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EĞİTİM YAYINEVİ GRUBU

İÇİNDEKİLER

THE TRANSFORMATION OF LEISURE: A CRITICAL EVALUATION IN THE CONTEXT OF LIQUID MODERNITY AND SOCIAL ACCELERATION

Ferdi Erişkin[1]

In the past, leisure largely persisted as a sphere that remained outside the obligations of everyday life; it was a domain that could be devoted, relatively, to rest, to engagement in particular activities, and to self-realization through pursuits marked by continuity. Today, however, it has assumed a quality experienced within a more fragmented, more interrupted, and more rapidly changing flow of life. Alongside this transformation, the meaning of leisure is also shifting from a fixed sphere of freedom toward a ground open to momentary orientations, transient interests, and variable experiences. In order to understand the transformation of contemporary leisure, it is first necessary to clarify the social ground on which this transformation has emerged. Liquid modernity and social acceleration provide two powerful theoretical axes for analyzing the structure of leisure today. The reshaping of contemporary leisure around features such as transience, fluidity, speed, and fragmentation can be interpreted as the reflection, within the sphere of leisure, of a broader social transformation. Indeed, understanding the change in leisure requires thinking together the transformations occurring in contemporary society's forms of time, relations, and everyday life.

Bauman argues that modernity is shaped in accordance with a logic of mobility, transience, and dissolution rather than permanence, stability, and long-term commitments. In today's world, value no longer resides in what is durable and long-lasting; rather, it is concentrated in the speed of circulation, renewability, disposability, and the capacity to adapt to continuous change (Bauman, 2017). This condition leads to the weakening of continuity across a wide range of domains, from social relations to forms of identity, while settled forms dissolve and bonds become increasingly fragile. In the context of liquid modernity, Bauman emphasizes that attachments are experienced less as permanent commitments than as temporary relations that continue only insofar as satisfaction persists (Bauman, 2017). Within such a historical-social

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climate, it becomes increasingly difficult for individuals to attach themselves to particular pursuits, ways of life, and, most importantly, enduring fields of belonging experienced over the long term. Flexibility now replaces continuity, transience replaces loyalty, and fluidity replaces settledness. Within this framework, Bauman's approach offers an important theoretical explanation for understanding why leisure has become increasingly open to fragmented, temporary, and superficial experiences.

The transformation associated with liquid modernity becomes more pronounced when considered together with Rosa's theory of social acceleration. According to Rosa, modern society is characterized not merely by the acceleration of technical processes, but also by the increasing rhythm of social change and the rising tempo of everyday life (Rosa, 2013). Rosa examines social acceleration in three interrelated dimensions: technical acceleration, the acceleration of social change, and the acceleration of the pace of life. This process weakens the permanence of social and cultural regularities and leads to a "contraction of the present" by shortening the period of validity of expectations derived from past experiences (Rosa, 2013). Thus, individuals' lifeworld assumes a more variable, more unpredictable structure that generates a higher pressure for adaptation. Leisure, too, does not remain outside this transformation; even when its quantity increases, it does not turn into a calmer, deeper, and more expansive field of experience. On the contrary, as Rosa also emphasizes, despite the increase in free time, stress and time pressure do not disappear, and the rhythm of leisure is determined by intensity, simultaneity, and fragmentation. Therefore, it is becoming increasingly difficult to establish a direct link between the quantitative increase of contemporary leisure and its qualitative deepening.

When the approaches of liquid modernity and social acceleration are considered together, they suggest that contemporary leisure can no longer be confined to a sphere of rest or self-realization. More precisely, leisure may turn into a field of experience increasingly shaped by the logics of speed, transience, intensity, and short-term gratification. Rosa (2013) states that under conditions of high time pressure, individuals tend to turn toward activities such as television, which can easily fit into short fragments of time, require low levels of energy, and offer immediate satisfaction. Indeed, such practices make visible the short-term gratification structure of late modern entertainment culture. Similarly, Bauman emphasizes that in liquid modernity, enduring attachments, stable orientations, and long-term investments are eroded, while transience, disposability, and the pursuit of instant gratification come to the fore (Bauman, 2017). When these two approaches are considered together, it becomes clearer why leisure is increasingly oriented toward rapidly consumed experiences, shorter-lived satisfactions, and practices that require low levels of commitment. Therefore, the central issue here concerns less whether individuals possess leisure than the social-temporal regime within which leisure is organized, experienced, and structured.

