British Journal of Cancer (2011) 105, S38 – S41
© 2011 Cancer Research UK All rights reserved 0007 – 0920/11
www.bjcancer.com

9.

Cancers attributable to inadequate physical exercise in the UK in 2010

DM Parkin*,[1]

[1]Centre for Cancer Prevention, Wolfson Institute of Preventive Medicine, Queen Mary University of London, Charterhouse Square, London EC1M 6BQ, UK

British Journal of Cancer (2011) **105,** S38 – S41; doi:10.1038/bjc.2011.482 www.bjcancer.com

Several studies suggest that regular physical exercise protects against development of breast cancer, large bowel cancer and endometrial cancer, independently of the effect of physical exercise in reducing body weight. The World Cancer Research Fund (WCRF, 2007) summarizes the evidence as 'convincing' for cancers of the colon, and 'probable' for cancers of the breast (in post-menopausal women only) and endometrium (WCRF, 2007).

The evidence that individuals with high levels of physical activity throughout their lives are at lower risk for colon cancer was considered 'sufficient' in the International Agency for Research on Cancer (IARC) evaluation (IARC, 2002), and convincing by WHO/FAO (2003). The relationship between physical exercise and risk of rectal cancer is much less certain (IARC, 2002; Wei *et al*, 2004; Friedenreich *et al*, 2006), although a few studies (e.g., Slattery *et al*, 2003) have shown an inverse association.

In relation to physical activity and risk of breast cancer, IARC (2002) concluded that, although studies have not been entirely consistent, the overall results support a reduction in risk with higher levels of activity. Evidence for a dose – response effect was found in most of the studies that examined the trend. The majority of studies have focused on postmenopausal breast cancer, although there is also some evidence for a protective effect of physical activity on premenopausal disease. In some of the studies, the nature of the physical activity (recreational, occupational, and household) has appeared to be of importance, too.

A recent review and meta-analysis of 13 studies (Voskuil *et al*, 2007) concluded, like WCRF (2007), that physical activity seems to be associated with a reduction in the risk of endometrial cancer, which is independent of body weight.

The Department of Health (2004) target for physical exercise is that everyone should aim to take at least 30 min of physical activity on five or more days of the week. This physical activity should be of at least moderate intensity – similar to brisk walking. Activity can be taken in bouts of 10 – 15 min, allowing for accumulation of activity throughout the day.

In this section, we examine how much cancer of the colon, female breast and endometrium observed in 2010 might be attributed to a deficit in physical activity in the population below this recommended minimum.

*Correspondence: Professor DM Parkin; E-mail: d.m.parkin@qmul.ac.uk

METHODS

Most studies of the effect of physical activity on cancer risk present results in terms of categories of activity (high/medium/low, or as quantiles of the population studied). In order to quantify the effect of change to exercise intensity on the health of the population, risk must be quantified in relation to energy expenditure in MET. (MET means metabolic equivalent, and is used to describe the intensity of activities. One MET is defined as the energy spent sitting quietly (equivalent to (4.184 kJ) per kg per hour), while, for example, moderate activity corresponds to 3 – 6 METs, and vigorous activity to >6 METs. A table showing MET values of different activities is available at http://www.cdc.gov/nccdphp/dnpa/physical/pdf/PA_Intensity_table_2_1.pdf).

At least four recent studies provide estimates of risk of colon cancer in relation to physical activity (adjusted for body mass index) expressed as MET hours: Giovannucci *et al* (1995), Chao *et al* (2004), Friedenreich *et al* (2006) and Wolin *et al* (2007).

At least four recent studies provide estimates of risk of breast cancer in relation to physical activity (adjusted for body mass index) expressed as MET hours: Friedenreich *et al* (2001), Carpenter *et al* (2003), McTiernan *et al* (2003) and Lahmann *et al* (2007).

For each of these studies, the relative risk (RR) per MET-hour per week was estimated by assuming a log-linear relationship between exposure and risk, so that:

$$\text{Relative risk}(x) = \exp\left(\ln\left(\text{risk per unit}\right) \times \text{exposure level}(x)\right)$$

where x is the exposure level (in MET-hours per week).

We used the simple mean of the RR per unit exposure in each study.

