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Sports-Associated Cancer Risk: A Narrative Review of Specific Neoplasms in Athletes

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Abstract

Introduction and Purpose: Sport is widely associated with a healthy lifestyle, greater longevity, enhanced physical performance, and improved mental health. Extensive research demonstrates that regular physical activity lowers the risk of several malignancies, including colorectal, breast, and endometrial cancers. Nevertheless, behaviors characteristic of competitive and aesthetic sports—such as chronic ultraviolet (UV) exposure and the use of anabolic-androgenic steroids (AAS), selective androgen receptor modulators (SARMs), or muscle-building supplements (MBS)—may paradoxically elevate the risk of organ-specific cancers. This review aims to collate and critically assess current evidence on neoplasms that occur more frequently or hold particular relevance among athletes, with attention to diagnostic challenges and public health implications.

State of Knowledge: The literature highlights several cancers that may be more prevalent or display distinct clinical features in physically active populations: cutaneous malignancies (notably melanoma and non-melanoma skin cancers), testicular cancer (germ cell tumors), hepatocellular carcinoma (HCC), and rare sarcomas (soft-tissue and bone), especially among athletes using performance-enhancing substances. Symptoms of cancer in athletes are often misattributed to sports-related injuries, which can delay diagnosis and worsen outcomes. Despite these concerns, epidemiological data consistently confirm the protective effect of moderate physical activity on overall cancer incidence and mortality.

Summary: Although sport generally confers oncological benefits, specific groups of athletes may face heightened risks for particular cancers, primarily due to environmental exposures and doping agents. Clinicians should maintain a high index of suspicion when evaluating atypical symptoms in young, physically active patients; in cases of persistent complaints not explained by trauma, prompt imaging and histopathological assessment are warranted.

Keywords: sports oncology; athlete health; steroid-associated neoplasms; skin cancer; testicular cancer

Introduction

Sport is widely regarded as a key component of a healthy lifestyle, and its beneficial effects on the cardiovascular, musculoskeletal, and mental health systems are well-documented [1]. Moreover, regular physical activity is associated with a reduced risk of numerous malignancies, including colorectal, breast, endometrial, and lung cancer [2]. Epidemiological evidence suggests that moderate and consistent exercise may influence immunomodulatory mechanisms, reduce oxidative stress, and regulate hormonal metabolism [3].

In this context, particular attention should be given to individuals who engage in sport actively—whether professionally, semi-professionally, or recreationally. Although sport is predominantly associated with disease prevention, scientific reports suggest that under specific conditions it may also constitute a risk factor for the development of certain cancers [4]. These factors include chronic exposure to ultraviolet (UV) radiation (among athletes training outdoors), injuries masking the symptoms of malignancy, and the use of hormonally active substances such as anabolic-androgenic steroids (AAS) and selective androgen receptor modulators (SARMs) [5–7].

Available data point to, among others, an increased incidence of skin cancer among surfers and skiers [8], hepatocellular carcinoma (HCC) in individuals abusing AAS [9], and delays in diagnosing soft tissue sarcomas in young athletes due to misinterpretation of symptoms as sports injuries [10].

The aim of this paper is to provide a synthetic and comprehensive review of the available data on cancers that may be of particular relevance in the athletic population, from both a pathogenetic and diagnostic perspective. This review does not challenge the overall health benefits of physical activity but rather seeks to highlight certain non-obvious risks that may emerge in specific environmental and behavioral contexts.

Materials and Methods

This article constitutes a narrative review aimed at collecting and systematizing data on malignant neoplasms of relevance to the athletic population. The analysis included cancer types

with potentially increased incidence in physically active individuals, as well as malignancies whose diagnosis may be delayed due to symptom masking by typical sports-related injuries.

The review encompassed melanoma and non-melanoma skin cancers (NMSC), testicular germ cell tumors (TGCT), hepatocellular carcinoma (HCC), and soft tissue and bone sarcomas (STS and BS).

The literature search was conducted using the PubMed, Scopus, Web of Science, ScienceDirect, and Google Scholar databases. Publications from the years 1980 to 2025 were considered, with particular emphasis on studies published after the year 2000. A combination of the following keywords was used: *cancer*, *athletes*, *melanoma*, *testicular cancer*, *hepatocellular carcinoma*, *sarcoma*, *AAS*, *SARMs*, *UV exposure*, *trauma*, and *misdiagnosis*.