As a consequence of liquid modernity, the form that leisure assumes today is related to changes in types of activity, as well as to the transformation of leisure's meaning and its logic of organization. Cleary's (2020) study discusses how leisure, under liquid modern conditions, becomes dependent on consumer life, while individuals are compelled to organize their pleasures on their own under conditions of uncertainty and unpredictability. Leisure appears less as a sphere of stable and continuous pursuits than as a domain opening onto short-term gratifications, rapidly consumed experiences, and easily accessible practices. In particular, the fact that consumption moves beyond the satisfaction of needs and carries the promise of producing meaning, security, and gratification leads leisure to be increasingly configured around consumable experiences.

Some recent studies indicate that contemporary leisure cannot be explained through a one-directional process of superficialization. On the one hand, under liquid modern conditions, leisure is reshaped by the logics of speed, consumption, and transience; on the other hand, some practices can provide individuals with meaning, attachment, and orientation. In this regard, the study conducted by Montelius and Ekholm (2026) on urban gardening is significant. This research reveals that, within an environment of late modern fragmentation and instability, certain leisure practices can enable individuals to regain a sense of attachment, meaning-making, and rootedness. In the study, urban gardening is treated as more than an ordinary leisure activity; it is considered a practice through which human beings can re-establish their relationship with nature, others, and themselves, and through which a sense of ethical responsibility, commitment, and connection can be generated against the disorder of everyday life. In this respect, the conclusion drawn from the study suggests that contemporary leisure cannot be entirely reduced to the logic of short-term gratification. Similarly, DaSilva, Hecquet, and King (2020) discuss veganism as a leisure lifestyle within liquid modernity, showing that contemporary leisure cannot be confined to particular activities alone. According to the study, veganism is more than a dietary preference; it is shaped as a broader set of practices involving identity, lifestyle, ethical orientation, and self-expression. This condition suggests that leisure is increasingly organized around lifestyle, consumption preferences, and identity construction. Thus, while the changing structure of leisure is shaped by speed, consumption, and transience, it is also reconstituted through structures that seek to provide individuals' lives under uncertainty with belonging, orientation, and meaning.

The contemporary appearance of leisure is increasingly losing its character as a spatially fixed sphere based on face-to-face interaction and clearly separated from everyday life. Snellgrove and Punch's (2025) study, through the transfer of older adults' face-to-face bridge practice into the digital environment, shows that leisure has acquired a new form of organization that can now be sustained through screens, connectivity infrastructures, and online communities. The study indicates that digital bridge preserves social bonds, develops new technical skills, and provides order and routine for some participants; however, it also emphasizes that, because the experience is mediated through the screen, it cannot fully replace face-to-face encounter, while also producing new limitations such as inequalities of access and excessive screen exposure. This situation suggests that leisure is becoming digitalized in terms of its content and reorganized through platforms. Similarly, Rainoldi et al. (2024) show that in digital work regimes, the classical distinction between work and leisure has weakened, that future digital workers establish more fluid transitions between work and leisure throughout the day, and that they develop different balancing strategies in response to this blurring of boundaries. Thus, leisure appears as a more hybrid field of experience that spreads across the day, becomes fragmented, is repeatedly replanned, and, in certain cases, intertwines with work.

A similar complexity emerges in terms of temporal organization. Johansen, Green, and Thurston's (2026) study on the active leisure lives of young Norwegians reveals that educational demands, friendships, family obligations, and digital media use intensify young people's experience of time. The pressures of fragmentation and acceleration may be considered to become more pronounced particularly during youth. However, it is also evident that leisure does not, in every case, turn into a sphere that produces pressure and exhaustion. According to the study, a significant proportion of young people experience their intensive leisure as rewarding and balancing. Active leisure activities and orientations, in particular, can function as a mental and bodily refuge in the face of school-based stress. This finding is highly important, because the transformation of contemporary leisure should not be interpreted in a one-directional manner as the increase of speed or time pressure. More precisely, leisure today is reshaped under the pressures of fragmentation, acceleration, and multiple demands, while it also continues to serve as a carrier of individuals' search for balance, meaning, and recovery within this intensive flow of life.

