International Journal of Innovative Technologies in Social Science

e-ISSN: 2544-9435

Scholarly Publisher
RS Global Sp. z O.O.
ISNI: 0000 0004 8495 2390

Dolna 17, Warsaw,
Poland 00-773
+48 226 0 227 03
editorial_office@rsglobal.pl

ARTICLE TITLE	THE PROTECTIVE POWER OF PHYSICAL ACTIVITY: INSIGHTS INTO COLON POLYPS AND COLORECTAL CANCER
DOI	https://doi.org/10.31435/ijitss.4(48).2025.4129
RECEIVED	07 September 2025
ACCEPTED	05 November 2025
PUBLISHED	11 November 2025
LICENSE	The article is licensed under a **Creative Commons Attribution 4.0 International License.**

THE PROTECTIVE POWER OF PHYSICAL ACTIVITY: INSIGHTS INTO COLON POLYPS AND COLORECTAL CANCER

Julia Groszewska *(Corresponding Author, Email: julia.groszewska@stud.umed.lodz.pl)*
Medical University of Lodz, Poland
ORCID ID: 0009-0002-4637-1264

Agata Mytych
Wroclaw Medical University, Poland
ORCID ID: 0009-0004-4575-6327

Michał Romaniuk
Medical University of Lodz, Poland
ORCID ID: 0009-0008-6002-000X

Agata Rapior
Medical University of Lodz, Poland
ORCID ID: 0009-0002-0300-2303

Daria Julia Makowska-Woszczyk
Medical University of Lodz, Poland
ORCID ID: 0009-0004-9897-0618

Kinga Lubomska
Medical University of Lodz, Poland
ORCID ID: 0009-0002-8777-5273

Patrycja Jagura
Medical University of Lodz, Poland
ORCID ID: 0009-0008-2394-3673

Jan Romaniuk
Medical University of Lublin, Poland
ORCID ID: 0009-0000-3017-3330

Marta Dziedziak
Wroclaw Medical University, Poland
ORCID ID: 0009-0004-3463-2804

Łukasz Nosek
Wroclaw Medical University, Poland
ORCID ID: 0009-0006-8294-5842

ABSTRACT

Background: Colorectal cancer (CRC) remains one of the most prevalent malignancies worldwide. Regular physical activity (PA) is increasingly recognized as a modifiable factor influencing both cancer prevention and patient outcomes. This review summarizes current evidence on the role of PA in CRC prevention, treatment, and survivorship, emphasizing its clinical significance and underlying biological mechanisms.
Methods: A narrative review of recent randomized trials, cohort studies, and meta-analyses published in peer-reviewed journals was conducted. Studies addressing PA in relation to CRC incidence, recurrence, postoperative recovery, and treatment-related outcomes were included.
Results: Evidence consistently demonstrates that regular PA reduces the risk of colorectal adenomas and cancer by approximately 20–30%. In CRC survivors, structured exercise programs improve physical and psychological well-being, mitigate treatment-related side effects, and may decrease recurrence and mortality risk. Randomized trials such as CHALLENGE and PHYSSURG-C highlight that supervision, intensity, and duration are critical for achieving clinical benefits. The beneficial effects of PA are mediated by metabolic, inflammatory, and immune pathways, including improved insulin sensitivity, reduced systemic inflammation, and enhanced immune function.
Conclusions: Regular physical activity should be considered as a component of colorectal cancer prevention and survivorship care, offering measurable benefits for both clinical outcomes and quality of life.

KEYWORDS

Colorectal Cancer, Physical Activity, Cancer Prevention, Recurrence Prevention

CITATION

Julia Groszewska, Agata Mytych, Michał Romaniuk, Agata Rapior, Daria Julia Makowska-Woszczyk, Kinga Lubomska, Patrycja Jagura, Jan Romaniuk, Marta Dziedziak, Łukasz Nosek. (2025) The Protective Power of Physical Activity: Insights into Colon Polyps and Colorectal Cancer. *International Journal of Innovative Technologies in Social Science.* 4(48). doi: 10.31435/ijitss.4(48).2025.4129

Introduction

Colorectal cancer (CRC) is a major public health issue globally—and Poland is no exception. Globally, CRC ranks third in terms of cancer incidence and second in cancer-related mortality, with over 1.9 million new cases and 903,859 deaths in 2022 [1]. In Poland, colorectal cancer is among the most commonly diagnosed malignancies: in recent years, about 18,000 to 20,000 new CRC cases are reported annually. Mortality from CRC in Poland is also substantial: more than 12,000 deaths per year are attributed to colorectal cancer [2]. According to the EU Country Cancer Profile: Poland 2025, overall cancer incidence in Poland has shown a slight decline over the past decade, while CRC mortality has decreased more substantially—by 14% among women and 11% among men since 2011. Despite these improvements, Poland continues to report some of the highest CRC incidence rates in the European Union, and the disease remains a leading cause of cancer-related deaths. Importantly, 5-year survival for CRC patients in Poland still lags behind the EU average, reflecting gaps in early detection and treatment [3].

The elevated mortality in colorectal cancer is largely attributable to the absence of distinct early symptoms, which often delays diagnosis. Incidence rises with advancing age, and individuals with a positive family history face an increased risk of developing CRC [4]. Recent evidence also highlights a concerning global trend of increasing CRC incidence among younger adults [5]. Several lifestyle factors—such as poor diet, physical inactivity, smoking, and alcohol consumption—are well-established contributors to CRC risk, and their modification offers preventive potential [6]. Worth noticing, the overall level of physical activity in Poland remains lower than the European average [7]. Physical activity is widely recognized as a determinant of both physical and mental health. Regular exercise not only improves somatic well-being but also enhances cognitive performance, underscoring its multifaceted role in disease prevention [8].

From a biological standpoint, most colorectal cancers develop from precursor adenomatous polyps, often over a period of 10–15 years. This natural history creates a critical window for preventive interventions, whether through organized screening or lifestyle modification [9]. The growing lack of movement and the tendency to spend long hours sitting have become defining health issues of our time, leading to increased rates

of disease, early deaths, and significant healthcare expenses [10]. Among various modifiable factors, regular physical activity has consistently been associated with a reduced risk of CRC, highlighting its potential as a simple yet powerful tool in mitigating disease burden [11]. The purpose of this review is to summarize current evidence on the role of exercise in colorectal cancer prevention and to highlight the biological pathways through which it exerts its protective effects.

