REVIEW

Recent advances in the link between physical activity, sedentary behavior, physical fitness, and colorectal cancer

[version 1; peer review: 2 approved]

Vikneswaran Namasivayam^{1,2}, Sam Lim^{3,4}

¹Department of Gastroenterology and Hepatology, Singapore General Hospital, Singapore, Singapore

²Duke NUS Medical School, Singapore, Singapore

³Respiratory Inflammation and General Medicine of AstraZeneca Global Medicine Development Centre, Shanghai, China

⁴Office of Clinical Science, Duke-NUS Medical School, Singapore, Singapore

V1 First published: 01 Mar 2017, 6(F1000 Faculty Rev):199
<https://doi.org/10.12688/f1000research.9795.1>

Latest published: 01 Mar 2017, 6(F1000 Faculty Rev):199
<https://doi.org/10.12688/f1000research.9795.1>

Abstract

Physical inactivity is a well-established risk factor for colorectal cancer (CRC). Recent studies have characterized physical activity (PA), sedentary behavior, and cardiorespiratory fitness as distinct, interrelated constructs that influence the risk of CRC and related outcomes. PA levels required to confer protection against CRC may be higher than previously thought. Sedentary behavior, defined as time spent sitting, increases CRC risk independent of PA and may require novel interventions distinct from those targeting PA. Finally, cardiorespiratory fitness is inversely associated with CRC risk and mortality and may provide a potential tool for risk stratification and intervention.

Keywords

colorectal cancer , sedentary behaviour , cardiorespiratory fitness , risk factor

Open Peer Review

Approval Status

	1	2
version 1
01 Mar 2017		

Faculty Reviews are review articles written by the prestigious Members of **Faculty Opinions**. The articles are commissioned and peer reviewed before publication to ensure that the final, published version is comprehensive and accessible. The reviewers who approved the final version are listed with their names and affiliations.

1. **Justin Y Jeon**, Yonsei University, Seoul, South Korea
Yonsei University, Seoul, South Korea
2. **Brigid Lynch**, Cancer Epidemiology Centre, Cancer Council Victoria, Melbourne, Australia

Any comments on the article can be found at the end of the article.

Corresponding author: Vikneswaran Namasivayam (vikneswaran.namasivayam@singhealth.com.sg)

Competing interests: VN has received institutional funding support from the following: the SingHealth Duke-NUS Academic Medical Centre through the Medicine Academic Clinical Programme Grant: Nurturing Clinician Scientist Scheme; NCC Research Fund and Oncology Academic Clinical Program; and the estate of Tan Sri Khoo Teck Puat. SL owns stock in AstraZeneca.

Grant information: VN has received institutional funding support from the following: the SingHealth Duke-NUS Academic Medical Centre through the Medicine Academic Clinical Programme Grant: Nurturing Clinician Scientist Scheme; NCC Research Fund and Oncology Academic Clinical Program; and the estate of Tan Sri Khoo Teck Puat.

Copyright: © 2017 Namasivayam V and Lim S. This is an open access article distributed under the terms of the [Creative Commons Attribution License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. Data associated with the article are available under the terms of the [Creative Commons Zero "No rights reserved" data waiver](#) (CC0 1.0 Public domain dedication).

How to cite this article: Namasivayam V and Lim S. **Recent advances in the link between physical activity, sedentary behavior, physical fitness, and colorectal cancer [version 1; peer review: 2 approved]** F1000Research 2017, 6(F1000 Faculty Rev):199 <https://doi.org/10.12688/f1000research.9795.1>

First published: 01 Mar 2017, 6(F1000 Faculty Rev):199 <https://doi.org/10.12688/f1000research.9795.1>

Introduction

A consistent body of literature demonstrates a protective role for physical activity (PA) against colon cancer. Up to a third of common cancers and a fifth of colorectal cancers (CRCs) in industrialized nations have been ascribed to excess weight and insufficient PA, and the disease burden attributable to inactivity is expected to rise in developing countries as well^{1–7}. In addition to counteracting obesity, PA confers beneficial effects against CRC through other pathways, and physical inactivity is a risk factor for CRC that is independent of obesity. Almost a third of adults worldwide are currently inactive, and the trend toward physical inactivity starts in early life—a reflection of modern-day living, working, and commuting being carried out in an environment designed to avoid physical labor⁸. It is now recognized that a sedentary lifestyle comprises three distinct but interrelated concepts: PA, sedentary behavior, and cardiorespiratory fitness (CRF). This review describes recent developments in our understanding of how each of these factors impacts on CRC risk.