The transformation in the structure of leisure has also led to a redefinition of the meaning this sphere carries in the post-pandemic period. Spracklen (2025) emphasizes that the boundaries between work and leisure in contemporary society have become more ambiguous compared with previous periods. He argues, in particular, that digitalization, precarity, and the pressure of constant availability have distanced leisure from being a distinct sphere of life. Upon closer examination, it can be said that leisure has moved beyond being a time of freedom outside work, since it appears to have turned into a field of experience into which work regimes directly or indirectly penetrate. This transformation, however, also renders leisure open to more invisible, more continuous, and more subtle forms of control through digital technologies. According to Aytaç (2023), the structure of modern society tends to ensure continuity and to keep everyday life within an effective network of surveillance. Developments in information and telecommunication technologies, in particular, have expanded the boundaries of control and further strengthened surveillance over social groups. The traces left within digital environments, voluntary forms of sharing, and data collected about individuals without their knowledge show that leisure, like other spheres of everyday life, can no longer be conceived as a pure domain of freedom. Therefore, the changing structure of leisure is moving toward a sphere that, while becoming a fragile field of experience penetrated by working life, is increasingly regulated, monitored, and shaped through the influence of digital surveillance and steering mechanisms.

Vitak and Zimmer's (2023) study, conducted during the pandemic period, provides a clear example in which digital surveillance is distinctly identified. The findings of the study show that employers turned to tools such as video and screenshot capture, monitoring the websites visited, recording the time allocated to specific tasks, and measuring levels of attention during online meetings in order to track employee communication and productivity. These findings reveal that, with the shift to working from home, surveillance techniques specific to the workplace were also transferred into private living spaces, thereby eroding the boundaries between work and home in temporal, spatial, and privacy-related terms. Employees' evaluations also show that although monitoring practices vary according to context, forms of data collection extending into the home environment are perceived as more problematic in terms of the loss of privacy and autonomy. As a result, the structure of leisure moves away from being a mere state of freedom; digital spaces, including the domestic environment, are increasingly opened to the data-collection and monitoring regimes of the logic of work.

Similarly, the study by Sivunen, Gibbs, and Leppäkumpu (2023) also shows how communication technologies render the boundaries of time, space, and home–work life more permeable. Today's global work order produces expectations of constant connectivity that extend beyond regular working hours. This situation creates new pressures on employees' time and attention. Particularly during remote work, the disappearance of the physical separation between the office and the home also weakens the transitions that signal the end of the working day. Accordingly, employees tend to keep their computers on, monitor messages during evening hours, and negotiate the boundaries between work and home life more frequently. At the same time, it is also observed that employees develop boundary-management strategies such as blocking their calendars, turning off notifications, using different devices, or being unavailable after certain hours. The emerging picture shows that the subtle networks of control referred to by Aytaç (2023) are not confined to external surveillance techniques; rather, they also lead individuals to reorganize their everyday lives under the pressure of constant connectivity, availability, and time management.

Algorithmic recommendation systems have played a major role in the changing structure of leisure. Haque, Islam, and Mikalef's (2025) study shows that the content presented on social media platforms is not always perceived by users as experiences they have chosen spontaneously. According to the study, users want to know why certain content, especially unfamiliar content that appears before them, is recommended. They also demand clearer information and assurance regarding how their personal data are used. This situation suggests that the flow of content associated with leisure in digital environments is increasingly acquiring a structure mediated by algorithmic recommendation systems. Therefore, the digital dimension of leisure can be evaluated as a field of experience shaped under the influence of opaque data-processing processes and platform logics.