Methodology

This review is based on a narrative synthesis of scientific literature examining the relationship between physical activity, colorectal polyps, and colorectal cancer prevention and outcomes. The literature search was conducted across major biomedical databases, including PubMed, Scopus, and Web of Science, covering publications from 1990 to 2025. The search strategy combined the following keywords: "colorectal cancer," "colon polyps," "physical activity," "exercise," "sedentary behavior," "cancer prevention," "recurrence," "rehabilitation," and "survivorship."

Both randomized controlled trials, prospective and retrospective cohort studies, as well as systematic reviews and meta-analyses were included. Only peer-reviewed articles published in English were considered eligible. Additional references were identified through manual searches of bibliographies from key review papers.

Studies were screened for methodological quality, clinical relevance, and consistency with the review objectives. Data extraction focused on the impact of physical activity on colorectal cancer incidence, recurrence, postoperative recovery, and overall survival. The analysis also examined proposed biological mechanisms underlying these associations, including metabolic, hormonal, inflammatory, and immune pathways.

This narrative approach allowed for a comprehensive integration of epidemiological and mechanistic evidence, highlighting the multifaceted role of physical activity across the continuum of colorectal cancer prevention and management.

Pathogenesis of colorectal cancer and the role of polyps

Colorectal polyps are a heterogeneous group of lesions with distinct histological features and clinical implications. According to the 5th edition WHO Classification of Tumours of the Digestive System, they can be broadly divided into four categories: conventional adenomas, serrated lesions, hamartomatous polyps, and inflammatory polyps [12]. Each group differs in malignant potential, recommended management, and association with hereditary polyposis syndromes (Table 1).

When a polyp is detected in the colon, timely and effective removal is essential to prevent malignant transformation. Careful classification of polyp subtypes is therefore crucial to guide individualized management approaches [13].

Table 1. Types of colorectal polyps and their clinical characteristics.

Type of polyp	Key features	Management	Associated polyposis syndromes
Conventional adenomas (tubular, tubulovillous, villous)	Neoplastic precursor lesions; malignant potential increases with size, villous component, and dysplasia grade.	Endoscopic or surgical excision required; surveillance according to guidelines.	Associated polyposis syndromes (FAP)
Serrated lesions (hyperplastic, sessile serrated lesions, traditional serrated adenomas)	Serrated crypt architecture. – Hyperplastic: small, distal, negligible malignant risk. – SSL: proximal, precursor in serrated pathway (BRAF, CIMP, MSI). – TSA: rare, dysplastic, high malignant potential.	Hyperplastic: usually no treatment unless atypical. SSL/TSA: complete excision and surveillance.	Serrated polyposis syndrome (SPS)
Hamartomatous polyps	Disorganized growth of normal tissue elements. Usually solitary but may occur in syndromes.	Removal if symptomatic or atypical; otherwise observation.	Juvenile polyposis syndrome (JPS), Peutz–Jeghers syndrome (PJS), Cowden syndrome (PTEN hamartoma tumor syndrome)
Inflammatory polyps	Reactive lesions associated with chronic colitis (e.g., IBD). Non-neoplastic.	Focus on treating underlying inflammation; removal if symptomatic or diagnosis uncertain.	Nonspecific (secondary to IBD)

Adenomas are benign neoplastic polyps of colon, yet their risk of malignant transformation, frequency, and recommended management vary according to their histological type, size, and degree of dysplasia [14]. Their formation is commonly initiated by APC inactivation, followed by mutations in KRAS and TP53, which promote carcinogenesis [15,16]. According to the European Society of Gastrointestinal Endoscopy (ESGE) 2020 guidelines, post-polypectomy surveillance should be tailored to the risk profile of the adenoma. Patients with high-risk adenomas—defined as at least one adenoma ≥10 mm, the presence of villous histology or high-grade dysplasia, or ≥5 adenomas of any size—should undergo surveillance colonoscopy after 3 years [15]. If no further high-risk findings are detected at the first surveillance, the next examination may be extended to 5 years. Conversely, patients with low-risk adenomas (1–4 tubular adenomas <10 mm with low-grade dysplasia) can be returned to routine screening, or, in the absence of an organized program, offered repeat colonoscopy at 10 years [17].

Serrated polyps are a broad category that includes hyperplastic polyps, sessile serrated lesions (SSLs), and traditional serrated adenomas (TSAs) [12]. The SSLs and TSAs can potentially become malignant, while the hyperplastic polyps are generally benign [13]. SSLs have molecular features such as hypermethylation of the CpG islands in the promoter regions of tumor suppressor genes and BRAF mutations [18]. Unlike their serrated counterparts, hyperplastic polyps typically lack chromosomal instability and CpG island methylation, which explains their negligible malignant potential [19]. In accordance with ESGE guidelines, all colorectal polyps should be completely resected, with the exception of typical diminutive (<5 mm) hyperplastic polyps located in the rectosigmoid colon, which do not require removal [17]. Clinically relevant serrated lesions—such as SSLs ≥10 mm, SSLs with dysplasia, or any TSA—are considered high-risk findings, and ESGE therefore advises surveillance colonoscopy after 3 years [17].

Hamartomatous polyps are malformations of normal mucosal tissue that appear in a disorganized manner and are frequently associated with hereditary syndromes such as Peutz–Jeghers syndrome, juvenile polyposis, and Cowden syndrome, all inherited in an autosomal dominant fashion [20,21]. Early recognition of these syndromes allows for targeted surveillance strategies, which can reduce morbidity and mortality among affected patients and their families [21].

Inflammatory polyps, also referred to as post-inflammatory polyps (PIPs) or pseudopolyps, arise as a consequence of repeated mucosal injury and regeneration in chronic inflammatory bowel disease (IBD) [22,23]. Although they lack malignant potential, their presence reflects extensive mucosal damage. Recent evidence suggests that patients with PIPs may be managed as an intermediate-risk group for colorectal neoplasia, warranting closer endoscopic follow-up in selected cases [22,23].

Protective power of physical activity

Physical activity exerts protective effects against seven cancer types, including colon, breast, endometrial, lung, esophageal, pancreatic cancers, and meningioma [24]. Among these, the association is especially pronounced for colon and breast cancer compared with the other malignancies [25]. Systematic reviews and meta-analyses consistently demonstrate that PA is protective against colorectal neoplasia, showing substantial risk reductions across studies. A contemporary meta-analysis indicates that physically active individuals have a 23% lower risk of any colorectal neoplasia and a 27% lower risk of advanced neoplasia compared to those who are inactive [26]. This aligns with earlier meta-analytic findings reporting a pooled relative risk of 0.76 for colon cancer among active versus inactive individuals [27]. Collectively, these analyses support a strong protective association of PA against colorectal neoplasia and colon cancer across various cohorts and methodologies.

