

PRECISION EXERCISE ONCOLOGY IN CANCER MANAGEMENT: CURRENT BODY OF KNOWLEDGE, OPPORTUNITIES, GAPS, AND FUTURE DIRECTIONS FROM A GERMAN–SLOVENIAN COLLABORATION

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ABSTRACT

In this work, we compare the supportive care models for cancer patients and survivors in two European Union countries, Germany and Slovenia. In summary, we highlight the following recommendations: integrating structured exercise facilities and clinical nutrition departments into hospital settings should become the standard of supportive care to address the projected rise in cancer incidence over the next 15 years. Current university curricula do not adequately prepare professionals to address the specific needs of cancer patients. This necessitates interdisciplinary, hospital-based exercise and nutrition programmes, supported by advanced diagnostics and delivered in accessible multilingual formats, to improve patient outcomes, enhance return-to-work rates, and justify dedicated health insurance funding through their demonstrated high economic and clinical value. These recommendations call for action to standardize supportive care protocols throughout partner countries and institutions. The success of this initiative depends on establishing sustainable funding streams from government

resources, health insurance providers, and third-party funders, justified by the clear economic and clinical benefits of early occupational reintegration.

Keywords: *cancer prevention, musculoskeletal disorders, physical activity*

PRECIZNA ONKOLOŠKA VADBA PRI OBRAVNAVI RAKA: TRENUTNO STANJE ZNANJA, PRILOŽNOSTI, VRZELI IN PRIHODNJE USMERITVE NEMŠKO-SLOVENSKEGA SODELOVANJA

IZVLEČEK

Namen tega članka je primerjati modele podporne oskrbe za bolnike z rakom in osebe, ki so preživele raka, med dvema državama Evropske unije – Nemčijo in Slovenijo. Kot povzetek našega dela se lahko poudarijo ta priporočila: zaradi predvidene rasti incidence raka v naslednjih 15 letih predlagamo vzpostavitev podporne oskrbe, ki temelji na strukturiranih vadbenih enotah in oddelkih za klinično prehrano v bolnišničnem okolju. Potrebno je preurediti trenutne univerzitetne učne načrte, saj ne ustrezajo strokovnim zahtevam, ki so potrebne za ustrezno obravnavo specifičnih potreb bolnikov z rakom. Sodobni ukrepi namreč zahtevajo interdisciplinarne, bolnišnično zasnovane programe vadbe in prehrane, podprte z napredno diagnostiko in v večjezičnih oblikah, kar dokazano izboljša klinične izide bolnikov in poveča stopnjo vrnitve na delo. Potrebna je vzpostavitev namenskega financiranja iz zdravstvenega zavarovanja, kar ima dokazano visoko gospodarsko in klinično vrednost. Ta priporočila pozivajo k ukrepanju za standardizacijo protokolov podporne oskrbe v partnerskih državah in institucijah. Uspeh te pobude je odvisen od vzpostavitve trajnostnih virov financiranja iz državnih sredstev, zdravstvenih zavarovalnic in tretjih virov financiranja, kar je utemeljeno z jasnimi gospodarskimi in kliničnimi koristmi zgodnje poklicne reintegracije.

Ključne besede: *preprečevanje raka, bolezni mišično-skeletnega sistema, telesna aktivnost*

CURRENT BODY OF KNOWLEDGE, GAPS, AND FUTURE DIRECTIONS IN EXERCISE ONCOLOGY

Although nearly 40 years have passed since the first paper on the role of exercise in cancer patients was published (Galvão et al., 2025), it is only in recent years that positive effects of exercise interventions in cancer patients have been recognized in clinical medicine. A growing body of literature highlights the beneficial role of exercise interventions in managing cancer during both acute treatment and survivorship. More specifically, evidence suggests that exercise interventions can effectively mitigate disease-related symptoms and treatment-related toxicities, such as chronic fatigue or cognitive dysfunction, depression, and anxiety, thereby improving quality of life (QoL) in cancer patients (Schmitz et al., 2010; Campbell et al., 2019; Schmitz et al., 2019), particularly when compared with standard care or pharmacological interventions (Mustian et al., 2017). Previous research has also shown that structured exercise interventions may help improve chemotherapy completion rates in women diagnosed with breast cancer (Courneya et al., 2007). More recently, evidence has emerged to suggest that structured exercise interventions can improve overall progression-free survival and overall survival in certain cancer types. For example, in 2025, the seminal findings of the CHALLENGE trial were published (Courneya et al., 2025). In this study, nearly 900 patients with colon cancer experienced significantly improved outcomes, including a 28% increase in 5-year progression-free survival and a 37% reduction in the relative risk of death among those who followed a structured exercise programme for three years. Thus, exercise interventions are increasingly recognized as an integrative component of first-line treatment for colon cancer. The question remains whether other types of cancer can also be influenced by exercise. In an animal study, Pedersen and colleagues (2016) showed that voluntary wheel running had a remarkable effect on tumour growth. Mice randomized to the exercise group exhibited more than a ~60% reduction in tumour incidence and progression across five different tumour models, as exercise led to adrenaline-dependent mobilization of immune cells and their migration into tumours. In humans, however, the evidence regarding the effects of exercise on tumour growth remains equivocal (Djurhuus et al., 2023).