The review included original research articles, review papers, case reports, and large epidemiological studies that met both linguistic (English or Polish) and substantive (references to physical activity, athletes, or causal associations) criteria. Ultimately, 64 publications were selected for analysis. Data extraction focused on cancer types, risk factors, pathogenetic mechanisms, epidemiology, and clinical and diagnostic implications.

State of Knowledge

Melanoma

Cutaneous melanoma is a highly malignant tumor originating from pigment-producing cells—melanocytes. Its global incidence continues to rise, primarily due to increasing exposure of populations to ultraviolet (UV) radiation. Recognized risk factors for melanoma development include fair skin, a personal history of sunburns, numerous melanocytic nevi, and chronic sun exposure, particularly during childhood and adolescence [11].

A particularly high-risk group includes individuals who are physically active outdoors. Athletes participating in disciplines such as running, cycling, swimming, triathlon, and skiing are especially vulnerable to intense and prolonged UV exposure—often exceeding the levels observed in the general population [12–15]. Frequent physical activity under high solar

irradiance, insufficient photoprotective measures, and increased perspiration further contribute to DNA damage and carcinogenesis [11–13]. The pathogenesis of melanoma is strongly associated with mutations in regulatory genes, with UV radiation acting as a key initiator of malignant transformation [11].

This phenomenon is corroborated by epidemiological data, which demonstrate rising incidence rates not only in the general population but also within specific geographical regions. In 2020, approximately 106,369 new cases of cutaneous melanoma were reported in the EU-27 countries, accounting for 4% of all new cancer diagnoses and ranking sixth among the most common malignancies [16]. In the same year, melanoma was responsible for 1.3% of cancer-related deaths [16,17].

The average age-standardized incidence rates (ASR-E) in Europe were approximately 20 cases per 100,000 individuals annually (approximately 23.2 for men and 18.2 for women) [16–18]. The number of melanoma-related deaths in the EU exceeded 25,000 [17,18]. Projections suggest a continued rise in incidence, reaching approximately 121,000 new cases annually by 2040, with the highest increases expected in countries such as Malta, Ireland, and Cyprus [19].

Even higher incidence rates are observed in Australia, where melanoma is among the most frequently diagnosed malignancies. In 2020, the age-standardized incidence rate (ASIR) was approximately 37 per 100,000 individuals, with 16,819 new diagnoses—accounting for roughly 7.9% of all cancer cases [18,20,21]. According to Cancer Australia, there were 14,686 cases reported in 2020, and the projected number of new diagnoses for 2024 may reach 18,964, with a predicted increase in ASR to 70 per 100,000 (approximately 73 for men and 47 for women) [22]. It is estimated that more than 2 in 3 Australians will develop skin cancer before the age of 85 [23,24], and the lifetime risk of dying from melanoma is 1 in 17—higher in men (1 in 14) than in women (1 in 21) [22].

The elevated melanoma risk among athletes is supported by epidemiological studies conducted in physically active populations. In an Australian cohort of surfers and swimmers, melanoma prevalence was 5.2% and 1.8%, respectively [8], while another study reported a prevalence of 1.5% among golfers in Spain and 1.4% among Australian surfers [25]. Although

these studies have methodological limitations, the data suggest a significant oncological burden among athletes involved in outdoor activities, highlighting the need for targeted prevention and further population-based research in this group.

Summary:

Cutaneous melanoma remains a significant public health concern in many parts of the world, particularly in Europe and Australia. Outdoor athletes exhibit a clearly increased incidence of melanoma, likely due to chronic UV radiation exposure. These findings underscore the necessity of implementing effective prevention strategies and health education within athletic communities.

Non-Melanoma Skin Cancers (NMSC: BCC and SCC)

Non-melanoma skin cancers (NMSC) represent the most commonly diagnosed malignant skin neoplasms. This group primarily includes two major histological subtypes: basal cell carcinoma (BCC), accounting for approximately 80% of all cases, and squamous cell carcinoma (SCC), responsible for about 20% of diagnoses [26,27].

The etiology of both cancer types is strongly associated with chronic exposure to ultraviolet (UV) radiation—both natural and artificial—particularly among individuals with fair skin phototypes (Fitzpatrick types I–II), the elderly, those with impaired immune function (e.g., transplant recipients), and individuals with certain genetic predispositions, such as Gorlin syndrome in the context of BCC [26,28].