Another dimension of the transformation in leisure is that leisure experiences are becoming increasingly visible and analyzable through digital traces. In their study on urban parks in Singapore, Song et al. (2020) show that social media posts do not remain as mere records of individual memories; rather, they turn into a data source capable of revealing which places people turn toward, what kinds of experiences they are interested in within these places, and how they make sense of their leisure. In the study, photographs collected from Flickr were evaluated together with users' locations and shared content, and differences among park use, spatial orientation, and recreation preferences were analyzed. Ultimately, leisure is being shaped toward a structure that can be read, grouped, and interpreted through the traces left in digital environments in line with certain tendencies. In general terms, the fact that contemporary leisure content may become more measurable, more classifiable, and therefore shaped on a ground more open to external interventions introduces a different problem.

For the changing structure of leisure, Lawrence's (2025) claustropolitan approach suggests thinking this transformation within a broader framework of cultural compression and contraction. Contemporary leisure is turning into a field of experience that is pre-narrowed, directed, and recorded within the predictive logics of digital platforms, rather than functioning as a sphere of openness in which options proliferate. Predictive algorithms, recommendation engines, and continuous data-capture processes, in particular, distance the individual's relation to leisure from spontaneity and reorganize it within pre-framed preferences, accelerated interactions, and forms of participation dependent on platform logic. For this reason, contemporary leisure is evolving toward a structure that is accelerated and increasingly restricted in its possibilities, preconfigured in advance, and shaped by commercial digital systems even at the level of participation itself.

The emerging structure of leisure becomes even more pronounced when considered together with the framework in which Cousineau, Kumm, and Schultz (2023) discuss the relationship among surveillance, capitalism, leisure, and data. It is stated that information and communication technologies blur the distinctions among home, work, and leisure, producing a multilayered structure of surveillance that increasingly transforms the individual's actions, body, and even existence into data points. Especially when viewed through the distinction between panoptic, post-panoptic, and contemporary forms of surveillance, leisure also becomes a sphere continuously processed for data production, behavioral steering, and the extraction of economic value. Everyday contact with digital devices, the traces left on platforms, and the logic of big data transform leisure content into a more measurable, more classifiable, and more easily governable social field. As a result, this transformation also changes the ontological and epistemological status of leisure. Ultimately, through the combined effect of these factors, leisure continues to become a domain of lived experience redefined within surveillance capitalism.

In contemporary society, it is precisely everyday time itself that is being reorganized by the logics of production, digital flows, and calls to consumption. The meaning of leisure has also moved far beyond a simple idea of freedom. Leisure is now a social indicator that reveals how and toward what the individual is directed, as much as it shows what the individual chooses. While the person appears to be living out their own preference, this experience often takes place through accelerated cultural circulation, algorithmic selectivity, expectations of symbolic status, and regimes of dispersed attention. Thus, leisure moves away from being an interval in which freedom is silently lived, and becomes one of the most sensitive, permeable, and explanatory surfaces of the subject's relationship with contemporary society. For precisely this reason, to think about leisure today means to think about how the human being is constituted, dissolved, and reshaped within everyday life.

One of the most distinctive characteristics of the contemporary period is that continuity gives way to transience, depth to flow, and attachment to circulation. Under these conditions, leisure also moves away from being a sphere of long-term belongings, patient pursuits, and experiences that transform the person from within; it instead acquires a more fragile, more fragmented, and more rapidly consumed quality. Experience is now often constructed less to be lived than to be put into circulation, less to be remembered than to be displayed, less to deepen than to be rapidly renewed. On such a plane, leisure may turn into an extension of a constantly updated economy of visibility rather than creating an inner world in which the person can remain alone with the self. Yet the existential depth of the human being is related not merely to the capacity to choose, but also to the power to remain within what has been chosen. For this reason, the contemporary problem of leisure is not simply a problem of activity diversity; it is, rather, the problem of how permanence can be preserved amid an abundance of options, meaning amid the discontinuity of attention, and inner rhythm amid cultural speed. Nevertheless, it would also be incomplete to claim that leisure has become an entirely lost sphere today.