Physical activity, sedentary behavior, and cardiorespiratory fitness

PA may be defined as any bodily movement produced by skeletal muscles that result in energy expenditure⁹. It is characterized by the following dimensions—frequency, duration, and intensity—and may be accumulated within the following domains: recreation, occupation, transportation, and domestic. PA levels can be measured by self-report through logs or questionnaires. PA increasingly is being assessed via objective measures such as accelerometers, which are wearable electronic devices that record the volume, intensity, and frequency of activity. PA is often quantified as hours of activity per week or as metabolic equivalent (MET)-hours per week. MET is a physiological measure expressing the energy cost of physical activities where 1 MET is the average resting energy expenditure of humans seated at rest. Moderate-to-vigorous physical activities are those that entail an energy expenditure of 3 to 8 METs, whereas light-intensity activity behaviors usually require an expenditure of less than 3 METs¹⁰. The MET score for various physical activities has been estimated by researchers and reported within the Compendium of Physical Activities¹⁰. The Compendium is frequently used to estimate the energy expenditure of physical activities reported within epidemiologic studies¹⁰.

Existing research and public health recommendations have placed an emphasis on increasing PA that fall within the moderate to vigorous intensity of the PA spectrum. However, there is growing recognition that light-intensity activities constitute a significant portion of daily energy expenditure with attendant health benefits^{11,12}.

Sedentary behavior refers to any waking behavior characterized by an energy expenditure of not more than 1.5 METs while in a sitting or reclining posture¹³. This includes activities such as sitting, watching TV, using the computer or other screen-based entertainment, and spending time in automobiles. Sedentary behavior is not merely inadequate amounts of moderate-to-vigorous PA but a behavioral entity that may have distinct physiological effects¹⁴. Sedentary behavior may vary among physically active populations.

Physically active individuals who satisfy expert recommendations for moderate-to-vigorous PA may still be sedentary for their remaining waking hours and thus are at risk of detrimental health outcomes^{12,15}. The importance of sedentary behavior stems from the risk it confers on longevity, cancer and other chronic diseases that are independent of PA, the growing epidemic of sedentary behavior that typifies urban living and the recognition that sedentary behavior may require different interventions that are not adequately addressed by current public health promotion measures targeting PA^{12,16–19}.

CRF is the capacity to use atmospheric oxygen for cellular energy production via aerobic metabolism. CRF is defined on the basis of maximal oxygen intake or maximal work capacity measured by incremental exercise testing with a cycle ergometer or treadmill. The gold-standard measure of CRF is the maximum oxygen uptake ($\text{VO}_2 \text{ max}$) (measured in liters per minute) and is a reflection of the patient's functional aerobic capacity. The term physical activity and fitness are sometimes used interchangeably but refer to distinct concepts. PA characterizes a behavior whereas CRF describes the capacity to achieve a certain performance level⁹. Although there is a significant inheritable component to $\text{VO}_2 \text{ max}$ (up to 50% in sedentary adults), PA is considered the primary determinant of CRF^{19–21}. Although CRF is modestly correlated with PA, both provide distinct information. Unlike PA and sedentary behavior, which are estimated by questionnaires, CRF is measured by incremental exercise testing and provides an objective, quantitative, and highly reproducible measure of the functional consequences of PA which may be used for risk stratification and serve as a potential target for intervention.

Physical activity and colorectal cancer

Regular PA is protective against colon cancer. PA reduces the risk of colon cancer by approximately 20%–25% among both men and women in a dose-response manner^{20,21}. The protective effect has been consistently found in studies of various designs, diverse populations, in subjects of varying body mass index (BMI), across various domains of PA, and after statistical control for various lifestyle factors, indicating that the relationship is unlikely to be due to confounding health behaviors^{22–26}. The protection conferred by PA appears to be similar in the proximal and distal colon^{27,28}, and conflicting results in earlier studies probably reflect small sample sizes and differing definitions of proximal and distal colon.

PA in the context of an overall healthy lifestyle characterized by healthy diet, low alcohol consumption, no smoking, PA, healthy BMI, and adequate sleep confers protection against colon cancer, but the relationship is inconsistent for rectal cancer^{29,30}. The evidence linking PA with rectal cancer, in contrast to that with colon cancer, is conflicting, although a recent meta-analysis indicates a protective effect of leisure-time PA on the risk of rectal cancer^{31–33}.

PA is also associated with an estimated 15% reduction in the risk of colonic adenoma, the precursors to carcinoma. The association holds for both genders and is stronger for advanced adenoma (35% risk reduction)^{34,35}. The risk of recurrent adenoma, in contrast to that of incident adenomas, appears to be reduced with PA only in

men but the duration of follow-up studied was relatively short^{36,37}. Unlike the case for adenoma, a protective effect for PA on serrated polyps, which represent an alternate pathway to colon carcinogenesis, remains to be established^{38–40}.