BCC is characterized by slow growth and infrequent metastasis but can cause extensive local tissue destruction. In contrast, SCC demonstrates a significantly higher metastatic potential, especially when arising in chronically damaged skin (e.g., scars, ulcers, burns) [27].

In Europe, the average incidence of BCC is approximately 224.6 cases per 100,000 individuals annually [29]. In Australia, it is estimated that the rate of excision procedures for keratinocyte cancers reaches 1,531 per 100,000 person-years, with separate standardized estimates of 770 per 100,000 for BCC and 270 per 100,000 for SCC [30].

As with melanoma, chronic UV exposure is the primary risk factor for NMSC development in individuals who spend significant time outdoors [13,25,31]. Among athletes, this exposure is recurrent and often intense, predisposing them to DNA damage and skin cancer formation [13,25,31].

Epidemiological studies in Australia reported BCC in 11.2% of surfers and 14.5% of swimmers, while SCC was diagnosed in 1.7% and 3.6% of these groups, respectively [8]. In a study involving professional mountaineers, BCC was found in 7% of participants, and SCC in 1% [13].

Furthermore, surfers from the Texas Gulf Coast were found to have a significantly higher prevalence of BCC compared to control groups [13]. Another analysis revealed skin cancer (all types combined) in 50% of surfers and 27.3% of swimmers, with SCC being more prevalent (44.7% vs. 11.3%) than BCC (24.2% vs. 7.6%) [8].

Summary:

Although non-melanoma skin cancers typically exhibit low systemic malignancy potential, they pose a significant health burden—especially among populations professionally or recreationally exposed to prolonged sun exposure. Epidemiological evidence indicates that outdoor athletes constitute a high-risk group, underscoring the need for comprehensive UV prevention strategies and routine screening programs.

Testicular Cancer – Germ Cell Tumor (TGCT)

Testicular germ cell tumor (TGCT) is a malignancy that occurs exclusively in men and predominantly affects the 15–40 age group. Although it accounts for only about 1% of all malignancies in adult males, it is the most common cancer among younger adults and has a significant impact on quality of life, fertility, and mental health [32–34].

The best-documented risk factors include [35,33]:

- Cryptorchidism (undescended testis) – associated with a 3.7- to 7.5-fold increased risk of TGCT;

- Family history of TGCT – risk increases approximately 3.1-fold for first-degree relatives, 6.3-fold for brothers, and 4.4-fold for fathers;
- Low birth weight and hypospadias – associated with a modest but significant risk increase;
- Prenatal and early childhood exposure to endocrine-disrupting chemicals (EDCs) – potentially increases risk, although data are limited;
- Use of muscle-building supplements (MBS) and strength-focused training – case-control studies report a higher TGCT risk among users of such products;
- Regular marijuana use – some analyses show a correlation with elevated TGCT risk.

In Western and Northern Europe, age-standardized incidence rates (ASR) of TGCT between 2010 and 2012 ranged from 8.5 to 9.1 per 100,000 men (in countries such as the Netherlands, Germany, and Switzerland), reaching 11–12 per 100,000 in Scandinavian countries like Denmark, Norway, and Sweden [36–38].

A study investigating the use of muscle-building supplements (MBS) revealed a significantly increased risk of TGCT: individuals who had ever used such supplements had an odds ratio (OR) of 1.65 (95% CI: 1.11–2.46), with stronger effects observed in early users, those using multiple products, and those with longer exposure duration [39].

Furthermore, the use of supraphysiological doses of anabolic-androgenic steroids (AAS), such as nandrolone or stanozolol, can disrupt endogenous testosterone synthesis and lead to hormonal alterations conducive to tumorigenesis, including the development of Leydig cell tumors [40]. Literature reviews warn that MBS—frequently used by athletes and adolescents—may contain carcinogenic substances capable of interfering with hormonal regulation and contributing to testicular cancer development [41].