For despite all the ways in which contemporary leisure is encircled, it still carries within itself the possibility for human beings to establish more authentic bonds with themselves, with others, and with the world. What is decisive here is the mode in which leisure is experienced, alongside its quantity. The same span of time may, under one condition, open onto a cycle of consumption that intensifies distraction, while under another condition it may make room for thinking, care, learning, solidarity, and the deepening of the sense of self.

Stebbins's (2020) serious leisure perspective offers an important point of balance for the structure of contemporary leisure. According to this perspective, the various forms of leisure cannot be explained entirely through the logic of superficial pleasure, instant consumption, and temporary stimulation. Some leisure practices, by contrast, produce stability, effort, skill acquisition, accumulated knowledge, belonging, and a "leisure career" that develops over time. As Stebbins (2024) emphasizes, serious leisure provides the participant with enduring benefits rather than a temporary sense of satisfaction. Self-realization, self-enrichment, self-expression, a sense of achievement, social interaction, and a sense of belonging are among these benefits. Such pursuits also construct an ethos and a cultural world of their own. In this way, instead of being swept along among scattered and fragmented experiences, the individual can attach the self to the internal logic, rhythm, and community of a practice.

When considered in detail, the serious leisure perspective shows that contemporary leisure has not become entirely fluidized, and that certain pursuits can still generate depth, continuity, and meaning. Therefore, when discussing the transformation of leisure today, it is necessary to think together, on the one hand, the pressures of speed, transience, and consumption, and, on the other, the forms of serious leisure that the individual builds through effort, that nourish identity, and that give lasting meaning to life.

Therefore, the meaning of leisure today does not carry a fixed essence. It is continuously reproduced within the tension between social structures and subjective orientations. Precisely at this point, leisure becomes one of the most favorable spheres of manipulation, while also turning into a possibility for resistance and awareness. For reflective distance remains possible against directed desire; slowing down against accelerated flow; inner intensity against spectacle; and the demand for privacy against lived experience transformed into data. From a philosophical standpoint, the issue concerns, before what leisure is filled with, the ontological function it possesses within human experience. If the human being is reduced to an entity that works, consumes, reacts, and remains connected, leisure will inevitably turn into an extension of this reduced human type. However, when the human being is understood as a being capable of establishing meaning with the world, turning back upon the self, taking distance, remembering, and attributing value to actions, leisure acquires an entirely different appearance. Thus, leisure becomes more than time left over from everyday obligations; it becomes a threshold through which the human being can partially withdraw from the pressure of instrumentality, reinterpret experience, and learn not to evaluate life solely through criteria of functionality. Perhaps the most fundamental difficulty of our age lies here: leisure itself has not disappeared, yet the silence, duration, attention, and inner openness capable of carrying its deeper meaning are gradually narrowing. This narrowing transforms the social forms of leisure as much as the human being's experience of self.

As a result, leisure today is one of the fields of lived experience in which the contradictions of modern society become most intensely visible. Within it, the promise of freedom and the risk of direction, the search for belonging and isolation, pleasure and fatigue, visibility and the fear of erasure circulate together. Therefore, understanding leisure is not merely a matter of classifying a set of activities. It requires analyzing within what kind of temporality the contemporary subject lives, within what kind of cultural atmosphere desire is formed, and within what kind of social architecture the subject seeks to constitute itself. Today, the central question is not what people do in their leisure. The central question is what leisure does to people. If this question is taken seriously, leisure can no longer be regarded as a secondary social sphere. On the contrary, it appears as one of the fundamental fields of thought through which the direction of contemporary life, the human capacity for freedom, and the future of everyday existence can be understood. For this reason, the question of leisure is quieter, deeper, and more political than it appears. Because even at the very moment when the human being assumes that time belongs to the self, the extent to which one can truly remain in possession of it is tested precisely here.

