible for cancer survivors to be active to some extent both during and soon after the completion of treatment with very few observed negative consequences (Battaglini, 2011; Keogh & MacLeod, 2012; Schmitz et al, 2011). Additionally, many of the barriers to physical activity which are frequently reported by cancer survivors are not treatment related (Rogers et al, 2007; Ottenbacher et al, 2011). This suggests that physical condition alone does not determine whether someone participates in physical activity or not. Theories of behaviour may be useful for understanding how psychological concepts such as motivation, self-efficacy, attitudes and subjective norms can influence an individual’s physical activity participation.

Addressing Psychological Barriers to Physical Activity

The Theory of Planned Behaviour (TPB) proposes that behaviour is a result of intention, which in turn is a product of an individual's attitudes towards the behaviour, their perceived behavioural control, and subjective norms (Ajzen, 1991). Perceived behavioural control is a person's confidence in their ability to perform a given behaviour (in this case, to engage in physical activity), and a subjective norm is the individual's perception how favourable the people around them consider the behaviour to be. According to this theory, an individual will be more likely to engage in physical activity if they hold favourable attitudes towards physical activity, if they believe that others around them do also, and if they have confidence in their own ability to be physically active. There is empirical evidence in support of this theory, with studies demonstrating that attitudes, subjective norms and perceived behavioural control can account for a significant amount of the variance in exercise behaviour in cancer survivors (Blanchard et al, 2002; Courneya & Friedenreich, 1997, 1999; Courneya et al, 2002).

In terms of favourable attitudes, the majority of cancer survivors appear to be well aware of the potential benefits of engaging in physical activity, and expect physical activity to improve heart/lung functioning, reduce disease risk, build muscle strength, aid weight loss, alleviate stress and improve state of mind (Craike et al, 2011; Rogers et al, 2004, 2007). Blaney et al (2010) reported that cancer survivors with CRF also recognised that being active is a way of achieving a goal and regaining a sense of normality. However, there is often a lack of communication between clinicians and patients regarding the level and nature of physical activity which can be safely undertaken. As a result, individuals may be unaware of the cancer-specific benefits of being active, they may be uncertain about how much physical activity is safe for them, and they may worry about negative physical consequences (Craike et al, 2011).

According to TPB an individual will also be more likely to engage in physical activity if being active is perceived as being important to others and accepted by the people around them (Ajzen, 2002). Okun et al (2003) found that social norms were a significant predictor of physical activity in the general population, but that an even stronger predictor was social support. Social support for physical activity from friends and family has also been positively associated with physical activity levels in cancer survivors (Eyler et al, 1999; Rogers et al, 2008). Pertinently, there is evidence from intervention studies showing that some cancer survivors gain significant social benefits from taking part in group-based physical activity interventions with other cancer survivors, which result in feelings of support and solidarity (Adamsen et al, 2001; Blaney et al, 2010; Campbell et al, 2005).

The third predictor of intention is perceived behavioural control, which is determined by perceived barriers to physical activity and perceived opportunities to be physically active. Although physical problems resulting from cancer disease and treatment do not necessarily prevent a person from being active, they may significantly lower an individual's *perception* of their ability to be active. For example, Rogers et al (2006) found that cancer survivors were least confident in their ability to exercise when they were feeling nauseated. The concept of perceived behavioural control stems from self-efficacy theory (Bandura, 1997), which, when applied to physical activity, states that individuals with high levels of self-efficacy (also defined as people's beliefs in their abilities) will perceive fewer barriers to physical activity, or be less affected by them. Indeed, self-efficacy has been shown to be a strong and consistent predictor of physical activity adherence in the general population and in cancer survivors (Booth et al, 2000; Pinto et al, 2009; Sternfeld et al, 1999). In order to improve an individual's self-efficacy it is necessary to address the four main information sources by which it is affected: personal accomplishments, vicarious experiences, verbal encouragement and physiological and affective states.