The relationship between physical activity and TGCT risk remains unclear. An early study found a significantly increased risk among cyclists (crude OR = 1.99; 95% CI: 1.04–3.81) and equestrians (OR = 3.31; 95% CI: 1.36–8.25), although adjusted data did not confirm an increased risk (cycling OR = 1.0; equestrian sports OR = 0.8) [42,43]. A 2018 review of the literature reported mixed findings—some studies suggested a protective effect of physical

activity, while others indicated the opposite; dose-response relationships were observed in both directions [44].

Summary:

TGCT affects exclusively young and middle-aged men, with a multifactorial etiology that includes both genetic predispositions and environmental factors such as cryptorchidism and exposure to endocrine-disrupting substances. Decades of research suggest a potentially significant role of anabolic supplementation—particularly among athletes—as a risk factor. However, the association with physical activity remains inconclusive and warrants further prospective and multicenter investigations.

Liver Cancer – Hepatocellular Carcinoma (HCC)

Hepatocellular carcinoma (HCC) is the most common primary malignant tumor of the liver, accounting for approximately 75–85% of all hepatic cancers. Epidemiologically, it ranks sixth worldwide in terms of cancer incidence and third among the leading causes of cancer-related mortality [45].

The development of HCC is almost invariably associated with chronic liver damage. The main predisposing conditions include liver cirrhosis—particularly that resulting from chronic HBV and HCV infection and alcohol abuse—non-alcoholic fatty liver disease (NAFLD/NASH), and metabolic disorders such as hemochromatosis [46].

Early symptoms of HCC are nonspecific and may include weight loss, abdominal pain, and fatigue. As a result, the disease is often diagnosed at an advanced stage, which significantly limits treatment options and worsens prognosis. Early detection is typically possible only in patients undergoing routine surveillance, especially in the context of pre-existing cirrhosis [45,47].

According to epidemiological data, the global number of new HCC cases in 2022 was approximately 905,000. The current age-standardized incidence rate (ASR) is around 9.5 per 100,000 persons annually, though these rates are significantly higher in Asia and Africa, where

HBV and HCV infections are endemic. In Europe and North America, a rising incidence is being observed, associated with the obesity epidemic, type 2 diabetes, and NAFLD/NASH [47].

Increasing attention is being paid to environmental and behavioral factors contributing to HCC development outside the classical cirrhotic context. Of particular concern is the long-term use of anabolic substances such as anabolic-androgenic steroids (AAS) and selective androgen receptor modulators (SARMs). A 2025 literature review identified that abuse of these substances—especially in athletic and bodybuilding populations—is associated with toxic liver injury and an increased risk of both benign (hepatic adenoma, HCA) and malignant liver tumors, including HCC [5].

Numerous case reports support this association. One report described a 37-year-old bodybuilder who developed HCC on the basis of pre-existing hepatocellular adenomas, despite the absence of cirrhosis [9]. Another case involved a 29-year-old man who developed HCC after six years of using high doses of AAS, with multiple hepatocellular adenomas expressing positive receptors for testosterone and β-catenin [48]. Similar cases have also been reported among recreational athletes, including descriptions of malignant transformation from hepatic adenomas to HCC [49,50].

Summary:

Hepatocellular carcinoma (HCC) is a highly aggressive primary liver cancer that almost exclusively arises in the setting of chronic liver disease—such as cirrhosis, chronic hepatitis B and C, or non-alcoholic fatty liver disease (NAFLD/NASH). Globally, HCC represents a major public health challenge, with the highest burden observed in Asia and Africa; however, increasing incidence is also noted in Western countries due to obesity and metabolic syndrome.

Of particular concern are reports suggesting a potential link between long-term use of anabolic-androgenic steroids (AAS) and selective androgen receptor modulators (SARMs) and the development of HCC in individuals engaged in bodybuilding and physique-focused sports. Case studies indicate that malignancy can arise even in the absence of cirrhosis, often evolving from pre-existing benign lesions (hepatic adenomas). These findings highlight the need for targeted educational, preventive, and surveillance strategies within high-risk groups—particularly among athletes misusing performance-enhancing substances.

Soft Tissue Sarcomas and Bone Tumors

Sarcomas represent a rare but clinically significant group of malignant tumors of mesenchymal origin. Within this category, the predominant types include [51]:

- Soft tissue sarcomas (STS) – accounting for approximately 84% of all sarcoma cases,
- Primary bone tumors (BS**)** such as osteosarcoma, chondrosarcoma, and Ewing sarcoma – comprising around 14% of cases.