PA, before and after a diagnosis of CRC, also reduces the risk of all-cause mortality and CRC-specific mortality in a dose-dependent manner^{41,42}. Every 15 MET-hours per week increase in PA – approximately equivalent to walking for 5 hours per week – after a diagnosis of CRC reduces total mortality by 38% and CRC-specific mortality by 35% respectively. Furthermore, *increasing* PA levels following a diagnosis of cancer was associated with a decreased risk of total mortality⁴¹. The conclusions of the meta-analysis may be affected by reverse causality resulting from inclusion of cancer patients who had lower PA levels due to symptoms of the disease at the time of PA assessment. Randomized controlled trials are ultimately required to establish causation and determine the true effect of PA as an intervention.

Emerging studies have shed further light on the optimum exercise dose (that is, frequency, duration, and intensity) and the relative benefits of aerobic PA versus resistance PA. Studies suggest that the level of PA required to reduce overall mortality risk may be higher than current public health recommendations^{43,44}. In a cohort study of over 43,000 US male health professions, PA was inversely associated with risk of digestive system cancers (hazard ratio (HR) 0.74 for ≥ 63.0 versus ≤ 8.9 MET-hours per week, 95% confidence interval (CI) 0.59–0.93). Aerobic exercise was especially beneficial compared with resistance exercise, and optimum benefit was derived at 30 MET-hours per week (HR 0.68, 95% CI 0.56–0.83), which translates to approximately 10 hours of walking per week at average pace⁴⁵. The benefit was similar irrespective of intensity of PA so long as the MET score was achieved. A similar level of PA has been associated with reduced mortality in patients with CRC⁴⁴. This contrasts with existing American Cancer Society recommendations of at least 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity activity each week, or an equivalent combination, preferably spread throughout the week⁴³. Although there is a dose-response association between PA and colon cancer, which suggest benefits even with a little additional PA, higher levels of PA may be required to attain optimal benefits in CRC prevention.

Sedentary behavior and colorectal cancer

Sedentary behavior is increasingly recognized as a risk factor for CRC incidence and mortality independent of PA^{44,46–49}. Sedentary behavior as characterized by time spent watching TV, occupational sitting time, and total sitting time was associated with a 54%, 24%, and 24% increased risk of colon cancer, respectively, in a meta-analysis⁴⁶. Sedentary behavior is also associated with an increased risk of all-cause mortality, CRC-specific mortality^{44,50}, and lower quality of life in CRC survivors⁵¹.

Prolonged TV viewing is associated with an increase in the risk of colorectal adenoma independent of leisure time PA, particularly for high-risk adenoma, in a study of male health professionals, suggesting that sedentary behavior potentially acts early in carcinogenesis⁵². Sedentary behavior is also associated with a

higher risk of colorectal adenoma recurrence among men but not women³⁷.

It is unclear whether the deleterious effects of prolonged sitting on CRC can be overcome by simply increasing PA levels. A recent meta-analysis of over 1 million subjects studied the association of PA and sedentary behavior with all-cause mortality and demonstrated that high levels of moderate-intensity PA (60–75 minutes daily) are required to eliminate the risk of all-cause mortality associated with a sedentary lifestyle⁵³. However, this level of activity decreases, but does not eliminate, the risks of all-cause mortality associated with prolonged TV viewing. It is unknown whether this applies to the risk of CRC as well.

There remain significant challenges in translating the current understanding of the impact of sedentary behavior on CRC into interventions with meaningful clinical impact.

Although sedentary behavior has been linked with various diseases, there are limited data on the minimum reduction in sedentary behavior required to give rise to health benefits. Current guidelines that advocate limiting sedentary behavior do not offer quantitative recommendations or specific strategies to reduce sitting time⁴³. Sedentary behavior may also require specific interventions, targeted at interrupting extended sitting with frequent short activity breaks, that are distinct from those designed to increase PA⁵⁴. Interventions focused on increasing PA levels do not have a consistent impact on reducing sedentary behavior^{55,56}. Current interventions targeting sedentary behavior have a modest impact on reducing sitting time and their impact on health outcomes remains to be determined^{56,57}. Assessment methods for sedentary behavior also need to be standardized and validated. Subjective measures based on self-report are limited by measurement error, whereas more objective measures are costly and lack information on specific domains of sedentary behavior⁵⁸. Existing studies linking sedentary behavior to CRC have focused largely on Caucasian males, and findings need to be corroborated in more diverse populations⁵⁹.

Cardiorespiratory fitness and colorectal cancer

CRF is associated with a decreased risk of CRC incidence and mortality. In a prospective cohort study of almost 14,000 community-dwelling men, high CRF at midlife was associated with a 44% reduction in the risk of CRC compared with low CRF. Every 1-MET increase in CRF was associated with a 9% relative risk reduction in CRC risk. In addition, CRF in midlife was associated with a decreased risk of death from cancer or cardiovascular disease following a diagnosis of lung, colorectal, or prostate cancer in men, suggesting a sustained benefit of fitness into old age even in the setting of a cancer diagnosis⁶⁰.