Cohort studies further substantiate this protective effect; for instance, research within the Netherlands and broader epidemiologic cohorts indicates that regular, long-term PA and decreased sedentary behavior are linked to a lower risk of colon cancer, particularly distal colon cancer, with mixed results observed for rectal cancer [28]. A Danish cohort study noted that adhering to recommended PA levels significantly reduced colorectal cancer risk, highlighting PA as essential in a favorable lifestyle profile for CRC [29].

Over 40% of colorectal cancer patients present with comorbidities such as diabetes, obesity, chronic obstructive pulmonary disease, or heart failure, and regular physical activity not only lowers the risk of these conditions but also improves outcomes in those already affected [30,31]. Importantly, these benefits appear to extend not only to cancer prevention but also to the reduction of adenomatous polyp formation [32]. Although physical activity protects against colorectal cancer, its effects appear less consistent in women, possibly due to hormonal, metabolic, and lifestyle differences [33,34].

As the protective association between physical activity and colorectal cancer risk is well established, recent research has focused on quantifying the amount and intensity of exercise required to achieve significant preventive effects. A recent cross-sectional study by Zou et al. (2025), based on data from the National Health and Nutrition Examination Survey (NHANES) 2007–2018, quantitatively assessed the relationship between daily physical activity levels and colon cancer risk in over 24,000 U.S. adults. Physical activity was expressed in metabolic equivalents (METs) and categorized into four levels. After multivariate adjustment, participants with low physical activity (≤120 MET/day) had a 22% higher risk of colon cancer (OR = 1.224; 95% CI 1.031–1.453; p = 0.023), whereas those with high-intensity activity (>1200 MET/day) demonstrated a 53% risk reduction (OR = 0.470; 95% CI 0.249–0.885; p = 0.022). Restricted cubic spline analysis revealed a significant nonlinear inverse relationship between METs and colon cancer risk, with an inflection point around 1879 MET/day. These findings highlight that maintaining moderate-to-high levels of physical activity significantly decreases colon cancer risk, even after accounting for sedentary behavior, smoking, alcohol use, and socioeconomic factors [35].

Complementary findings were reported by Stein et al. in the UK Biobank cohort, who examined not only total activity but also its diurnal timing. They observed that participants maintaining continuous day-long activity, or early- and late-day activity patterns had significantly lower colorectal cancer risk (HR = 0.94 and HR = 0.89, respectively). These associations persisted after adjusting for BMI, smoking, alcohol intake, and sedentary time. Importantly, their results suggest that distributing physical activity across morning and afternoon hours may provide greater protective benefits than concentrating it in a single period of the day [36].

Together, these studies emphasize that both the quantity and the timing of physical activity play an important role in colorectal cancer prevention, highlighting that regular, moderately to highly active lifestyles—especially when activity is spread throughout the day—can substantially lower disease risk.

Physical activity among colorectal cancer survivors

With the growing incidence of colorectal cancer, the development of effective post-treatment strategies is becoming increasingly important. Among them, physical activity has emerged as a key factor improving survival and overall health in cancer survivors. Nevertheless, despite growing evidence supporting the role of exercise in survivorship, physical inactivity remains a major concern. According to Lynch et al., 68% of colorectal cancer survivors reported no regular physical activity after the treatment period [37]. Most barriers to physical activity reported by colorectal cancer survivors mirror those seen in the general population, such as lack of time, older age or limited agility, travel distance, and financial constraints. However, certain obstacles are specific to this group, including issues like poor bladder control or the presence of an ostomy [38].

One of the most important recent contributions in this field is the CHALLENGE trial, a phase 3 randomized study reported in 2025 in the New England Journal of Medicine. The trial enrolled 889 patients with stage III or high-risk stage II colon cancer who had completed adjuvant chemotherapy, randomizing them to either a three-year structured exercise program or health-education materials alone. After a median follow-up of 7.9 years, disease-free survival was significantly longer in the exercise group (hazard ratio (HR) 0.72; 95% CI, 0.55–0.94; p = 0.02), with 5-year DFS rates of 80.3% versus 73.9%. Moreover, overall survival (OS) was improved (HR for death 0.63; 95% CI, 0.43–0.94), corresponding to an 8-year OS of 90.3% versus 83.2%. Although musculoskeletal adverse events were more frequent in the exercise arm (18.5% vs. 11.5%), the overall benefit–risk ratio strongly favored structured exercise. These findings provide the first level 1 evidence that physical activity after adjuvant chemotherapy can improve both disease-free and OS in colon cancer, supporting its integration into standard survivorship care [39].

Consistent with these observations, Brown et al. analyzed data from two large Alliance trials, CALGB 89803 and 80702, including a total of 2876 patients with stage III colon cancer. Patients reported their post-treatment physical activity, quantified in MET-hours per week, and were compared with a matched general population. In CALGB 89803, 3-year survival was 17.1% lower among those performing <3 MET-h/week compared with the general population, but only 3.5% lower in patients achieving ≥18 MET-h/week. Similarly, in CALGB 80702, the differences were 10.8% and 4.4%, respectively. In a combined analysis of 1908 patients without disease recurrence, those with ≥18 MET-h/week demonstrated a 2.9% higher 3-year survival compared to the general population [40].

Among individuals with a history of colorectal cancer, factors such as age, sex, family history, and obesity have been identified as significant predictors of recurrence. Body fatness and obesity, in particular, are key modifiable risk factors for neoplasia recurrence, positioning physical activity as an essential strategy for risk reduction through improvements in body composition and metabolic health. Park et al. specifically

examined the influence of physical activity and adiposity on polyp recurrence following treatment, highlighting its role in secondary prevention through mechanisms involving inflammation and metabolic regulation [41]. In broader prevention contexts, physical activity is consistently cited as a protective factor that reduces the overall burden of colorectal neoplasia, including recurrence risk, given the persistent mucosal susceptibility after initial cancer or adenoma removal. These findings align with international guidelines advocating for an active lifestyle as an integral component of comprehensive colorectal cancer prevention and surveillance strategies [13,27,29].