Firstly, self-efficacy is enhanced by personal experiences which have proved successful and is undermined by those which have not. Research by Hughes et al has shown that completing an exercise session is associated with significant increases in self-efficacy in endometrial cancer survivors, and can predict future physical activity behaviour in the short-term (Hughes et al, 2010). Setting small goals which can be easily achieved in a sensible time frame, and placing individuals in situations where they are likely to succeed may therefore be effective ways of boosting self-efficacy for physical activity (van de Laar & van der Bijl, 2001). Personal experiences are thought to be the most influential source of self-efficacy since they are most relevant to the individual. However, Social Learning Theory (Bandura, 1986) states that individuals are also influenced by their observations of the experiences of others (often referred to in the literature as 'models'). According to this theory, an individual will be more likely to engage in physical activity if doing so is seen to result in positive outcomes for those around them. Similarly, the success of other people's experiences will be more likely to enhance or weaken an individual's self-efficacy if the observed model is perceived to be similar to them, as this similarity increases the chances of the action having the same outcome for the observer. It may therefore be possible to increase a cancer-survivor's self-efficacy or 'confidence' in their ability to be active by encouraging them to observe the benefits of physical activity in cancer survivors who have experienced, and overcome, similar barriers.

Thirdly, studies have found that verbal encouragement positively influences physical activity self-efficacy, participation and effort (Bickers et al, 1993; Burton et al, 1999; Clark & Nothwehr, 1999; Moffatt et al, 1994). Jones et al (2004) found that oncologist recommendations to exercise led to increased levels of physical activity in newly diagnosed breast cancer patients. However, studies have shown that physical activity is not routinely discussed between cancer survivors and their oncologist (Craike et al, 2011; Daley et al, 2008; Jones & Courneya, 2002), and this is notable since the majority of oncologists view physical activity during cancer treatment as important, beneficial and safe (Jones et al, 2005).

Finally, Bandura (1977) argued that self-efficacy is affected by individuals' awareness and interpretation of somatic responses to behaviour. Muscle ache and fatigue experienced during or after physical activity may be interpreted as a sign of physical inefficacy, particularly among cancer survivors who may perceive these responses as more serious (Hughes et al, 2010). Self-efficacy may therefore be improved by helping cancer survivors to re-interpret their responses to physical activity – for example, perceiving muscle ache and fatigue as temporary steps towards long term health benefits (Lee et al, 2008). A key part of this will be ensuring that cancer survivors are provided with sufficient and appropriate individually tailored information about the safety and benefits of physical activity for them, both during and following treatment.

There is some evidence in the literature which suggests that techniques based on self-efficacy theory involving encouragement, vicarious experiences, reward systems and learning to recognise and alter negative responses to physical activity, are feasible and can be successful in increasing physical activity levels (Borsody et al, 1999; Cromwell & Adams, 2006; Lee et al, 2008, 2012). However, this evidence is based on healthy populations and populations with other health conditions (e.g. heart failure, hypertension) and there is a need for theory-based interventions with cancer survivors specifically.

Even if an individual is aware that physical activity is beneficial, socially approved and achievable, this positive intention may or may not lead to active change in behaviour. Another key concept related to intention is that of motivation or ‘willpower’. Ottenbacher et al (2011) found that, of their sample of breast and prostate cancer survivors, those who reported ‘no willpower’ to be physically active engaged in less physical activity. Significantly, ‘no willpower’ was reported as a barrier by 51% of breast and 44% of prostate cancer survivors.

According to Self-Determination Theory (SDT) motives lie on a continuum between the extremes of *controlling* and *autonomous* (Deci and Ryan, 1985, 2002; Sheldon et al, 2003). Controlling motives are at work when an individual performs an action in order to gain a reward or avoid a punishment, and the cause of the behaviour is seen to be external. In contrast, motives are autonomous when the behaviour is inherently pleasurable and valued so that the behaviour will be undertaken without the need for external pressure or incentive, and the cause of the behaviour is perceived as internal. The majority of factors which cancer survivors report as motivating are controlling, such as improved physical functioning, aiding recovery from surgery, increasing self-esteem, social contact, improving body image and weight loss, although some survivors also report that they find physical activity relaxing (Blaney et al, 2010; Craike et al, 2011; Rogers et al, 2004, 2007; Schrop et al, 2007).