These findings expand on earlier studies demonstrating a protective effect of CRF^{59–61}. In an earlier study of over 38,000 men followed up for 29 years, CRF was inversely associated with the risk of total digestive cancer mortality, and men in the moderate and high CRF groups showed 34% and 44% lower risk, respectively, of dying of digestive cancers. Men with an exercise capacity of less than 8 METs had a threefold higher risk of dying of digestive cancer compared with those with higher MET level (≥ 11). Being

fit (the upper 80% of CRF) was also associated with a lower risk of mortality from colon cancer (HR 0.61, 95% CI 0.37–1.00) and CRC (HR 0.58, 95% CI 0.37–0.92) compared with being unfit (the lowest 20% of CRF)⁶¹.

In an earlier cohort study of 21,000 men with pre-diabetes and diabetes, moderate fitness was associated with a 29%–47% reduction and high fitness was associated with 24%–56% reduction in the risks of cancer mortality. Among all men, being fit was associated with a 45% lower risk of mortality from gastrointestinal cancer and 47% risk of CRC⁶². These findings are consistent with those of a study of Finnish men, which demonstrated that good CRF was associated with decreased cancer incidence and mortality⁶³.

These findings indicate that CRF, which provides a more objective and reproducible measure of the functional consequence of PA, confers beneficial effects on CRC incidence and mortality²⁰. In addition, the decreased risk of death from cancer or cardiovascular disease following a CRC diagnosis may relate to the significant burden of cardiac and metabolic diseases present in CRC patients that stems from sharing common risk factors⁶⁴. Improvements in CRC management may increase the contribution of heart disease as a competing cause of mortality in CRC survivors and thus account for part of the beneficial effects of CRF on mortality following a diagnosis of CRC. Also, increased CRF potentially leads to better tolerance and completion of surgery and adjuvant treatment for CRC, thus leading to improved survival^{65,66}.

These studies raise the potential for improving cancer-related outcomes through CRF-based risk stratification and exercise-based interventions targeting an improvement in CRF. However, several challenges need to be overcome. Existing studies have focused largely on men and these findings need to be replicated in studies on women. Future studies need to move beyond studying disease associations to demonstrate whether CRF actually improves discrimination of risk of CRC-related outcomes and improves classification of risk profiles for individual subjects. Current cohort studies have measured CRF at a single time point, given the logistic challenges of conducting exercise testing on a large scale. Disease associations have also been defined in relation to the lowest category of CRF as the reference point. It is unclear what target CRF or minimum improvement in CRF over time must be attained and sustained through interventions to achieve an improvement in CRC-related outcomes, if any. There are currently no published randomized

controlled trials to confirm that PA lowers the risk of CRC in the general population or CRC recurrence or mortality among CRC survivors. The ongoing CHALLENGE (Colon Health and Lifelong Exercise Change) trial will provide further insight into whether PA will improve outcomes in colon cancer⁶⁷. Future studies may aim to use CRF measures as a potential means to titrate the dosimetry of exercise regimens to achieve increments in CRF needed to improve CRC outcomes.

Conclusions

Our understanding of the link between physical inactivity and CRC has expanded to recognize PA, sedentary time and CRF as distinct, interrelated concepts which impact on CRC incidence and outcomes. PA levels required to confer protection against CRC may be higher than previously thought. Sedentary behavior is now recognized to have deleterious effects on CRC independent of PA and may require distinct and novel interventions from those targeting PA. CRF is associated with CRC risk and mortality and may provide a potential tool for risk stratification and intervention. Future studies should focus on translating current knowledge into interventions that improve health outcomes.

Abbreviations

BMI, body mass index; CI, confidence interval; CRC, colorectal cancer; CRF, cardiorespiratory fitness; HR, hazard ratio; MET, metabolic equivalent; PA, physical activity; VO₂ max, maximum oxygen uptake.

Competing interests

VN has received institutional funding support from the following: the SingHealth Duke-NUS Academic Medical Centre through the Medicine Academic Clinical Programme Grant: Nurturing Clinician Scientist Scheme; NCC Research Fund and Oncology Academic Clinical Program; and the estate of Tan Sri Khoo Teck Puat. SL owns stock in AstraZeneca.

Grant information

VN has received institutional funding support from the following: the SingHealth Duke-NUS Academic Medical Centre through the Medicine Academic Clinical Programme Grant: Nurturing Clinician Scientist Scheme; NCC Research Fund and Oncology Academic Clinical Program; and the estate of Tan Sri Khoo Teck Puat.