Beyond long-term survivorship, early physical activity may also play a crucial role in postoperative recovery among colorectal cancer patients. Ahn et al. conducted a randomized controlled trial including patients with stage I–III colon cancer who underwent colectomy and participated in a structured inpatient exercise program twice daily during hospitalization. The intervention significantly reduced hospital stay (7.8 vs. 9.9 days, $p = 0.005$) and accelerated bowel function recovery (time to first flatus: 52 vs. 72 h, $p = 0.036$), without increasing postoperative complications. These results indicate that even low-intensity, supervised exercise during hospitalization can safely enhance postoperative recovery and should be considered an integral component of modern perioperative care in colorectal cancer [42]

In contrast, the large multicentre PHYSSURG-C trial by Onerup et al. investigated a short-term, home-based program involving moderate-intensity exercise performed for 2 weeks before and 4 weeks after colorectal cancer surgery in 761 patients. After 12 months, there were no significant differences in physical recovery (OR 0.91, $p = 0.60$), reoperations, or readmissions compared with usual care. These findings suggest that short, unsupervised, moderate-intensity exercise interventions may be insufficient to improve long-term outcomes, highlighting the importance of supervision, intensity, and duration in designing effective perioperative rehabilitation programs [43].

Several studies have confirmed that exercise interventions are both safe and feasible during chemotherapy or chemoradiotherapy in colorectal cancer patients [44]. Supervised training programs have been shown to reduce physical and general fatigue, while aerobic exercise performed for at least 150 minutes per week during or after neoadjuvant therapy was also reported to be well tolerated [45,46]. Longer interventions, such as one year of regular exercise three times per week, improved physical fitness and quality of life [47]. Combined aerobic and resistance training further enhanced muscle strength, cardiorespiratory fitness, emotional well-being, and sleep quality [48]. Moreover, exercise alleviates multiple chemotherapy-related side effects, including peripheral neuropathy, fatigue, pain, muscle weakness, cardiovascular and pulmonary complications, immune dysfunction, anemia, anxiety, depression, and sleep disorders [49].

Collectively, these data underscore the importance of structured, supervised, and sufficiently intensive exercise programs across all phases of colorectal cancer care—from perioperative rehabilitation to long-term survivorship.

Biological mechanisms underlying the protective effects of physical activity

The association between physical activity and reduced CRC risk is supported by a range of biological mechanisms that collectively influence metabolic, hormonal, inflammatory, and cellular pathways involved in colorectal carcinogenesis [30].

Insulin and insulin-like growth factor signaling pathways are central to colorectal tumorigenesis, as they promote cellular proliferation, inhibit apoptosis, and support tumor progression through activation of the IGF1 receptor [50]. Elevated circulating insulin and IGF-1 levels, as well as insulin resistance, have been consistently associated with increased colorectal cancer incidence and mortality [51,52]. Regular physical activity improves insulin sensitivity and modulates IGF signaling, thereby reducing insulin exposure and downstream proliferative stimuli. Although studies have reported variable changes in IGF-1 and IGFBP-3 levels following exercise, the overall trend toward reduced IGF-1 bioactivity provides a plausible explanation for the inverse relationship between physical activity and colorectal cancer risk [53,54].

Some studies have demonstrated that exercise can modulate colonic crypt morphology, resulting in suppressed epithelial proliferation and an upregulation of apoptotic markers in colorectal tissue [55,56]. The study by Pedersen et al. provided compelling evidence that regular physical activity can suppress tumor growth by more than 60% across several mouse models. The underlying mechanism was shown to involve the mobilization and redistribution of natural killer (NK) cells, driven by exercise-induced epinephrine release and muscle-derived interleukin-6 (IL-6). Exercise increased circulating NK cell numbers and promoted their infiltration into tumor tissue, where they played a pivotal role in initiating antitumor immunity. Importantly,

blockade of adrenergic signaling or neutralization of IL-6 abolished these effects, demonstrating that physical activity exerts direct immunomodulatory influences on the tumor microenvironment [57].

Chronic inflammation is a well-established contributor to colorectal carcinogenesis, linking metabolic disorders such as obesity and the metabolic syndrome to increased cancer risk. Proinflammatory cytokines, including interleukin-6 (IL-6), tumor necrosis factor-α (TNF-α), and C-reactive protein (CRP), promote tumor initiation and progression by creating a microenvironment that favors cellular proliferation and inhibits apoptosis [58]. Regular physical activity mitigates systemic inflammation and enhances immune regulation, which together reduce this carcinogenic stimulus. In preclinical models, treadmill exercise in *APC min/+* mice resulted in lower circulating IL-6 levels and a reduced number of intestinal polyps, supporting a mechanistic link between exercise and suppression of inflammation-driven tumorigenesis [59]. Moreover, experimental data indicate that cyclooxygenase (COX-1 and COX-2) enzymes play a central role in inflammation-associated intestinal tumor formation, consistent with epidemiological findings showing that long-term use of COX inhibitors or nonsteroidal anti-inflammatory drugs (NSAIDs) reduces colon cancer risk by up to 40% [60,61].

Skeletal muscle acts as an endocrine organ by releasing signaling molecules known as myokines, which contribute to the systemic benefits of exercise. Among the most studied exercise-induced myokines are IL-6, interleukin-8, interleukin-15, brain-derived neurotrophic factor, and leukemia inhibitory factor. These molecules enhance insulin sensitivity, promote lipid and glucose metabolism, and suppress the production of proinflammatory cytokines, thereby linking muscular activity to improved metabolic and immune regulation that may underlie the protective effects of exercise against colorectal cancer [62].

Growing evidence indicates that the gut microbiota plays a pivotal role in mediating the systemic health benefits of physical activity, including its protective effects against colorectal cancer. Exercise has been shown to independently alter gut microbial diversity and composition, promoting the growth of beneficial short-chain fatty acid (SCFA)-producing species such as *Faecalibacterium prausnitzii*, *Roseburia hominis*, and *Akkermansia muciniphila*. These bacteria generate butyrate, a SCFA that serves as a primary energy source for colonocytes and exhibits anti-inflammatory and antineoplastic properties by modulating gene expression through histone acetylation and suppressing nuclear factor-κB signaling. In addition, regular exercise may reduce intestinal transit time, improve epithelial barrier integrity, and enhance gut-associated immune responses, collectively contributing to a less procarcinogenic intestinal microenvironment [63].

Future directions

Despite growing evidence supporting the benefits of exercise in colorectal cancer, several critical research gaps persist. To date, relatively few clinical trials have been specifically designed to evaluate the therapeutic efficacy of exercise or its potential to enhance treatment outcomes when combined with modern oncologic therapies such as radiotherapy, targeted therapy, or immunotherapy. Moreover, the optimal timing, duration, and intensity of exercise interventions across different stages of cancer treatment remain poorly defined.