The values were as follows:

Post-menopausal breast cancer: RR 0.9955 per MET-hour per week.

Colon cancer: RR 0.9940 per MET-hour per week.

The value for post-menopausal breast cancer in the meta-analysis of WCRF (2007) is very similar – for postmenopausal breast cancer and recreational activity, an RR of 0.97 per 7 MET-hours per week.

As we are concerned with quantifying the effect of a deficit in exercise, we calculate the increase in risk associated with a *decreased* exercise intensity of 1 MET-hour per week as

$$(1/\mathrm{RR}) - 1$$

The values were the following:

0.00457 for post-menopausal breast cancer.
0.00602 for colon cancer.

With respect to endometrial cancer, none of the case–control and cohort studies so far reported provide results with respect to physical activity in comparable units. It is thus not possible to estimate directly the relationship in terms of RR (or ERR) per MET-hour per week. However, in a large case–control study in Sweden, comparable results are given for post-menopausal breast cancer (Moradi *et al*, 2000a) and endometrial cancer (Moradi *et al*, 2000b). The strength of the association between recreational and occupational activity, comparing the lowest with the highest activity categories, is more or less the same for both cancers (RR = 1.3). Therefore, the values per MET-hour per week estimated for breast cancer (as above) have also been used for endometrial cancer.

The latent period, or interval between 'exposure' to an inadequate level of physical activity, and the appropriate increase in risk of these cancers (or, conversely, the duration of exercise required to eliminate the excess risk of a suboptimal level) are not known. For the four cohort studies contributing to the estimate of RR of colon cancer in this analysis (Giovannucci *et al*, 1995; Chao *et al*, 2004; Friedenreich *et al*, 2006; Wolin *et al*, 2007) the mean duration of follow-up was 8.9 years. In the two cohort studies contributing to the estimate for breast cancer (McTiernan *et al*, 2003; Lahmann *et al*, 2007) it was shorter (5.6 years), while in the seven cohort studies in the meta-analysis of endometrial cancer by Voskuil *et al* (2007) mean duration of follow-up was 14.8 years. We chose to assume the same latency for all three of 10 years and thus examine the effects on cancers occurring in 2010 from suboptimal levels of physical activity in 2000.

The minimum target would envisage all those doing less than 30 min, 5 days a week, to move to this minimum (but no increase in exercise levels in those individuals already achieving the target level).

The National Diet and Nutrition Survey (FSA, 2004) provides tables showing reported levels of physical exercise, by age group and sex, for adults aged 19–64 in a sample of households in Great Britain in 2000–2001. There are four categories: moderate exercise of 30 min duration for 5 or more days a week, 1–2 days, 3–4 days and <1 day per week. In all, 36% of men and 26% of women aged 19–64 were already at the target level of at least 30 min moderate physical exercise on at least 5 days a week. For those of age >65, equivalent data were obtained from the Health Survey for England (Health and Social Care Information Centre, 2010) by averaging the values in the surveys of 1997 and 2003. The middle category (1–4 days moderate exercise per week) was split into two (1–2 and 3–4), based on the ratios observed at ages 50–64 in the 2000–2001 National Diet & Nutrition Survey.

The results for all adult age groups (ages 19 and above) are shown in Table 1.

Assuming that exercise of moderate intensity is equivalent to 6 METS, so that 30 min of moderate exercise consumes 3 MET-hours, we estimate the deficit in MET hours below the recommended level of 15 per week (3 × 5). Thus, for the proportion of the population exercising moderately 3–4 days a week, the deficit is, on average, 4.5 MET-hours per week (15−[3 × 3.5]), for those exercising 1–2 days 10.5 MET-hours per week and for those exercising less than 1 day per week 13.5 MET-hours (15−[3 × 0.5]) per week. These values are shown in the first row of Table 1.