References

1. Friedenreich CM, Neilson HK, Lynch BM: **State of the epidemiological evidence on physical activity and cancer prevention**. *Eur J Cancer*. 2010; **46**(14): 2593–604. [PubMed Abstract](#) | [Publisher Full Text](#)
2. Erdreich J, Zhang X, Giovannucci E, et al.: **Proportion of colon cancer attributable to lifestyle in a cohort of US women**. *Cancer Causes Control*. 2015; **26**(9): 1271–9. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
3. (IARC). IAFRoC: **Weight Control and Physical Activity**. IARC Handbook on Cancer Prevention. IARC, Lyon, France, 2002; 6. [Reference Source](#)
4. Wang D, Zheng W, Wang SM, et al.: **Estimation of cancer incidence and mortality attributable to overweight, obesity, and physical inactivity in China**. *Nutr Cancer*. 2012; **64**(1): 48–56. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
5. Lee IM, Shiroma EJ, Lobelo F, et al.: **Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy**. *Lancet*. 2012; **380**(9838): 219–29. [PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#) | [F1000 Recommendation](#)
6. Brenner DR: **Cancer incidence due to excess body weight and leisure-time**

- physical inactivity in Canada: implications for prevention. *Prev Med.* 2014; **66**: 131–9.
[PubMed Abstract](#) | [Publisher Full Text](#)
7. Wiseman M: **The second World Cancer Research Fund/American Institute for Cancer Research expert report. Food, nutrition, physical activity, and the prevention of cancer: a global perspective.** *Proc Nutr Soc.* 2008; **67**(3): 253–6.
[PubMed Abstract](#) | [Publisher Full Text](#)
 8. Hallal PC, Andersen LB, Bull FC, *et al.*: **Global physical activity levels: surveillance progress, pitfalls, and prospects.** *Lancet.* 2012; **380**(9838): 247–57.
[PubMed Abstract](#) | [Publisher Full Text](#)
 9. Caspersen CJ, Powell KE, Christenson GM: **Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research.** *Public Health Rep.* 1985; **100**(2): 126–31.
[PubMed Abstract](#) | [Free Full Text](#)
 10. Ainsworth BE, Haskell WL, Whitt MC, *et al.*: **Compendium of physical activities: an update of activity codes and MET intensities.** *Med Sci Sports Exerc.* 2000; **32**(9 Suppl): S498–504.
[PubMed Abstract](#) | [Publisher Full Text](#)
 11. Donahoo WT, Levine JA, Melanson EL: **Variability in energy expenditure and its components.** *Curr Opin Clin Nutr Metab Care.* 2004; **7**(6): 599–605.
[PubMed Abstract](#) | [Publisher Full Text](#)
 12. Owen N, Healy GN, Matthews CE, *et al.*: **Too much sitting: the population health science of sedentary behavior.** *Exerc Sport Sci Rev.* 2010; **38**(3): 105–13.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 13. Sedentary Behaviour Research Network: **Letter to the editor: standardized use of the terms "sedentary" and "sedentary behaviours".** *Appl Physiol Nutr Metab.* 2012; **37**(3): 540–2.
[PubMed Abstract](#) | [Publisher Full Text](#)
 14. Bey L, Hamilton MT: **Suppression of skeletal muscle lipoprotein lipase activity during physical inactivity: a molecular reason to maintain daily low-intensity activity.** *J Physiol.* 2003; **551**(Pt 2): 673–82.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 15. Healy GN, Dunstan DW, Salmon J, *et al.*: **Television time and continuous metabolic risk in physically active adults.** *Med Sci Sports Exerc.* 2008; **40**(4): 639–45.
[PubMed Abstract](#) | [Publisher Full Text](#)
 16. Matthews CE, George SM, Moore SC, *et al.*: **Amount of time spent in sedentary behaviors and cause-specific mortality in US adults.** *Am J Clin Nutr.* 2012; **95**(2): 437–45.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 17. Owen N, Sparling PB, Healy GN, *et al.*: **Sedentary behavior: emerging evidence for a new health risk.** *Mayo Clin Proc.* 2010; **85**(12): 1138–41.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 18. Matthews CE, Chen KY, Freedson PS, *et al.*: **Amount of time spent in sedentary behaviors in the United States, 2003–2004.** *Am J Epidemiol.* 2008; **167**(7): 875–81.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 19. Biswas A, Oh PI, Faulkner GE, *et al.*: **Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: a systematic review and meta-analysis.** *Ann Intern Med.* 2015; **162**(2): 123–32.