Across the globe there are approximately 150 established exercise programmes for cancer patients, as presented by the American College of Sports Medicine's Roundtable in 2018 (Campbell et al., 2019). A positive example from Europe, Germany in particular, is the establishment of the Oncological Exercise Therapy (OTT) care model at the University Hospital Cologne in 2012 (Baumann et al., 2015). The model was approved by the Review Board of the

Medical Faculty of the University of Cologne (No. 13–050) and was permanently implemented at the Centre for Integrative Oncology Cologne in 2020. What is particularly noteworthy about this model is that it was designed to deliver state-of-the-art, evidence-based and quality-assured exercise therapy for cancer patients undergoing acute medical treatment. More specifically, it is based on four key components, the OTT exercise therapy concept, targeted at the specific needs of oncology patients undergoing medical treatment; selective care contracts with major health insurance providers to secure financial reimbursement for OTT services; the OTT Academy, a professional education programme for physiotherapists and sports science graduates; and an independent quality management and certification system. Completing the OTT professional training and fulfilling defined quality standards relating to infrastructure and staffing enables institutions employing certified OTT therapists to receive reimbursement for exercise therapy from health insurance providers covering approximately 60% of the German health insurance market. To date, around 1000 professionals have obtained OTT certification and the programme is now offered at over 300 clinics and private practices across Germany, Austria, and Switzerland. The integration of the OTT care model as a standard service within the German health care system is currently under consideration by the German government. Furthermore, the principal OTT location at University Hospital Cologne functions as an ongoing research platform, enabling researchers to conduct exercise intervention studies embedded within clinical settings. Recently, Sonntag et al. (2026) published finding from the first eight years of the OTT programme at University Hospital Cologne's Centre for Integrative Oncology. The authors analysed data from more than 1,600 patients over 8 years and reported that only 1% of cancer patients and survivors achieved the recommended average of ≥ 2 weekly sessions within the OTT programme. Older age was identified as the main factor associated with lower attendance, while shorter travel distance was associated with higher attendance rates. Importantly, the study also demonstrated that structured exercise improved both strength and endurance, with greater improvement observed in patients who attended exercise sessions more frequently.

In Slovenia, a neighbouring European Union country, all patients diagnosed with cancer, regardless of age, ethnicity, or socioeconomic status, will receive the best available possible medical treatment, with treatment decisions made independently of cost. The leading national institution is the Institute of Oncology, where nearly 75% of all cancer patients in Slovenia are treated. However, a fully established supportive exercise programme is not yet available in hospital settings, despite the inclusion of exercise and physical rehabilitation

in the national plan to combat cancer. Still, some progress was made with a multidisciplinary Support Unit at the Institute of Oncology, bringing together several departments dedicated to comprehensive supportive care. One of these is the Department of Physical Medicine and Rehabilitation, which was established only a few years ago. The department provides specialist consultations following a referral from an oncology clinician, typically due to mobility limitations or pain syndromes. After an initial baseline assessment, patients may be offered an on-site physiotherapy consultation, either during their hospital stay or in the outpatient setting. A limited number of supervised sessions can be provided to teach patients how to perform the prescribed exercises safely and effectively. Basic equipment, such as resistance bands, may also be supplied for home exercise. Due to current spatial constraints, the facility does not yet have a dedicated gym or exercise room.

Another key component of the Multidisciplinary Support Unit is the Department of Clinical Nutrition and Intestinal Failure, established in 2008. The department provides comprehensive supportive care through routine nutritional screening and specialized consultations. When nutritional problems are identified, patients receive individualized medical nutrition therapy—an approach that, as discussed below, forms a critical foundation of integrated supportive cancer care. Adequate nutritional support helps prevent or mitigate malnutrition, maintains muscle mass and immune function, improves treatment tolerance, reduces complications, and contributes to better survival and quality of life. These principles are strongly supported by the ESPEN Guidelines on Nutrition in Cancer Patients (Arends et al., 2017).