Table 1 Estimated percentage of the population performing physical activity at the level given, in 2000

	% Performing physical activity[a] with specified frequency per week			
Age (years)	**<1 day**	**1 or 2 days**	**3 or 4 days**	**≥5 days**
Deficit in METs per week	13.5	10.5	4.5	0
Men				
19–24[b]	21	14	17	49
25–34[b]	12	21	21	46
35–49[b]	20	27	19	34
50–64[b]	30	28	18	24
65–74[c]	52.6	20.1	12.9	14.5
≥75[c]	73.0	11.9	7.6	7.5
All (19+)[d]	28.2	22.9	17.5	31.5
Women				
19–24[b]	20	36	15	29
25–34[b]	14	29	26	30
35–49[b]	21	29	24	25
50–64[b]	24	34	21	22
65–74[c]	57.0	20.1	12.4	10.5
≥75[c]	81.7	8.7	5.4	4.0
All (19+)[d]	31.6	27.3	19.4	21.5

Abbreviations: METs = metabolic equivalents. [a]Defined as moderate intensity activity of at least 30 min duration. [b]From National Diet and Nutrition Survey, FSA (2004). [c]From Health Survey for England (2009 trend tables), average for 1997 and 2003; the middle physical activity category (1–4 days per week) was split into 1–2 and 3–4 days per week in proportions observed at ages 50–64 in the National Diet and Nutrition Survey, FSA (2004). [d]Based on UK 2000 population.

Population-attributable fractions (PAFs) were calculated for each sex-age group in Table 1 according to the usual formula:

$$\mathrm{PAF} = \frac{(p_1 \times \mathrm{ERR}_1) + (p_2 \times \mathrm{ERR}_2) + (p_3 \times \mathrm{ERR}_3) + (p_4 \times \mathrm{ERR}_4)}{1 + [(p_1 \times \mathrm{ERR}_1) + (p_2 \times \mathrm{ERR}_2) + (p_3 \times \mathrm{ERR}_3) + (p_4 \times \mathrm{ERR}_4)}$$

where p_x is the proportion of population in exercise category x and ERR_x the excess RR in exercise category x.

ERR_x is calculated as

$$\{\exp(R_m \times M_x) - 1\}$$

where R_m is the increase in risk for a deficit of 1 MET-hour per week and M_x is the deficit in MET-hours per week (less than 15) in exercise category x.

RESULTS

Table 2 shows the estimated PAF and the number of cases of breast, endometrial and colon cancer 'caused' in 2010 by the deficit in exercise (in 2000), by age group and sex. The excess number of cases is also expressed in terms of cancer as a whole.

An estimated 3.4% of breast cancer cases, 3.8% of endometrial cancer cases and 5.3% of colon cancer cases are attributable to exercising less than the minimum recommended. The 5.3% of colon cancers correspond to 3.3% of large bowel cancers (colon and rectum). This corresponds to 1.0% of all cancer cases, 0.4% in men and 1.7% in women.

DISCUSSION

Although a beneficial effect of physical activity levels on the risk of various cancers has been observed in various individual studies – notably for cancers of the lung, pancreas and prostate – the

Table 2 Cancer cases diagnosed in 2010, attributable to below-target exercise level in 2000

Age (years)		Breast (post-menopausal)			Uterus (endometrium)			Colon			All cancers[a]	
At exposure	At outcome (+10 years)	PAF	Observed cases	Excess attributable cases	PAF	Observed cases	Excess attributable cases	PAF	Observed cases	Excess attributable cases	Observed cases	Excess attributable cases
Men												
19–24	29–34	—	—	—	—	—	—	0.031	58	1.8	1333	1.8
25–34	35–44	—	—	—	—	—	—	0.029	216	6.2	4124	6.2
35–49	45–59	—	—	—	—	—	—	0.038	1451	55.5	22388	55.5
50–64	60–74	—	—	—	—	—	—	0.046	5331	247.3	68043	247.3
65–74	75–84	—	—	—	—	—	—	0.058	4339	250.6	44085	250.6
⩾75	⩾85	—	—	—	—	—	—	0.067	1598	106.9	16064	106.9
Total (%)		—	—	—	—	—	—		13044	668.3 (5.1%)	158667	668.3 (0.4%)
Women												
19–24	29–34	0	582	0	0.032	28	0.9	0.043	60	2.5	2248	3.4
25–34	35–44	0	3857	0	0.028	211	5.9	0.037	236	8.6	8619	14.5
35–49	45–59	0.032	14 628	461.7	0.032	1926	60.8	0.042	1301	54.0	31 631	576.5
50–64	60–74	0.035	17 194	602.8	0.035	3844	134.8	0.046	3914	180.3	54 966	917.9
65–74	75–84	0.046	7584	352.4	0.046	1570	73.0	0.061	3873	235.9	35 386	661.2
⩾75	⩾85	0.054	4367	237.1	0.054	605	32.8	0.071	2299	163.3	20 050	433.3
Total (%)			48 385	1654.1 (3.4%)		8195	308.1 (3.8%)		11 732	644.7 (5.5%)	155 584	2606.9 (1.7%)
Persons												
19–24	29–34		582	0		28	0.9		117	4.3	3582	5.2
25–34	35–44		3857	0		211	5.9		452	14.8	12 743	20.7
35–49	45–59		14 628	461.7		1926	60.8		2752	109.6	54 019	632.1
50–64	60–74		17 194	602.8		3844	134.8		9245	427.6	123 009	1165.2
65–74	75–84		7584	352.4		1570	73.0		8212	486.4	79 472	911.8
⩾75	⩾85		4367	237.1		605	32.8		3897	270.2	36 114	540.1
Total (%)			48 385	1654.1 (3.4%)		8195	308.1 (3.8%)		24 776	1312.9 (5.3%)	314 251	3275.2 (1.0%)