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EMBODIED EXPERIENCE IN RECREATIONAL ACTIVITIES: BODY, MEANING, AND PARTICIPATION

Merve Karaman[1]

Introduction

Recreational activities have traditionally been positioned as secondary to productive life domains; however, recent scholarship increasingly recognizes leisure as a central mechanism through which individuals construct meaning, pursue purpose, and sustain well-being (Fancourt et al., 2021; Iso-Ahola and Baumeister, 2023, Şahin et al., 2025). This transition in understanding aligns with a broader paradigm shift in cognitive science, moving away from traditional models that viewed the mind as a disembodied processor of abstract symbols toward the theory of embodied cognition (Lakoff, 2012; Shirvani & Shirvani, 2023). Under this new cognitive framework, human experience is recognized as being fundamentally rooted in physical interactions with the environment, where bodily states and sensorimotor inputs are not merely peripheral but are essential to thinking and perception (Barsalou, 2007). Within the context of recreation, the body serves as an active agent and an open spatio-temporal horizon, providing a dynamic boundary where the self and the world are negotiated through continuous, unfinished interaction (Cappuccio & Ilundain-Agurruza, 2020; in press, akt. Farina, 2020). Consequently, engagement in recreational pursuits functions as a complex adaptive system that integrates biological, psychological, and social processes (Fancourt et al., 2021) to foster individual flourishing.

Analytical explorations into the relationship between embodied cognition and recreation suggest that leisure is particularly well positioned to bridge the gap between abstract meaning and corporeal reality (Amiri-Savitzky et al., 2023; Cox et al., 2017; Jamrozik et al., 2016; Owen et al., 2024).Unlike routine labor, which may lead to bodily alienation or a purely instrumental use of the physique, recreation often facilitates a “feeling of doing” that integrates the subject and object through kinetic engagement (Crouch, 2000; Mayoh et al., 2020; Owen et al., 2024). From an embodied cognition perspective, such immersion is not merely psychological but is embrained and embodied: cognitive processes

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arise from the dynamic interplay of brain, body, and world, where sensorimotor engagement and situated action help organize how we perceive, categorize, and understand our surroundings (Farina, 2020; Lickliter, 2021). The leisure–meaning–embodiment chain suggests that the more an activity engages the body's sensory-motor apparatus, the more it fosters cognition as an embodied, situated interaction between brain, body, and environment (Lickliter, 2021). This process is foundational to human development, as it allows individuals to construct knowledge through their exchanges with the physical and social environments, thereby making the body the primary medium of both health and existential verification (Barsalou, 2020; Lundh &Foster, 2024; Purser, 2021).

The significance of the "lived body" in recreation is further underscored by the way individuals grasp the world multisensorially, moving beyond a detached visual gaze to a state of being "surrounded" by the volume and materiality of place (Crouch, 2000; Huang et al., 2024). This transition from a "consuming" to a "doing" body reflects a radical departure from ocularcentrism, emphasizing that place-making is an active bodily practice (Crouch, 2000; Rakić & Chambers 2012). As individuals engage in these practices, they do not just inhabit space; they actively "make" place through their presence and sensory attunement, a process that establishes a sense of ownership and empowerment (Crouch, 2000; Rakić & Chambers, 2012; Everingham et al., 2021; Witte, 2021). Recreational embodiment constitutes a kinetic and sensual process that disrupts conventional ways of knowing, revealing that the body is the primary nexus through which identity and well-being are constructed (Allen-Collinson & Leledaki, 2015; Lundh & Foster, 2024; Mayoh et al., 2020;).

Conceptual Foundations of Embodiment

The theoretical landscape of embodiment is anchored in the phenomenological tradition, particularly the work of Maurice Merleau-Ponty, who posited that the lived body is the stand-point of all perception and the stand-point from which we inhabit the World. This perspective rejects the Cartesian dualism that separates mind from body, suggesting instead that we "are" our bodies and that our motor intentions receive the answers they expect from the world through action. Within this framework, the body is not an object but a system of actions that is defined by the tasks and situations it engages in, essentially being there where it has something to do. This "perception-action loop" is vital for understanding recreational skills, as the acquisition of physical abilities represents a "bodily intelligence of habit" that allows mastery to move from conscious effort to an integrated, pre-reflective capacity. By mastering a mountain bike or a dance sequence, the individual expands their "intentional arc," where the world is perceived as a field of motor possibilities rather than an array of abstract data (Bailliard et al., 2018; Cappuccio et al., 2020; Dreyfus, 2002; Kosma, 2023; Purser, 2017; Ravn, 2022).