Mechanistic research is also limited, particularly regarding the molecular and cellular pathways through which physical activity influences tumor metabolism, immune surveillance, and systemic inflammation. Future studies should integrate biological sampling and molecular profiling to elucidate these mechanisms, enabling the identification of biomarkers predictive of exercise responsiveness.

From a clinical perspective, future efforts should prioritize large, multicenter randomized controlled trials with treatment efficacy and recurrence prevention as primary endpoints, rather than focusing solely on quality of life or physical fitness. Developing standardized, evidence-based exercise prescriptions—tailored to patient characteristics, treatment modality, and comorbidities—will be essential for clinical translation.

Finally, the integration of exercise oncology into standard cancer care pathways represents a promising direction for personalized medicine. Collaborative models involving oncologists, physiotherapists, and exercise specialists could support individualized, supervised exercise programs as part of comprehensive survivorship and rehabilitation strategies. Strengthening health system infrastructure to support such programs will be crucial to translating the well-established benefits of physical activity into real-world clinical outcomes for colorectal cancer patients.

Conclusions

Regular physical activity plays a crucial role across the continuum of colorectal cancer care—from primary prevention and recurrence reduction to postoperative recovery and long-term survivorship. A growing body of evidence indicates that exercise not only improves physical performance, quality of life, and treatment tolerance but may also exert biological effects that modulate cancer progression. The proposed mechanisms include regulation of insulin and inflammatory pathways, enhancement of immune surveillance, improved mitochondrial and metabolic function, and beneficial alterations in body composition.

Despite strong evidence, physical inactivity remains highly prevalent among colorectal cancer survivors, emphasizing the need for structured and accessible exercise-based interventions. Future efforts should focus on developing standardized, supervised programs integrated into oncology care, supported by mechanistic research and multidisciplinary collaboration. Promoting active lifestyles should be recognized as an essential component of comprehensive colorectal cancer management, with the potential to improve both survival and overall well-being.

REFERENCES

1. Bray, F., Laversanne, M., Sung, H., Ferlay, J., Siegel, R. L., Soerjomataram, I., & Jemal, A. (2024). Global cancer statistics 2022: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *CA: A Cancer Journal for Clinicians*, *74*(3), 229–263. https://doi.org/10.3322/caac.21834
2. Wojciechowska, U., Barańska, K., Miklewska, M., & Didkowska, J. A. (2023). Cancer incidence and mortality in Poland in 2020. *Nowotwory. Journal of Oncology*, *73*(3), 129–145. https://doi.org/10.5603/NJO.2023.0026
3. *Country Cancer Profiles 2025 | ECIR - European Cancer Inequalities Registry*. (n.d.). Retrieved October 1, 2025, from https://cancer-inequalities.jrc.ec.europa.eu/country-cancer-profiles-2025
4. Nasaif, H. A., & Al Qallaf, S. M. (2018). Knowledge of Colorectal Cancer Symptoms and Risk Factors in the Kingdom of Bahrain: A Cross- Sectional Study. *Asian Pacific Journal of Cancer Prevention: APJCP*, *19*(8), 2299–2304. https://doi.org/10.22034/APJCP.2018.19.8.2299
5. Kędzia-Berut, R., Berut, M., Włodarczyk, M., Włodarczyk, J., Dziki, Ł., Dziki, A., & Mik, M. (2023). Colorectal Cancer: Is it Still a Disease of the Elderly? *Polski Przeglad Chirurgiczny*, *96*(0), 41–45. https://doi.org/10.5604/01.3001.0054.0956
6. Durko, L., & Malecka-Panas, E. (2014). Lifestyle Modifications and Colorectal Cancer. *Current Colorectal Cancer Reports*, *10*(1), 45–54. https://doi.org/10.1007/s11888-013-0203-4
7. Metelski, A. (2019). Physical activity in Poland and the European Union. *Quality in Sport*, *5*(3), 7–21. https://doi.org/10.12775/QS.2019.013
8. Dwojaczny, B., & Bejtka, M. (2023). Influence of physical activity on cognitive functions—Potential mechanisms and benefits. *Journal of Education, Health and Sport*, *13*(3), 181–185. https://doi.org/10.12775/JEHS.2023.13.03.026
9. Dekker, E., Tanis, P. J., Vleugels, J. L. A., Kasi, P. M., & Wallace, M. B. (2019). Colorectal cancer. *Lancet (London, England)*, *394*(10207), 1467–1480. https://doi.org/10.1016/S0140-6736(19)32319-0
10. Noël Racine, A., Margaritis, I., Duclos, M., Carré, F., Vuillemin, A., & Gautier, C. (2022). Costing the economic burden of prolonged sedentary behaviours in France. *European Journal of Public Health*, *32*(Suppl 1), i3–i7. https://doi.org/10.1093/eurpub/ckac071
11. Sun, Y., Keat, O. B., & Rajabi, S. (2025). The role of physical activity and epigenetic changes in colorectal cancer prevention. *Cancer Cell International*, *25*, 227. https://doi.org/10.1186/s12935-025-03872-1
12. Nagtegaal, I. D., Odze, R. D., Klimstra, D., Paradis, V., Rugge, M., Schirmacher, P., Washington, K. M., Carneiro, F., Cree, I. A., & WHO Classification of Tumours Editorial Board. (2020). The 2019 WHO classification of tumours of the digestive system. *Histopathology*, *76*(2), 182–188. https://doi.org/10.1111/his.13975
13. Wang, J.-D., Xu, G.-S., Hu, X.-L., Li, W.-Q., Yao, N., Han, F.-Z., Zhang, Y., & Qu, J. (2024). The histologic features, molecular features, detection and management of serrated polyps: A review. *Frontiers in Oncology*, *14*, 1356250. https://doi.org/10.3389/fonc.2024.1356250
14. Kyzer, S., Bégin, L. R., Gordon, P. H., & Mitmaker, B. (1992). The care of patients with colorectal polyps that contain invasive adenocarcinoma. Endoscopic polypectomy or colectomy? *Cancer*, *70*(8), 2044–2050. https://doi.org/10.1002/1097-0142(19921015)70:8%253C2044::aid-cncr2820700805%253E3.0.co;2-x
15. Snover, D. C., Jass, J. R., Fenoglio-Preiser, C., & Batts, K. P. (2005). Serrated polyps of the large intestine: A morphologic and molecular review of an evolving concept. *American Journal of Clinical Pathology*, *124*(3), 380–391. https://doi.org/10.1309/V2EP-TPLJ-RB3F-GHJL
16. Kahi, C. J., & Rex, D. K. (2015). Advances in colonoscopy. *Gastrointestinal Endoscopy Clinics of North America*, *25*(2), xv–xvi. https://doi.org/10.1016/j.giec.2015.01.001