Abbreviations: PAF = population-attributable fraction. [a]Excluding non-melanoma skin cancer.

evidence is far from conclusive, and in this section we include only those (colon, post-menopausal breast cancer and endometrial cancer) for which the evidence is considered convincing or probable in the reviews of WRCF (2007) or ‘sufficient’ by IARC (2002).

There are several probable mechanisms underlying the protective effects of physical activity (McTiernan *et al*, 1998; Quadrilatero and Hoffman-Goetz, 2003). They include modification of levels of metabolic hormones and growth factors, improvement of the anti-tumour immune system, promotion of antioxidant defence and DNA repair. Physical activity may reduce exposure to endogenous oestrogens implicated in breast and endometrial cancer. With respect to colon cancer, physical activity can speed up the transit of food, with reduced exposure to intraluminal carcinogens. Changes to levels of insulin, prostaglandin and bile acids reduce proliferation of mucosal cells.

The current estimate – that around 1% of cancers in the UK may be related to physical inactivity (below a modest aspiration of 30 min five times a week) – is similar to the estimate of Doll and Fau (2003), that less than 1% of cancer deaths are due to physical inactivity. However, the estimates of the proportions of cancers related to inadequate ‘physical activity’ in the UK in 2002 by WCRF (2009) are substantially higher: 12% of colorectal cancer, 12% of breast cancer and 30% of endometrial cancer. There are several reasons for these larger estimates. WCRF selected ‘representative’ studies from which to take the RRs; only one (for colon cancer) is referenced to be from their own meta-analyses (WCRF, 2007), where the value (1.33 for more than 150 hours exercise per week *vs* none) is not actually reported. The RR for endometrial cancer, 0.57 for $\geqslant$60 minutes of non-occupational exercise per day compared with $<$30 min (Schouten *et al*, 2004), is particularly significant. The reference category (optimum physical activity) was different for the three cancers, and in all was higher than the equivalent of 5×30 min of moderate exercise per week. Finally, the translation of the exposure prevalence (from the National Diet and Nutrition Survey) to the categories used in the calculation of three different estimates was particularly imaginative.

Using a modelling approach, de Vries *et al* (2010) estimated that, in 2040, 8.7% of colon cancer cases in men and 17.4% in women would be due to suboptimal levels of physical activity during the previous 20 years. The higher percentages than those estimated in the current analysis (4.9% in men and 5.3% in women) are due to several differences in the methods. The main difference is the dichotomizing of the population into ‘optimal’ and inactive, with RRs from a meta-analysis of leisure-time activity and colon cancer (Samad *et al*, 2005) that suggested substantial risk in inactive individuals *vs* those ‘physically active’ (1.28 in men, 1.41 in women), which contrasts with the risk of 1.09 in the least active group of Tables 1 and 2 relative to the optimum of 5×30 min of moderate exercise per week (substantially less active than the baseline category of Samad *et al*, 2005).