Expanding upon these foundations, Drew Leder's conceptualization of the "disappearing" and "dys-appearing" body provides a nuanced lens for examining sensory awareness during recreation. In everyday life, a healthy body often "disappears" from the conscious mind as rays of intentionality radiate outward to tasks, yet recreational experiences often bring the body back into a state of intense embodiment. This heightened awareness can manifest as "dys-appearance" when the body is perceived interoceptively through the shock of cold water or the pain of physical exertion, effectively demanding that the subject attend to their corporeal state Conversely, recreation frequently facilitates eu-appearance a state where the body appears to the subject as something light, effortless, and easy. This systematic shift between a body that is "absent" and one that is "positively present" allows the individual to experience a vibrant sense of "aliveness," reinforcing the idea that the body is not just a container but the ground of existential joy (Allen-Collinson & Leledaki, 2015; Grønborg, 2020; Lev, 2020; Neale, 2008; Zeiler, 2010; Zhang & Chen, 2022)

Nick Crossley's contributions to the sociology of the body bridge the gap between individual experience and social practice, arguing that body techniques are learned ways of being that facilitate social interaction and the development of shared identities. These techniques are manifest in "serious leisure," where the systematic pursuit of an activity allows participants to acquire specialized skills that define their social world. This embodied cultural capital is not just cerebral; it is a form of incorporation where social dispositions are internalized and expressed through the sentient body. By synthesizing these perspectives, we can view recreational embodiment as a skillful know-how in situated action that involves the whole organism in a continuous negotiation with its environment. The body is the hinge between the individual's mental states and the socio-cultural world, proving that doing is for thinking (Crossley, 2007; Crossley, 2015; Murphy et al., 2018; Rossetti & Quinn, 2022; Ravn, 2022; Shilling, 2017; Sutton & Bicknell, 2022).

Embodied Experience in Recreational Activities

The diversity of recreational activities offers varying degrees of micro-experiences that fundamentally restructure the participant's perception of self and environment. During these activities, the sensuousness of practice involves becoming attuned to micro-phenomena like movement, rhythm, and fatigue. A mountain biker, for instance, must explore the limits of the "body-bike" unit while rolling over textured terrain, a process that requires intense concentration on the haptic "feel" of granularity and gradient. These kinesthetic forms of play provide a sense of control and mastery, where the subject's perception of the world is shaped by the physical resistance and feedback of the landscape. Such micro-level sensory engagements reveal that the body is not a passive receiver of signals but an active generator of meaning through movement (Allen-Collinson & Leledaki, 2015; Cook & Hockey, 2023; Crouch, 2000; Kurt et al., 2025; Ravn, 2022; Woods et al., 2021).

Furthermore, recreational embodiment has the profound capacity to alter the perception of time, shifting it from linear clock-time to subjectively lived durée (Naghibi et al., 2023; Woermann & Rokka, 2015). During states of total immersion or flow, individuals often experience "temporal compression," where the discrepancy between perceived and actual time makes hours feel like minutes (Hancock et al., 2019; Rutrecht et al., 2021). In contrast, periods of intense difficulty or fatigue can create a perception of "protracted duration," where each second of physical struggle is felt with heightened interoceptive weight (Naghibi et al., 2023; Woermann & Rokka, 2015;). This temporal flexibility is closely linked to the state of "flow," where the merging of action and awareness allows the individual to escape the temporal constraints of modern life (Hancock et al., 2019; Kılıçarslan et al., 2024; Lemmens et al., 2025). In flow, the body becomes its own time-structuring element, where the rhythm of breathing and the pace of movement dictate the subject's existential speed (Naghibi et al., 2023; Woermann & Rokka, 2015;).