Although either type of motivation can result in physical activity, application of this theory in research has shown that autonomous motivation tends to lead to more favourable and consistent outcomes, whilst higher levels of external regulation are associated with physical activity cessation (Garcia Calvo et al, 2010). Individuals may be less likely to continue with a physical activity programme if they rely on motivation from external rewards, since these may not always occur. For example, Segar et al (2002) note that for women in the general population, weight loss is often a key motivation to engage in physical activity. However, if changes in body composition are not seen immediately, or are not as significant as they would like, motivation may be lost and the physical activity discontinued. Further, some of the potential benefits of physical activity for cancer survivors (such as reduced risk of disease recurrence) are not always well understood by participants, or well communicated to cancer survivors by clinicians. Conversely, studies have found that autonomous motives are linked with more positive attitudes towards exercise both in the general population and amongst cancer survivors, and it has been shown that autonomous motivations result in a higher level of physical activity engagement (Ryan et al, 1997; Wilson et al, 2003, 2006). Since cancer survivors report lack of enjoyment as a barrier to physical activity (Leddy, 1997; Rogers et al, 2006; Rogers et al, 2007), it may be important to take into account cancer survivors’ preferences in constructing physical activity programmes in order that they are more intrinsically enjoyable, providing autonomous motives and may therefore be more likely to be adhered to.

However, it is recognised that the majority of motives for action lie somewhere along this continuum rather than at one of two extremes. These motives are internalised to varying degrees depending on how personally significant and valued an individual views the outcome to be. The degree of internalisation determines how likely it is that the behaviour will be performed. For example, there is evidence that some older people see physical activity as irrelevant in their own lives, although they acknowledge the benefits it brings to others

(Campbell et al, 2001); indeed, cancer survivors over the age of 65 are less likely to engage in physical activity (Bellizzi et al, 2005). Importantly, SDT also posits that controlled motives can actually be internalised and become more autonomous (Ryan & Deci, 2000). For this to happen, supportive conditions need to be in place which encourage an individual's autonomy, competence and relatedness (which SDT holds are three basic human psychological needs). Similarly to self-efficacy, these are fostered by rewards, feedback, success, and social care and support. If engaging in physical activity serves to satisfy these needs, the motivations which lead to physical activity will become more internally regulated (Silva et al, 2008; Wilson & Rogers, 2003). Lukowski et al (2012) found that endometrial cancer survivors who had been physically active for more than six months were more likely than non-active participants to report the immediate positive physical and emotional responses to physical activity as important reasons to be active. Conversely, the non-active participants were more likely to report extrinsic motivations, such as long-term health benefits, as important reasons for being active.

Just as motivations can move towards the autonomous end of the scale, they can also become more controlling. Ryan and Deci (2000) argue that threats, deadlines, imposed goals and external pressures can lead to an individual perceiving behaviour as being externally controlled. Silva et al (2008) argue that people need to feel that they have an strong element of choice over their behavior; cancer survivors often feel a loss of control as a result of their diagnosis (National Research Council, 2008) and therefore interventions which promote feelings of autonomy may be the most successful in increasing physical activity levels (Silva et al, 2008, 2010). To understand this more fully there is a need for more theory-based interventions to be conducted with cancer populations specifically.

Despite low rates of engagement in physical activity, many cancer survivors do show interest in increasing their activity levels (Rogers et al, 2009; Szymlek-Gay et al, 2011). For example, Jones et al (2007a) reported that 45.2% and 70% of brain cancer patients said that they would like to receive information about an exercise programme during and after treatment respectively. Similarly, Jones and Courneya (2002) found that 84% of mixed cancer survivors reported an interest in receiving exercise counselling. Contamination issues arising from randomised controlled trials have shown that cancer survivors are often keen to be active even when they are not asked to and manage to find their own motivation to be physically active outside of an intervention setting (Mock et al, 2005; Thorsen et al, 2005). Despite the barriers to physical activity that cancer survivors face, the majority of this population appear to be interested in engaging in a physical activity programme of some sort. Although the observed proportion of cancer survivors engaging in recommended levels of physical activity appears low, there is some suggestion that cancer survivors may actually be more motivated to engage in physical activity than the general population. Bellizzi et al (2005) found that only 29.6% of cancer survivors were meeting physical activity recommendations compared with 36.6% of those without a history of cancer, but when they adjusted for demographic and health factors (such as functional limitations), a multivariate analysis showed that cancer survivors were actually 9% more likely to meet physical activity guidelines than those with no cancer history. The key issue is how this interest might be translated into action and behavioural theories provide some useful suggestions. It would seem that physical activity may be encouraged by increasing feelings of competency and autonomy, providing positive physiological or verbal feedback, modelling examples, and providing social support.