17. Hassan, C., Antonelli, G., Dumonceau, J.-M., Regula, J., Bretthauer, M., Chaussade, S., Dekker, E., Ferlitsch, M., Gimeno-Garcia, A., Jover, R., Kalager, M., Pellisé, M., Pox, C., Ricciardiello, L., Rutter, M., Helsingen, L. M., Bleijenberg, A., Senore, C., van Hooft, J. E., … Quintero, E. (2020). Post-polypectomy colonoscopy surveillance: European Society of Gastrointestinal Endoscopy (ESGE) Guideline - Update 2020. *Endoscopy*, *52*(8), 687–700. https://doi.org/10.1055/a-1185-3109
18. Sano, W., Hirata, D., Teramoto, A., Iwatate, M., Hattori, S., Fujita, M., & Sano, Y. (2020). Serrated polyps of the colon and rectum: Remove or not? *World Journal of Gastroenterology*, *26*(19), 2276–2285. https://doi.org/10.3748/wjg.v26.i19.2276
19. Mezzapesa, M., Losurdo, G., Celiberto, F., Rizzi, S., d'Amati, A., Piscitelli, D., Ierardi, E., & Di Leo, A. (2022). Serrated Colorectal Lesions: An Up-to-Date Review from Histological Pattern to Molecular Pathogenesis. *International Journal of Molecular Sciences*, *23*(8), 4461. https://doi.org/10.3390/ijms23084461
20. Yehia, L., Heald, B., & Eng, C. (2023). Clinical Spectrum and Science Behind the Hamartomatous Polyposis Syndromes. *Gastroenterology*, *164*(5), 800–811. https://doi.org/10.1053/j.gastro.2023.01.026
21. Gorji, L., & Albrecht, P. (2023). Hamartomatous polyps: Diagnosis, surveillance, and management. *World Journal of Gastroenterology*, *29*(8), 1304–1314. https://doi.org/10.3748/wjg.v29.i8.1304
22. He, D.-G., Chen, X.-J., Huang, J.-N., Chen, J.-G., Lv, M.-Y., Huang, T.-Z., Lan, P., & He, X.-S. (2022). Increased risk of colorectal neoplasia in inflammatory bowel disease patients with post-inflammatory polyps: A systematic review and meta-analysis. *World Journal of Gastrointestinal Oncology*, *14*(1), 348–361. https://doi.org/10.4251/wjgo.v14.i1.348
23. Candel, I., Wetwittayakhlang, P., Bessissow, T., & Lakatos, P. L. (2025). The Importance of Post-Inflammatory Polyps (PIPs) in Colorectal Cancer Surveillance in Inflammatory Bowel Diseases. *Journal of Clinical Medicine*, *14*(2), 333. https://doi.org/10.3390/jcm14020333
24. Rezende, L. F. M. de, Sá, T. H. de, Markozannes, G., Rey-López, J. P., Lee, I.-M., Tsilidis, K. K., Ioannidis, J. P. A., & Eluf-Neto, J. (2018). Physical activity and cancer: An umbrella review of the literature including 22 major anatomical sites and 770 000 cancer cases. *British Journal of Sports Medicine*, *52*(13), 826–833. https://doi.org/10.1136/bjsports-2017-098391
25. Kruk, J., & Czerniak, U. (2013). Physical activity and its relation to cancer risk: Updating the evidence. *Asian Pacific Journal of Cancer Prevention: APJCP*, *14*(7), 3993–4003. https://doi.org/10.7314/apjcp.2013.14.7.3993
26. Wang, J., Huang, L., Gao, Y., Wang, Y., Chen, S., Huang, J., Zheng, W., Bao, P., Gong, Y., Zhang, Y., Wang, M., & Wong, M. C. S. (2020). Physically active individuals have a 23% lower risk of any colorectal neoplasia and a 27% lower risk of advanced colorectal neoplasia than their non-active counterparts: Systematic review and meta-analysis of observational studies. *British Journal of Sports Medicine*, *54*(10), 582–591. https://doi.org/10.1136/bjsports-2018-100350
27. Wolin, K. Y., Yan, Y., Colditz, G. A., & Lee, I.-M. (2009). Physical activity and colon cancer prevention: A meta-analysis. *British Journal of Cancer*, *100*(4), 611–616. https://doi.org/10.1038/sj.bjc.6604917
28. Simons, C. C. J. M., Hughes, L. A. E., van Engeland, M., Goldbohm, R. A., van den Brandt, P. A., & Weijenberg, M. P. (2013). Physical activity, occupational sitting time, and colorectal cancer risk in the Netherlands cohort study. *American Journal of Epidemiology*, *177*(6), 514–530. https://doi.org/10.1093/aje/kws280
29. Kirkegaard, H., Johnsen, N. F., Christensen, J., Frederiksen, K., Overvad, K., & Tjønneland, A. (2010). Association of adherence to lifestyle recommendations and risk of colorectal cancer: A prospective Danish cohort study. *BMJ (Clinical Research Ed.)*, *341*, c5504. https://doi.org/10.1136/bmj.c5504
30. Oruç, Z., & Kaplan, M. A. (2019). Effect of exercise on colorectal cancer prevention and treatment. *World Journal of Gastrointestinal Oncology*, *11*(5), 348–366. https://doi.org/10.4251/wjgo.v11.i5.348
31. Edwards, B. K., Noone, A.-M., Mariotto, A. B., Simard, E. P., Boscoe, F. P., Henley, S. J., Jemal, A., Cho, H., Anderson, R. N., Kohler, B. A., Eheman, C. R., & Ward, E. M. (2014). 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*, *120*(9), 1290–1314. https://doi.org/10.1002/cncr.28509
32. Wolin, K. Y., Yan, Y., & Colditz, G. A. (2011). Physical activity and risk of colon adenoma: A meta-analysis. *British Journal of Cancer*, *104*(5), 882–885. https://doi.org/10.1038/sj.bjc.6606045
33. Wele, P., Wu, X., & Shi, H. (2022). Sex-Dependent Differences in Colorectal Cancer: With a Focus on Obesity. *Cells*, *11*(22), 3688. https://doi.org/10.3390/cells11223688
34. Hautala, A. J., Kiviniemi, A. M., Mäkikallio, T. H., Kinnunen, H., Nissilä, S., Huikuri, H. V., & Tulppo, M. P. (2006). Individual differences in the responses to endurance and resistance training. *European Journal of Applied Physiology*, *96*(5), 535–542. https://doi.org/10.1007/s00421-005-0116-2
35. Zou, D., Xin, X., Xu, Y., Xu, H., & Xu, T. (2025). A cross-sectional study on the association between physical activity and the risk of colon cancer based on NHANES 2007-2018. *Scientific Reports*, *15*(1), 3297. https://doi.org/10.1038/s41598-025-88067-4