[PubMed Abstract](#) | [Publisher Full Text](#)
 20. Wolin KY, Yan Y, Colditz GA, *et al.*: **Physical activity and colon cancer prevention: a meta-analysis.** *Br J Cancer.* 2009; **100**(4): 611–6.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 21. Harriss DJ, Atkinson G, Batterham A, *et al.*: **Lifestyle factors and colorectal cancer risk (2): a systematic review and meta-analysis of associations with leisure-time physical activity.** *Colorectal Dis.* 2009; **11**(7): 689–701.
[PubMed Abstract](#) | [Publisher Full Text](#)
 22. Thun MJ, Calle EE, Namboodiri MM, *et al.*: **Risk factors for fatal colon cancer in a large prospective study.** *J Natl Cancer Inst.* 1992; **84**(19): 1491–500.
[PubMed Abstract](#) | [Publisher Full Text](#)
 23. Slattery ML, Potter J, Caan B, *et al.*: **Energy balance and colon cancer—beyond physical activity.** *Cancer Res.* 1997; **57**(1): 75–80.
[PubMed Abstract](#)
 24. Giovannucci E, Ascherio A, Rimm EB, *et al.*: **Physical activity, obesity, and risk for colon cancer and adenoma in men.** *Ann Intern Med.* 1995; **122**(5): 327–34.
[PubMed Abstract](#) | [Publisher Full Text](#)
 25. Inoue M, Yamamoto S, Kurahashi N, *et al.*: **Daily total physical activity level and total cancer risk in men and women: results from a large-scale population-based cohort study in Japan.** *Am J Epidemiol.* 2008; **168**(4): 391–403.
[PubMed Abstract](#) | [Publisher Full Text](#)
 26. Wolin KY, Lee IM, Colditz GA, *et al.*: **Leisure-time physical activity patterns and risk of colon cancer in women.** *Int J Cancer.* 2007; **121**(12): 2776–81.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 27. Robsahm TE, Aagnes B, Hjartaker A, *et al.*: **Body mass index, physical activity, and colorectal cancer by anatomical subsites: a systematic review and meta-analysis of cohort studies.** *Eur J Cancer Prev.* 2013; **22**(6): 492–505.
[PubMed Abstract](#) | [Publisher Full Text](#)
 28. Boyle T, Keegel T, Bull F, *et al.*: **Physical activity and risks of proximal and distal colon cancers: a systematic review and meta-analysis.** *J Natl Cancer Inst.* 2012; **104**(20): 1548–61.
[PubMed Abstract](#) | [Publisher Full Text](#) | [F1000 Recommendation](#)
 29. Odegaard AO, Koh WP, Yuan JM: **Combined lifestyle factors and risk of incident colorectal cancer in a Chinese population.** *Cancer Prev Res (Phila).* 2013; **6**(4): 360–7.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#) | [F1000 Recommendation](#)
 30. Aleksandrova K, Pischon T, Jenab M, *et al.*: **Combined impact of healthy lifestyle factors on colorectal cancer: a large European cohort study.** *BMC Med.* 2014; **12**: 168.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 31. Samad AK, Taylor RS, Marshall T, *et al.*: **A meta-analysis of the association of physical activity with reduced risk of colorectal cancer.** *Colorectal Dis.* 2005; **7**(3): 204–13.
[PubMed Abstract](#) | [Publisher Full Text](#)
 32. Spence RR, Heesch KC, Brown WJ: **A systematic review of the association between physical activity and colorectal cancer risk.** *Scand J Med Sci Sports.* 2009; **19**(6): 764–81.
[PubMed Abstract](#) | [Publisher Full Text](#)
 33. Moore SC, Lee IM, Weidnerpass E, *et al.*: **Association of Leisure-Time Physical Activity With Risk of 26 Types of Cancer in 1.44 Million Adults.** *JAMA Intern Med.* 2016; **176**(6): 816–25.
[PubMed Abstract](#) | [Publisher Full Text](#)