Evidently, there are many factors which may motivate or discourage cancer survivors from engaging in physical activity. Given the many benefits of being active for this population, it is important that health care providers help their patients to overcome barriers which hinder their participation in physical activity, being careful to assess their personal circumstances to ensure that advice is appropriately tailored for the individual. Karvinen et al (2007) note that barriers to and motivators of physical activity may differ between cancer groups, and therefore it should not be assumed that the effectiveness of techniques to increase physical activity with one cancer population can be generalised to all cancer survivors. Characteristics of individuals, such as gender and age, may also play a role in physical activity participation. Physical activity participation is typically found to be higher in men than in women (Trost et al, 2002), and gender differences in reported barriers and motivation may help to explain differences between gender-specific cancers (Kim et al, 2010; Smith et al, 1998; Ottenbacher et al, 2011). Further, some barriers are related to, or exacerbated by, physical decline in old age, such as muscular and joint problems (Craike et al, 2011) and fear of falling (Arfken et al, 1994), and older age has been associated both with lower levels of self-efficacy and lower levels of physical activity in cancer survivors (Bellizzi et al, 2005; Rogers et al, 2006).

Conclusion

In the last decade there have been significant contributions to the field of physical activity and cancer. There is now enough evidence to confidently assume an inverse association between physical activity and the risk of colon, breast and endometrial cancers. However there are still important gaps in our knowledge, particularly relating to the biological mechanisms through which physical activity affects cancer risk, and therefore the amount of physical activity which is required in order to significantly reduce the risk of cancer occurrence. The positive relationship between physical activity and quality of life is well established, and it is has been clearly demonstrated that physical activity can play a vital role in breast cancer recovery. However, the exact nature of the relationship between physical activity, cancer recurrence and cancer-specific mortality is unclear, although findings from a limited number of studies suggest that there may be a protective effect. In both primary and secondary prevention cancer research there is a significant lack of high-quality research for most types of cancer which limits our ability to draw firm conclusions from the evidence-base.

The growing number of randomised controlled trials in this field serve to increase our awareness of the potential benefits of physical activity for cancer survivors, and the nature of those physical activity programmes which are likely to be most effective at producing short-term benefits in cancer survivors, although the evidence for longer-term effects are less well understood. Studies reporting longer follow-ups are required to help to better understand the nature and level of physical activity which needs to be maintained for cancer survivors to continue receiving its protective and health-enhancing benefits.

It is clear that there are many individual differences which may influence a person’s actual or perceived confidence in their ability to perform physical activity, and their physical activity preferences. Particularly with regards to type of activity, and whether programmes are individual or group based/supervised or independent, it may be that the success of certain interventions may rely more on how they fit with an individual's needs, prior experiences and current preferences rather than an intrinsic design advantage. Taking into account commonly experienced problems while at the same time being aware of individual needs may help to improve the quality of lifestyle advice given to cancer survivors.

A number of studies have investigated the timing for delivery of physical activity intervention and these have shown promising findings, although there are a lack of studies reporting physical activity interventions which have been conducted during the pre-treatment and resumption phases. It is possible that intervening at the pre-treatment stage may have implications for the efficacy of treatment or recovery from treatment but there is currently a lack of available evidence from which to draw conclusions.

Whilst it is generally accepted that physical activity is beneficial for health and wellbeing, and the research has shown positive outcomes specifically with people who have cancer, it would appear that cancer survivors are not receiving sufficient information from their healthcare providers regarding these benefits, and also on the safety of engaging in physical activity during and following their treatment. It is important that health care professionals are aware of the benefits of physical activity for those with different types of cancer, and that they can provide (or signpost to) information and services to encourage them to engage in some form of physical activity. Whilst physical activity should be promoted in the general population not least because of the preventative effect of active lifestyles on risk of colon, breast and endometrial cancers, those who have, or have had, a diagnosis of cancer should endeavour to meet as a minimum the population guidelines for physical activity when their physical condition allows, until further evidence becomes available.

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