36. Stein, M. J., Baurecht, H., Bohmann, P., Fervers, B., Fontvieille, E., Freisling, H., Friedenreich, C. M., Konzok, J., Peruchet-Noray, L., Sedlmeier, A. M., Leitzmann, M. F., & Weber, A. (2024). Diurnal timing of physical activity and risk of colorectal cancer in the UK Biobank. *BMC Medicine*, *22*(1), 399. https://doi.org/10.1186/s12916-024-03632-4
37. Lynch, B. M., Cerin, E., Owen, N., Hawkes, A. L., & Aitken, J. F. (2008). Prospective relationships of physical activity with quality of life among colorectal cancer survivors. *Journal of Clinical Oncology: Official Journal of the American Society of Clinical Oncology*, *26*(27), 4480–4487. https://doi.org/10.1200/JCO.2007.15.7917
38. McGowan, E. L., Speed-Andrews, A. E., Rhodes, R. E., Blanchard, C. M., Culos-Reed, S. N., Friedenreich, C. M., & Courneya, K. S. (2013). Sport participation in colorectal cancer survivors: An unexplored approach to promoting physical activity. *Supportive Care in Cancer: Official Journal of the Multinational Association of Supportive Care in Cancer*, *21*(1), 139–147. https://doi.org/10.1007/s00520-012-1501-0
39. Courneya, K. S., Vardy, J. L., O'Callaghan, C. J., Gill, S., Friedenreich, C. M., Wong, R. K. S., Dhillon, H. M., Coyle, V., Chua, N. S., Jonker, D. J., Beale, P. J., Haider, K., Tang, P. A., Bonaventura, T., Wong, R., Lim, H. J., Burge, M. E., Hubay, S., Sanatani, M., … CHALLENGE Investigators. (2025). Structured Exercise after Adjuvant Chemotherapy for Colon Cancer. *The New England Journal of Medicine*, *393*(1), 13–25. https://doi.org/10.1056/NEJMoa2502760
40. Brown, J. C., Ma, C., Shi, Q., Saltz, L. B., Shields, A. F., & Meyerhardt, J. A. (2025). The association of physical activity with survival in colon cancer versus a matched general population: Data from Cancer and Leukemia Group B 89803 and 80702 (Alliance). *Cancer*, *131*(5), e35727. https://doi.org/10.1002/cncr.35727
41. Park, J., Kim, J. H., Lee, H. J., Park, S. J., Hong, S. P., Cheon, J. H., Kim, W. H., Park, J. S., Jeon, J. Y., & Kim, T. I. (2017). The Effects of Physical Activity and Body Fat Mass on Colorectal Polyp Recurrence in Patients with Previous Colorectal Cancer. *Cancer Prevention Research (Philadelphia, Pa.)*, *10*(8), 478–484. https://doi.org/10.1158/1940-6207.CAPR-17-0065
42. Ahn, K.-Y., Hur, H., Kim, D.-H., Min, J., Jeong, D. H., Chu, S. H., Lee, J. W., Ligibel, J. A., Meyerhardt, J. A., Jones, L. W., Jeon, J. Y., & Kim, N. K. (2013). The effects of inpatient exercise therapy on the length of hospital stay in stages I-III colon cancer patients: Randomized controlled trial. *International Journal of Colorectal Disease*, *28*(5), 643–651. https://doi.org/10.1007/s00384-013-1665-1
43. Onerup, A., Li, Y., Afshari, K., Angenete, E., de la Croix, H., Ehrencrona, C., Wedin, A., & Haglind, E. (2024). Long-term results of a short-term home-based pre- and postoperative exercise intervention on physical recovery after colorectal cancer surgery (PHYSSURG-C): A randomized clinical trial. *Colorectal Disease: The Official Journal of the Association of Coloproctology of Great Britain and Ireland*, *26*(3), 545–553. https://doi.org/10.1111/codi.16860
44. Amirsasan, R., Akbarzadeh, M., & Akbarzadeh, S. (2022). Exercise and colorectal cancer: Prevention and molecular mechanisms. *Cancer Cell International*, *22*(1), 247. https://doi.org/10.1186/s12935-022-02670-3
45. Van Vulpen, J. K., Velthuis, M. J., Steins Bisschop, C. N., Travier, N., Van Den Buijs, B. J. W., Backx, F. J. G., Los, M., Erdkamp, F. L. G., Bloemendal, H. J., Koopman, M., De Roos, M. A. J., Verhaar, M. J., Ten Bokkel-Huinink, D., Van Der Wall, E., Peeters, P. H. M., & May, A. M. (2016). Effects of an Exercise Program in Colon Cancer Patients undergoing Chemotherapy. *Medicine and Science in Sports and Exercise*, *48*(5), 767–775. https://doi.org/10.1249/MSS.0000000000000855
46. Morielli, A. R., Usmani, N., Boulé, N. G., Tankel, K., Severin, D., Nijjar, T., Joseph, K., & Courneya, K. S. (2016). A Phase I Study Examining the Feasibility and Safety of an Aerobic Exercise Intervention in Patients With Rectal Cancer During and After Neoadjuvant Chemoradiotherapy. *Oncology Nursing Forum*, *43*(3), 352–362. https://doi.org/10.1188/16.ONF.352-362
47. Piringer, G., Fridrik, M., Fridrik, A., Leiherer, A., Zabernigg, A., Greil, R., Eisterer, W., Tschmelitsch, J., Lang, A., Frantal, S., Burgstaller, S., Gnant, M., Thaler, J., & Austrian Breast and Colorectal Cancer Study Group (ABCSG). (2018). A prospective, multicenter pilot study to investigate the feasibility and safety of a 1-year controlled exercise training after adjuvant chemotherapy in colorectal cancer patients. *Supportive Care in Cancer: Official Journal of the Multinational Association of Supportive Care in Cancer*, *26*(4), 1345–1352. https://doi.org/10.1007/s00520-017-3961-8
48. Lin, K.-Y., Shun, S.-C., Lai, Y.-H., Liang, J.-T., & Tsauo, J.-Y. (2014). Comparison of the effects of a supervised exercise program and usual care in patients with colorectal cancer undergoing chemotherapy. *Cancer Nursing*, *37*(2), E21-29. https://doi.org/10.1097/NCC.0b013e3182791097
49. Mols, F., Beijers, A. J. M., Vreugdenhil, G., Verhulst, A., Schep, G., & Husson, O. (2015). Chemotherapy-induced peripheral neuropathy, physical activity and health-related quality of life among colorectal cancer survivors from the PROFILES registry. *Journal of Cancer Survivorship: Research and Practice*, *9*(3), 512–522. https://doi.org/10.1007/s11764-015-0427-1
50. Giovannucci, E. (2001). Insulin, insulin-like growth factors and colon cancer: A review of the evidence. *The Journal of Nutrition*, *131*(11 Suppl), 3109S-20S. https://doi.org/10.1093/jn/131.11.3109S
51. Giovannucci, E. (2007). Metabolic syndrome, hyperinsulinemia, and colon cancer: A review. *The American Journal of Clinical Nutrition*, *86*(3), s836-842. https://doi.org/10.1093/ajcn/86.3.836S