Based on short-term trend data from the Health Survey for England (Health and Social Care Information Centre, 2010), it does seem that, in the period 1997–2009, there has been an increase in the proportion of persons exercising five or more times per week. There is evidence from reviews that interventions to increase individual exercise levels in community, health-care and occupational settings can be successful (Hillsdon *et al*, 2005), although at present there is little review-level evidence of the effectiveness of modifications to the built environment in increasing physical activity in the general population.

See acknowledgements on page Si.

Conflict of interest

The author declares no conflict of interest.

REFERENCES

Carpenter CL, Ross RK, Paganini-Hill A, Bernstein L (2003) Effect of family history, obesity and exercise on breast cancer risk among postmenopausal women. *Int J Cancer* **106:** 96 – 102

Chao A, Connell CJ, Jacobs EJ, McCullough ML, Patel AV, Calle EE, Cokkinides VE, Thun MJ (2004) Amount, type, and timing of recreational physical activity in relation to colon and rectal cancer in older adults: the Cancer Prevention Study II Nutrition Cohort. *Cancer Epidemiol Biomarkers Prev* **13:** 2187 – 2195

Department of Health (2004) *At Least Five a Week: Evidence on the Impact of Physical Activity and Its Relationship to Health. A Report from the Chief Medical Officer*. http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_4080994

de Vries E, Soerjomataram I, Lemmens VE, Coebergh JW, Barendregt JJ, Oenema A, Møller H, Brenner H, Renehan AG (2010) Lifestyle changes and reduction of colon cancer incidence in Europe: a scenario study of physical activity promotion and weight reduction. *Eur J Cancer* **46:** 2605 – 2616

Doll R, Fau PJ (2003) Epidemiology of cancer. In *Oxford Textbook of Medicine*, Warrell DA, Cox TM, Firth JD, Benz Jr EJ (eds). Oxford University Press: Oxford

Food Standards Agency (FSA) (2004) *National Diet and Nutrition Survey: Adults Aged 19 to 64, Vol. 4. Table 5.4: Nutritional Status, Physical Measurements and Physical Activity Levels*. http://www.food.gov.uk/multimedia/pdfs/ndnsfour.pdf

Friedenreich C, Norat T, Steindorf K, Boutron-Ruault MC, Pischon T, Mazuir M, Clavel-Chapelon F, Linseisen J, Boeing H, Bergman M, Johnsen NF, Tjonneland A, Overvad K, Mendez M, Quiros JR, Martinez C, Dorronsoro M, Navarro C, Gurrea AB, Bingham S, Khaw KT, Allen N, Key T, Trichopoulou A, Trichopoulos D, Orfanou N, Krogh V, Palli D, Tumino R, Panico S, Vineis P, Bueno-de-Mesquita HB, Peeters PH, Monninkhof E, Berglund G, Manjer J, Ferrari P, Slimani N, Kaaks R, Riboli E (2006) Physical activity and risk of colon and rectal cancers: the European prospective investigation into cancer and nutrition. *Cancer Epidemiol Biomarkers Prev* **15:** 2398 – 2407

Friedenreich CM, Courneya KS, Bryant HE (2001) Influence of physical activity in different age and life periods on the risk of breast cancer. *Epidemiology* **12:** 604 – 612

Giovannucci E, Ascherio A, Rimm EB, Colditz GA, Stampfer MJ, Willett WC (1995) Physical activity, obesity, and risk for colon cancer and adenoma in men. *Ann Intern Med* **122:** 327 – 334

Health and Social Care Information Centre (2010) *Health Survey for England – 2009: Trend Tables*. http://www.ic.nhs.uk/statistics-and-data-collections/health-and-lifestyles-related-surveys/health-survey-for-england/health-survey-for-england–2009-trend-tables

Hillsdon M, Foster C, Cavill N, Crombie, Naidoo B (2005) The effectiveness of public health interventions for increasing physical activity among adults: a review of reviews. *Evidence Briefing*. Health Development Agency. http://www.nice.org.uk/aboutnice/whoweare/aboutthehda/hdapublications/p103.jsp

International Agency for Research on Cancer (IARC) WHO (2002) *IARC Handbooks of Cancer Prevention: Weight Control and Physical Activity*, Vol. 6. International Agency for Research on Cancer: Lyon