 34. Wolin KY, Yan Y, Colditz GA: **Physical activity and risk of colon adenoma: a meta-analysis.** *Br J Cancer.* 2011; **104**(5): 882–5.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 35. Song JH, Kim YS, Yang SY, *et al.*: **Physical activity and other lifestyle factors in relation to the prevalence of colorectal adenoma: a colonoscopy-based study in asymptomatic Koreans.** *Cancer Causes Control.* 2013; **24**(9): 1717–26.
[PubMed Abstract](#) | [Publisher Full Text](#)
 36. Colbert LH, Lanza E, Ballard-Barbash R, *et al.*: **Adenomatous polyp recurrence and physical activity in the Polyp Prevention Trial (United States).** *Cancer Causes Control.* 2002; **13**(5): 445–53.
[PubMed Abstract](#) | [Publisher Full Text](#)
 37. Molmenti CL, Hibler EA, Ashbeck EL, *et al.*: **Sedentary behavior is associated with colorectal adenoma recurrence in men.** *Cancer Causes Control.* 2014; **25**(10): 1387–95.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 38. Burnett-Hartman AN, Passarelli MN, Adams SV, *et al.*: **Differences in epidemiologic risk factors for colorectal adenomas and serrated polyps by lesion severity and anatomical site.** *Am J Epidemiol.* 2013; **177**(7): 625–37.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 39. Fu Z, Shrubsole MJ, Smalley WE, *et al.*: **Lifestyle factors and their combined impact on the risk of colorectal polyps.** *Am J Epidemiol.* 2012; **176**(9): 766–76.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 40. Haque TR, Bradshaw PT, Crockett SD: **Risk factors for serrated polyps of the colorectum.** *Dig Dis Sci.* 2014; **59**(12): 2874–89.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 41. Schmid D, Leitzmann MF: **Association between physical activity and mortality among breast cancer and colorectal cancer survivors: a systematic review and meta-analysis.** *Ann Oncol.* 2014; **25**(7): 1293–311.
[PubMed Abstract](#) | [Publisher Full Text](#)
 42. Je Y, Jeon JY, Giovannucci EL, *et al.*: **Association between physical activity and mortality in colorectal cancer: a meta-analysis of prospective cohort studies.** *Int J Cancer.* 2013; **133**(8): 1905–13.
[PubMed Abstract](#) | [Publisher Full Text](#)
 43. Kushi LH, Doyle C, McCullough M, *et al.*: **American Cancer Society Guidelines on nutrition and physical activity for cancer prevention: reducing the risk of cancer with healthy food choices and physical activity.** *CA Cancer J Clin.* 2012; **62**(1): 30–67.
[PubMed Abstract](#) | [Publisher Full Text](#)
 44. Arem H, Pfeiffer RM, Engels EA, *et al.*: **Pre- and postdiagnosis physical activity, television viewing, and mortality among patients with colorectal cancer in the National Institutes of Health-AARP Diet and Health Study.** *J Clin Oncol.* 2015; **33**(2): 180–8.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 45. Keum N, Bao Y, Smith-Warner SA, *et al.*: **Association of Physical Activity by Type and Intensity With Digestive System Cancer Risk.** *JAMA Oncol.* 2016; **2**(9): 1146–53.
[PubMed Abstract](#) | [Publisher Full Text](#)
 46. Schmid D, Leitzmann MF: **Television viewing and time spent sedentary in relation to cancer risk: a meta-analysis.** *J Natl Cancer Inst.* 2014; **106**(7): pii: dju098.
[PubMed Abstract](#) | [Publisher Full Text](#)
 47. Cao Y, Meyerhardt JA, Chan AT, *et al.*: **Television watching and colorectal cancer survival in men.** *Cancer Causes Control.* 2015; **26**(10): 1467–76.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 48. Simons CC, Hughes LA, van Engeland M, *et al.*: **Physical activity, occupational sitting time, and colorectal cancer risk in the Netherlands cohort study.** *Am J Epidemiol.* 2013; **177**(6): 514–30.
[PubMed Abstract](#) | [Publisher Full Text](#)
 49. Shen D, Mao W, Liu T, *et al.*: **Sedentary behavior and incident cancer: a meta-analysis of prospective studies.** *PLoS One.* 2014; **9**(8): e105709.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)