In recent years, some progress has been made through the efforts of individual clinical researchers with the OREH study (**O**ncological **R**ehabilitation study, from 2019–2022, V3-1906). One of the study's conclusions was that physical rehabilitation leads to better QoL, reduces lymphoedema, and translates into faster return to work in breast cancer patients in Slovenia. Another nationally funded pilot study on comprehensive rehabilitation of patients diagnosed with colorectal cancer (2022–24, V3-2241) in collaboration with the Faculty of Sport aimed to evaluate the effectiveness of a comprehensive rehabilitation programme in colorectal cancer patients using a randomized controlled trial design, and focusing on the QoL, sick leave duration, and disability retirement. However, these initiatives have not yet been sufficiently recognized by policymakers for exercise- and rehabilitation-based supportive care to become permanently integrated into hospital settings.

Since it is now well established that the incidence of cancer diagnosis will increase dramatically on a global scale, and 27.5 million new cases are predicted

by 2040 (Sung et al., 2021), an increase in the number cancer survivors is also expected due to advances in comprehensive and personalized medical oncology treatment. This disparity represents both a challenge and an opportunity for cross-border collaboration and standardization. Therefore, establishing supportive care programmes in hospital settings is becoming increasingly important, even more so given the trends of ageing, cancer and cancer incidence and survivorship across the European Union. Therefore, several gaps and obstacles that should be addressed in this regard are summarized below:

- Current human movement science, kinesiology, and physiotherapy curricula in public universities overlook the specific needs of cancer populations, leading to a critical shortage of staff trained in managing therapy side-effects and optimizing precision exercise prescriptions. This approach may create new employment opportunities for exercise scientists and kinesiologists, while simultaneously delivering clinically meaningful benefits for patients. To advance precision oncology, academic programmes must bridge the knowledge gap regarding symptoms, treatment-related toxicities, and specialized exercise programming, ensuring staff are fully equipped to work with cancer patients, as presented in the OTT Academy, which should be delivered not only in German but also in English or possibly other official European Union languages. Nevertheless, the professional OTT Academy programme should be aligned with the standards of nationally accredited university curricula.
- Establishing exercise facilities within hospital settings with an interdisciplinary team—modelled after successful initiatives like the OTT in Cologne, CIO—helps eliminate travel barriers, raises the quality of integrative care, and significantly boosts patient adherence to both supportive care and clinical research programmes. Co-locating clinical nutrition departments with exercise facilities creates a synergistic “*two sides of the same coin*” approach, providing patients with comprehensive nutritional support, mitigating malnutrition during and after treatment, and thereby enhancing the efficacy of integrative oncology interventions, as observed in the model of Institute of Oncology in Ljubljana.
- The development of integrated cancer rehabilitation centres requires state-of-the-art diagnostic tools, including objective physical activity assessments with comprehensive digital databases, resting metabolic rate assessment, dual-energy X-ray absorptiometry scans, and gait and posture analysis. Furthermore, these facilities should utilize routine isokinetic testing, aerobic fitness assessments, metabolic profiling, sarcopenia assessment, and heart rate variability monitoring, all of which can be

expertly administered by kinesiologists, exercise scientists, and human movement specialists and are prerequisites for successful cancer supportive care. Moreover, by focusing on skeletal muscle plasticity, we can protect patients from muscle atrophy, sarcopenia development, and even excessive muscle mass loss – cachexia, while in parallel mitigating the chronic musculoskeletal and neurological disorders caused by systemic cancer treatments.

- Because integrated supportive care facilitates an earlier return to work and reduces long-term disability, health insurance providers should establish funding streams to cover exercise and nutritional interventions for all cancer patients and survivors across the European Union. Positive examples of structured cancer rehabilitation programmes from Australia show an exceptionally high return on investment to health insurance companies (about 25–26 times the cost), while significantly improving patients' return-to-work outcomes, especially when started early.

Taken together, integrating structured exercise and clinical nutrition programmes should become the standard of supportive care across the European Union to address the projected increase in cancer incidence over the next 15 years. The contrast between Germany and Slovenia illustrates a broader pattern across the European Union: while standards of medical oncology are largely comparable, supportive care models vary significantly. Many cancer risk factors, as well as factors related to disease recurrence, can be modified and managed through structured exercise and nutritional interventions and should be permanently integrated into hospital settings. This represents a clear call to action to establish and standardize supportive care protocols across the European Union. The success such initiatives will depend on sustainable funding from health insurance providers, supported by evidence demonstrating the economic and clinical benefits of early occupational reintegration. By addressing existing educational and financial gaps, comprehensive supportive care can be accessible, professionally delivered, and fully integrated into standard oncology care—not only in the partner countries and institutions examined in this study, but throughout the European Union.

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The authors declare that generative AI tools were not used to write this manuscript.