Lahmann PH, Friedenreich C, Schuit AJ, Salvini S, Allen NE, Key TJ, Khaw K-T, Bingham S, Peeters PHM, Monninkhof E, Bas Bueno-de-Mesquita H, Wirfält E, Manjer J, Gonzales CA, Ardanaz E, Amiano P, Quirós JR, Navarro C, Martinez C, Berrino F, Palli D, Tumino R, Panico S, Vineis P, Trichopoulou A, Bamia C, Trichopoulos D, Boeing H, Schulz M, Linseisen J, Chang-Claude J, Clavel Chapelon F, Fournier A, Boutron-Ruault M-C, Tjønneland A, Føns Johnson N, Overvad K, Kaaks R, Riboli E (2007) Physical activity and breast cancer risk: the European Prospective Investigation into Cancer and Nutrition. *Cancer Epidemiol Biomarkers Prev* **16:** 36 – 42

McTiernan A, Kooperberg C, Wise E, Wilcox S, Coates R, Adams-Campbell LL, Woods N, Okene J (2003) Recreational physical activity and the risk of breast cancer in post menopausal women. The Womens Health Initiative Cohort Study. *JAMA* **290:** 1331 – 1336

McTiernan A, Ulrich C, Slate S, Potter J (1998) Physical activity and cancer etiology: associations and mechanisms. *Cancer Causes Control* **9:** 487 – 489

Moradi T, Nyrén O, Zack M, Magnusson C, Persson I, Adami HO (2000a) Breast cancer risk and lifetime leisure-time and occupational physical activity (Sweden). *Cancer Causes Control* **11:** 523 – 531

Moradi T, Weiderpass E, Signorello LB, Persson I, Nyrén O, Adami HO (2000b) Physical activity and postmenopausal endometrial cancer risk (Sweden). *Cancer Causes Control* **11:** 829 – 837

Quadrilatero J, Hoffman-Goetz L (2003) Physical activity and colon cancer: a systematic review of potential mechanisms. *J Sport Med Phys Fit* **43:** 121 – 138

Samad AK, Taylor RS, Marshall T, Chapman MA (2005) A meta-analysis of the association of physical activity with reduced risk of colorectal cancer. *Colorectal Dis* **7:** 204 – 213

Schouten LJ, Goldbohm RA, van den Brandt PA (2004) Anthropometry, physical activity, and endometrial cancer risk: results from The Netherlands Cohort Study. *J Natl Cancer Inst* **96:** 1635 – 1638

Slattery ML, Edwards S, Curtin K, Ma K, Edwards R, Holubkov R, Schaffer D (2003) Physical activity and colorectal cancer. *Am J Epidemiol* **158:** 214 – 224

Voskuil DW, Monninkhof EM, Elias SG, Vlems FA, van Leeuwen FE (2007) Task force physical activity and cancer. Physical activity and endometrial cancer risk, a systematic review of current evidence. *Cancer Epidemiol Biomarkers Prev* **16:** 639 – 648

Wei EK, Giovannucci E, Wu K, Rosner B, Fuchs CS, Willett WC, Colditz GA (2004) Comparison of risk factors for colon and rectal cancer. *Int J Cancer* **108:** 433 – 442

Wolin KY, Lee IM, Colditz GA, Glynn RJ, Fuchs C, Giovannucci E (2007) Leisure-time physical activity patterns and risk of colon cancer in women. *Int J Cancer* **121:** 2776 – 2781

World Cancer Research Fund (WCRF)/American Institute for Cancer Research (AICR) (2009) *Policy and Action for Cancer Prevention. Food, Nutrition and Physical Activity: A Global Perspective*. AICR: Washington, DC

World Cancer Research Fund (WCRF) Panel (2007) *Food, Nutrition, Physical Activity, and the Prevention of Cancer: A Global Perspective*. World Cancer Research Fund: Washington, DC

World Health Organization (WHO)/Food and Agriculture Organization (FAO) (2003) *Diet, Nutrition and the Prevention of Chronic Diseases: Report of a Joint WHO/FAO Expert Consultation* WHO Technical Report Series 916. WHO: Geneva