52. Hakam, A., Yeatman, T. J., Lu, L., Mora, L., Marcet, G., Nicosia, S. V., Karl, R. C., & Coppola, D. (1999). Expression of insulin-like growth factor-1 receptor in human colorectal cancer. *Human Pathology*, *30*(10), 1128–1133. https://doi.org/10.1016/s0046-8177(99)90027-8
53. Sax, A. T., Jenkins, D. G., Devin, J. L., Hughes, G. I., Bolam, K. A., & Skinner, T. L. (2014). The insulin-like growth factor axis: A biological mechanism linking physical activity to colorectal cancer survival. *Cancer Epidemiology*, *38*(4), 455–459. https://doi.org/10.1016/j.canep.2014.05.011
54. Devin, J. L., Bolam, K. A., Jenkins, D. G., & Skinner, T. L. (2016). The Influence of Exercise on the Insulin-like Growth Factor Axis in Oncology: Physiological Basis, Current, and Future Perspectives. *Cancer Epidemiology, Biomarkers & Prevention: A Publication of the American Association for Cancer Research, Cosponsored by the American Society of Preventive Oncology*, *25*(2), 239–249. https://doi.org/10.1158/1055-9965.EPI-15-0406
55. McTiernan, A., Yasui, Y., Sorensen, B., Irwin, M. L., Morgan, A., Rudolph, R. E., Surawicz, C., Lampe, J. W., Ayub, K., Potter, J. D., & Lampe, P. D. (2006). Effect of a 12-month exercise intervention on patterns of cellular proliferation in colonic crypts: A randomized controlled trial. *Cancer Epidemiology, Biomarkers & Prevention: A Publication of the American Association for Cancer Research, Cosponsored by the American Society of Preventive Oncology*, *15*(9), 1588–1597. https://doi.org/10.1158/1055-9965.EPI-06-0223
56. Campbell, K. L., McTiernan, A., Li, S. S., Sorensen, B. E., Yasui, Y., Lampe, J. W., King, I. B., Ulrich, C. M., Rudolph, R. E., Irwin, M. L., Surawicz, C., Ayub, K., Potter, J. D., & Lampe, P. D. (2007). Effect of a 12-month exercise intervention on the apoptotic regulating proteins Bax and Bcl-2 in colon crypts: A randomized controlled trial. *Cancer Epidemiology, Biomarkers & Prevention: A Publication of the American Association for Cancer Research, Cosponsored by the American Society of Preventive Oncology*, *16*(9), 1767–1774. https://doi.org/10.1158/1055-9965.EPI-07-0291
57. Pedersen, L., Idorn, M., Olofsson, G. H., Lauenborg, B., Nookaew, I., Hansen, R. H., Johannesen, H. H., Becker, J. C., Pedersen, K. S., Dethlefsen, C., Nielsen, J., Gehl, J., Pedersen, B. K., Thor Straten, P., & Hojman, P. (2016). Voluntary Running Suppresses Tumor Growth through Epinephrine- and IL-6-Dependent NK Cell Mobilization and Redistribution. *Cell Metabolism*, *23*(3), 554–562. https://doi.org/10.1016/j.cmet.2016.01.011
58. Klampfer, L. (2011). CYTOKINES, INFLAMMATION AND COLON CANCER. *Current Cancer Drug Targets*, *11*(4), 451–464. https://doi.org/10.2174/156800911795538066
59. Mehl, K. A., Davis, J. M., Clements, J. M., Berger, F. G., Pena, M. M., & Carson, J. A. (2005). Decreased intestinal polyp multiplicity is related to exercise mode and gender in ApcMin/+ mice. *Journal of Applied Physiology (Bethesda, Md.: 1985)*, *98*(6), 2219–2225. https://doi.org/10.1152/japplphysiol.00975.2004
60. Oshima, M., & Taketo, M. M. (2002). COX selectivity and animal models for colon cancer. *Current Pharmaceutical Design*, *8*(12), 1021–1034. https://doi.org/10.2174/1381612023394953
61. Guffey, C. R., Fan, D., Singh, U. P., & Murphy, E. A. (2013). Linking obesity to colorectal cancer: Recent insights into plausible biological mechanisms. *Current Opinion in Clinical Nutrition and Metabolic Care*, *16*(5), 595–600. https://doi.org/10.1097/MCO.0b013e328362d10b
62. Hojman, P., Gehl, J., Christensen, J. F., & Pedersen, B. K. (2018). Molecular Mechanisms Linking Exercise to Cancer Prevention and Treatment. *Cell Metabolism*, *27*(1), 10–21. https://doi.org/10.1016/j.cmet.2017.09.015
63. Mailing, L. J., Allen, J. M., Buford, T. W., Fields, C. J., & Woods, J. A. (2019). Exercise and the Gut Microbiome: A Review of the Evidence, Potential Mechanisms, and Implications for Human Health. *Exercise and Sport Sciences Reviews*, *47*(2), 75–85. https://doi.org/10.1249/JES.0000000000000183