REFERENCES

- Arends, J., Baracos, V., Bertz, H., Bozzetti, F., Calder, P. C., Deutz, N. E. P., Erickson, N. ... Weimann, A. (2017). ESPEN expert group recommendations for action against cancer-related malnutrition. *Clinical Nutrition*, 36(5), 1187-1196. <https://doi.org/10.1016/j.clnu.2017.06.017>.
- Baumann, F. T., Hallek, M., Meyer, J., Galvão, D. A., Bloch, W., & Elter, T. (2015). Onkologische Trainings- und Bewegungstherapie (OTT) [Evidence and recommendations for oncologic clinical exercise - a personalized treatment concept for cancer patients]. *Deutsche Medizinische Wochenschrift*, 140(19), 1457-1461. <https://doi.org/10.1055/s-0041-104465>.
- Campbell, K. L., Winters-Stone, K. M., Wiskemann, J., May, A. M., Schwartz, A. L., Courneya, K. S., ... Schmitz, K. H. (2019). Exercise guidelines for cancer survivors: consensus statement from international multidisciplinary roundtable. *Medicine & Science in Sports & Exercise*, 51(11), 2375-2390. <https://doi.org/10.1249/MSS.0000000000002116>.
- Courneya, K. S., Segal, R. J., Mackey, J. R., Gelmon, K., Reid, R. D., Friedenreich, C. M., ... McKenzie, D. C. (2007). Effects of aerobic and resistance exercise in breast cancer patients receiving adjuvant chemotherapy: a multicenter randomized controlled trial. *Journal of Clinical Oncology*, 25(28), 4396-4404. <https://doi.org/10.1200/JCO.2006.08.2024>.
- Courneya, K. S., Vardy, J. L., O'Callaghan, C. J., Gill, S., Friedenreich, C. M., Wong, R. K. S., ... Booth, C. M. (2025). Structured exercise after adjuvant chemotherapy for colon cancer. *New England Journal of Medicine*, 393(1), 13-25. <https://doi.org/10.1056/NEJMoa2502760>.
- Djurhuus, S. S., Simonsen, C., Toft, B. G., Thomsen, S. N., Wielsøe, S., Røder, M. A., ... Christensen, J. F. (2023). Exercise training to increase tumour natural killer-cell infiltration in men with localised prostate cancer: a randomised controlled trial. *BJU International*, 131(1), 116-124. <https://doi.org/10.1111/bju.15842>.
- Galvão, D. A., Courneya, K. S., Lucia, A., May, A. M., Mustian, K., Warner, A. B., ... Newton, R. U. (2025). History informing the future of exercise oncology.

- Journal of the National Cancer Institute Monographs*, 2025(71), 306-314. <https://doi.org/10.1093/jncimonographs/lgaf025>.
- Mustian, K. M., Alfano, C. M., Heckler, C., Kleckner, A. S., Kleckner, I. R., Leach, C. R., ... Miller, S. M. (2017).** Comparison of pharmaceutical, psychological, and exercise treatments for cancer-related fatigue: a meta-analysis. *JAMA Oncology*, 3(7), 961-968. <https://doi.org/10.1001/jamaoncol.2016.6914>.
- Pedersen, L., Idorn, M., Olofsson, G. H., Lauenborg, B., Nookaew, I., Hansen, R. H., ... 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>.
- Schmitz, K. H., Campbell, A. M., Stuiver, M. M., Pinto, B. M., Schwartz, A. L., Morris, G. S., ... Matthews, C. E. (2019).** Exercise is medicine in oncology: engaging clinicians to help patients move through cancer. *CA: A Cancer Journal for Clinicians*, 69(6), 468-484. <https://doi.org/10.3322/caac.21579>.
- Schmitz, K. H., Courneya, K. S., Matthews, C., Demark-Wahnefried, W., Galvão, D. A., Pinto, B. M., ... Schwartz, A. (2010).** American College of Sports Medicine roundtable on exercise guidelines for cancer survivors. *Medicine & Science in Sports & Exercise*, 42(7), 1409-1426. <https://doi.org/10.1249/MSS.0b013e3181e0c112>.
- Sonntag, T., Safi, A., Coutellier, V., Lorenz, A., Zimmer, P., Zopf, E. M., ... Baumann, F. T. (2026).** Innovative exercise in routine cancer care: insights from eight years of integrated oncological exercise therapy (OTT). *Sports Medicine - Open*, 12(1), 22. <https://doi.org/10.1186/s40798-026-00988-0>.
- Sung, H., Ferlay, J., Siegel, R. L., Laversanne, M., Soerjomataram, I., Jemal, A., & Bray, F. (2021).** Global cancer statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *CA: A Cancer Journal for Clinicians*, 71(3), 209-249. <https://doi.org/10.3322/caac.21660>.