In total, soft tissue sarcomas constitute approximately 0.7–1%, and bone tumors around 0.2% of all adult malignancies [51]. Soft tissue sarcomas are most commonly diagnosed after the age of 50, with increasing incidence beyond 65 years of age [51,52], and they are more frequent in males (sex ratio ≈ 1.3) [52,53]. The most common anatomical sites include the lower extremities, thigh regions, and the retroperitoneum—superficial tumors tend to have a better prognosis than deeply located lesions [53–55].

Although rare (< 0.2%), bone tumors occur more frequently in younger individuals (children, adolescents, and young adults), particularly osteosarcoma and Ewing sarcoma, which typically arise in the rapidly growing regions of long bones. In contrast, chondrosarcoma is more common in individuals over 40 years of age and is often located in the pelvis, ribs, and femur [56–58].

Current data do not indicate an increased risk of STS or bone tumors among athletes compared to the general population. For instance, a long-term observational study of a German athlete cohort reported a lower overall cancer incidence than the general population (SIR = 0.82; 95% CI 0.73–0.91), with elevated risk observed only among hurdlers—a finding that requires confirmation in further studies [59].

Nonetheless, clinicians emphasize the diagnostic challenge posed by sarcomas mimicking sports-related injuries, particularly in young, physically active individuals. Bone and soft tissue tumors may resemble hematomas, sprains, or post-traumatic conditions. Important red flags include pain unrelated to activity and lack of improvement following standard injury management [60].

Illustrative cases include a pleomorphic spindle cell sarcoma in a 45-year-old man initially misdiagnosed as a chronic hematoma after a fall [61], and a series of STS cases presenting as traumatic hematomas, only correctly diagnosed after biopsy [62].

In the athletic population, persistent post-traumatic pain that does not resolve despite conservative management—especially when inconsistent with the mechanism of injury—should prompt imaging studies and consideration of a neoplastic cause [60,63].

Interesting experimental findings suggest that regular physical activity may inhibit sarcoma progression in animal models, potentially through modulation of oxidative stress and immune signaling pathways [64]. Although data in humans are limited, this line of research supports a possible protective role of moderate physical activity against these malignancies.

Summary:

Hepatocellular Soft tissue and bone sarcomas are rare but aggressive malignancies, and their diagnosis in athletes may be delayed due to symptom overlap with orthopedic injuries. Although epidemiological data do not indicate an increased incidence in this population, the risk of delayed diagnosis remains significant. Early differentiation of persistent pain syndromes and lack of response to conservative treatment should prompt advanced imaging and histopathological evaluation. Notably, moderate physical activity may exert a potential protective effect, although this hypothesis requires further investigation.

Summary and Conclusions

Despite the well-documented health benefits of regular physical activity—including improvements in cardiovascular, metabolic, and mental function, as well as a reduced risk of many common cancers—certain types of physical activity and associated behaviors may expose specific populations, such as athletes, to unique oncological risks. This review synthesizes current knowledge on cancers of particular relevance in the athletic population, including skin cancers (melanoma and non-melanoma), testicular germ cell tumors, hepatocellular carcinoma, and soft tissue and bone sarcomas.

Key risk factors include repeated exposure to ultraviolet (UV) radiation (particularly among outdoor athletes), the use of anabolic-androgenic steroids (AAS), and unregulated muscle-building supplements (MBS). Although increased incidence of sarcomas or testicular cancer has not been demonstrated in athletes, their clinical presentation may be misinterpreted as sports-related injuries, leading to delayed diagnosis. Liver cancers, while rare in young adults, have been reported in association with long-term AAS use, even in the absence of underlying cirrhosis.

Clinicians caring for athletes and physically active individuals should maintain a high index of suspicion in cases of persistent symptoms such as chronic pain, swelling, or skin lesions that do not resolve with conservative treatment. Early imaging and histopathological evaluation are crucial for excluding malignant causes. Preventive efforts are equally important and should include education on sun protection and the oncological risks of doping agents.

This review highlights the need to consider less obvious cancer risks in the context of sport and physical activity. While exercise remains a cornerstone of cancer prevention in the general population, there is a need to recognize distinct risk patterns in athletes. Further prospective and multicenter studies are needed to better characterize these associations and to optimize preventive and early diagnostic strategies in sports medicine.

Disclosure

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