50. Campbell PT, Patel AV, Newton CC, *et al.*: **Associations of recreational physical activity and leisure time spent sitting with colorectal cancer survival.** *J Clin Oncol.* 2013; **31**(7): 876–85.
[PubMed Abstract](#) | [Publisher Full Text](#)
51. Lynch BM, Cerin E, Owen N, *et al.*: **Television viewing time of colorectal cancer survivors is associated prospectively with quality of life.** *Cancer Causes Control.* 2011; **22**(8): 1111–20.
[PubMed Abstract](#) | [Publisher Full Text](#)
52. Cao Y, Keum NN, Chan AT, *et al.*: **Television watching and risk of colorectal adenoma.** *Br J Cancer.* 2015; **112**(5): 934–42.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
53. **F** Ekelund U, Steene-Johannessen J, Brown WJ, *et al.*: **Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality? A harmonised meta-analysis of data from more than 1 million men and women.** *Lancet.* 2016; **388**(10051): 1302–10.
[PubMed Abstract](#) | [Publisher Full Text](#) | [F1000 Recommendation](#)
54. Peddie MC, Bone JL, Rehrer NJ, *et al.*: **Breaking prolonged sitting reduces postprandial glycemia in healthy, normal-weight adults: a randomized crossover trial.** *Am J Clin Nutr.* 2013; **98**(2): 358–66.
[PubMed Abstract](#) | [Publisher Full Text](#)
55. Prince SA, Saunders TJ, Gresty K, *et al.*: **A comparison of the effectiveness of physical activity and sedentary behaviour interventions in reducing sedentary time in adults: a systematic review and meta-analysis of controlled trials.** *Obes Rev.* 2014; **15**(11): 905–19.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
56. Martin A, Fitzsimons C, Jepson R, *et al.*: **Interventions with potential to reduce sedentary time in adults: systematic review and meta-analysis.** *Br J Sports Med.* 2015; **49**(16): 1056–63.
[PubMed Abstract](#) | [Publisher Full Text](#)
57. Lynch BM, Courneya KS, Sethi P, *et al.*: **A randomized controlled trial of a multiple health behavior change intervention delivered to colorectal cancer survivors: effects on sedentary behavior.** *Cancer.* 2014; **120**(17): 2665–72.
[PubMed Abstract](#) | [Publisher Full Text](#)
58. Healy GN, Clark BK, Winkler EA, *et al.*: **Measurement of adults' sedentary time in population-based studies.** *Am J Prev Med.* 2011; **41**(2): 216–27.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
59. Gibbs BB, Hergenroeder AL, Katzmarzyk PT, *et al.*: **Definition, measurement, and health risks associated with sedentary behavior.** *Med Sci Sports Exerc.* 2015; **47**(6): 1295–300.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
60. Lakoski SG, Willis BL, Barlow CE, *et al.*: **Midlife Cardiorespiratory Fitness, Incident Cancer, and Survival After Cancer in Men: The Cooper Center Longitudinal Study.** *JAMA Oncol.* 2015; **1**(2): 231–7.
[PubMed Abstract](#) | [Publisher Full Text](#)
61. Peel JB, Sui X, Matthews CE, *et al.*: **Cardiorespiratory fitness and digestive cancer mortality: findings from the aerobics center longitudinal study.** *Cancer Epidemiol Biomarkers Prev.* 2009; **18**(4): 1111–7.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
62. Thompson AM, Church TS, Janssen I, *et al.*: **Cardiorespiratory fitness as a predictor of cancer mortality among men with pre-diabetes and diabetes.** *Diabetes Care.* 2008; **31**(4): 764–9.
[PubMed Abstract](#) | [Publisher Full Text](#)
63. Laakkonen JA, Pukkala E, Rauramaa R, *et al.*: **Cardiorespiratory fitness, lifestyle factors and cancer risk and mortality in Finnish men.** *Eur J Cancer.* 2010; **46**(2): 355–63.
[PubMed Abstract](#) | [Publisher Full Text](#)
64. Edwards BK, Noone A, Mariotto AB, *et al.*: **Annual Report to the Nation on the status of cancer, 1975–2010, featuring prevalence of comorbidity and impact on survival among persons with lung, colorectal, breast, or prostate cancer.** *Cancer.* 2014; **120**(9): 1290–314.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
65. Mayo NE, Feldman L, Scott S, *et al.*: **Impact of preoperative change in physical function on postoperative recovery: argument supporting prehabilitation for colorectal surgery.** *Surgery.* 2011; **150**(3): 505–14.
[PubMed Abstract](#) | [Publisher Full Text](#)
66. West MA, Loughney L, Lythgoe D, *et al.*: **Effect of prehabilitation on objectively measured physical fitness after neoadjuvant treatment in preoperative rectal cancer patients: a blinded interventional pilot study.** *Br J Anaesth.* 2015; **114**(2): 244–51.
[PubMed Abstract](#) | [Publisher Full Text](#)
67. Courneya KS, Booth CM, Gill S, *et al.*: **The Colon Health and Life-Long Exercise Change trial: a randomized trial of the National Cancer Institute of Canada Clinical Trials Group.** *Curr Oncol.* 2008; **15**(6): 279–85.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)

Open Peer Review

Current Peer Review Status:

Editorial Note on the Review Process

Faculty Reviews are review articles written by the prestigious Members of **Faculty Opinions**. The articles are commissioned and peer reviewed before publication to ensure that the final, published version is comprehensive and accessible. The reviewers who approved the final version are listed with their names and affiliations.

The reviewers who approved this article are:

Version 1

1. Brigid Lynch

Cancer Epidemiology Centre, Cancer Council Victoria, Melbourne, Australia

Competing Interests: No competing interests were disclosed.

2. Justin Y Jeon

¹ Department of Sport and Leisure Studies, Yonsei University, Seoul, South Korea

² Exercise Medicine Center for Diabetes and Cancer Patients, Yonsei University, Seoul, South Korea

Competing Interests: No competing interests were disclosed.

The benefits of publishing with F1000Research:

- Your article is published within days, with no editorial bias
- You can publish traditional articles, null/negative results, case reports, data notes and more
- The peer review process is transparent and collaborative
- Your article is indexed in PubMed after passing peer review
- Dedicated customer support at every stage

For pre-submission enquiries, contact research@f1000.com

F1000Research