Comparing different recreational environments reveals that nature-based, urban, and digital settings offer distinct affordances for embodiment and leisure (Araújo et al., 2019; Huang et al., 2024;). Nature-based recreation provides a multisensory, panoramic experience in which camping environments and outdoor activities elicit rich sensory perceptions that stimulate physiological, cognitive, and social reactions, leading to embodied experiences and psychological restoration (Huang et al., 2024; Kou et al., 2024). In these green spaces, acts such as taking a deep breath or feeling wind, ground textures, and temperature changes are part of visual, olfactory, and haptic sensescapes that support attention restoration and wellbeing through multi-sensory engagement (Allen-Collinson & Leledaki, 2015; Kou et al., 2024;). Conversely, urban recreation often requires the body to negotiate more rigid and maddening structures, where walking and other everyday movements become a tactile and sensory navigation of surfaces, materials, and urban rhythms (Crouch, 2000; Middleton, 2010; Parker et al., 2024). Here, cutaneous, kinaesthetic, and proprioceptive awareness are central to how people experience sidewalks, textures, and spatial constraints while moving through the city (Middleton, 2010; Parker et al., 2024). Digital recreation, such as VR or exergaming, uses embodied metaphors and mappings between physical movements and virtual outcomes to generate a sense of embodiment, immersion, and enjoyment. Higher levels of embodied metaphor design, richer multimodal feedback, and 3D visual/tactile cues significantly increase older adults' sense of embodiment, immersion, and acceptance of exergames, while immersive VR exergames more strongly enhance presence, embodiment, motivation, and performance than non-immersive versions (Born et al., 2019; Li & Yang, 2024;). In VR marketing and tourism experiences, the felt embodiment of a virtual body further boosts immersion and enjoyment, which in turn strengthen intentions to visit real destinations (Leveau & Camus, 2023).

The technology embodiment found in virtual environments represents a critical extension of the body's boundaries into the digital realm. Through multimodal feedback-including visual and tactile signals-individuals can develop a sense of agency over virtual avatars that mimics the control they have over their biological bodies. For older adults, exergames that incorporate embodied metaphors derived from daily tasks, such as window cleaning or shuttlecock kicking, enhance familiarity and acceptance by bridging the gap between digital action and physical habit. This suggests that the "embodied mind" is highly plastic, capable of creating hybrid physical digital environments where the body's knowledge is offloaded and extended. Thus, whether in a forest or a virtual forest, the body remains the primary stand-point from which experience is co-created (Guy et al., 2023; Riva et al., 2019; Stalheim & Somby, 2024; Venkatraj et al., 2024).

Psychological Dimensions

The psychological benefits of recreational participation are mediated by states of flow, autonomy, and meaning-making, which promote specific aspects of well-being (Ilies et al.,2026). Flow, characterized by effortless concentration and reduced self-reflective consciousness, is a frequent outcome of activities that balance challenge with skill (Csikszentmihalyi, 1990). This optimal experience involves a critical shift from self-awareness which can be critical and objectifying to body-awareness, a pre-reflective sense of being in the zone (Kılıçarslan et al., 2023; Mackenzie et al., 2023). By focusing attention on the present moment and the feeling of doing, individuals can escape the "problem body" associated with clinical conditions, finding a temporary sense of completeness through their sensate selves This embodied route to mindfulness is particularly effective because it uses bottom-up sensorimotor pathways to regulate emotion and arousal (Lazzarelli et al., 2024; Roemer et al., 2015).

Resilience functions as a crucial psychological outcome of recreational embodiment, emerging through a mechanism of "accumulated effort" across multiple domains. Research indicates that participating in "complex" activities that simultaneously demand mental, physical, and social effort (such as team sports or dance) enhances cognitive reserve and psychological strength. For instance, outdoor adventure sports allow participants to "practice with fear," generating a sense of self-efficacy that facilitates adaptation to biographical disruptions. This resilience is not merely a mental state but is grounded in the body's physiological capacity to manage stress, where repeated movement re-establishes the connection between brain and mind. Mastery of a physical challenge thus becomes a transferable psychological resource, empowering individuals to "are" their bodies in more assertive ways (Bentley, 2024; Buckley & Cooper, 2025; Liu et al., 2025).

Furthermore, the mechanism of cognitive restoration is deeply tied to the soft fascinations of the natural and recreational environment. Attention Restoration Theory (ART) explains that natural environments reduce mental fatigue because they afford stimuli that are involuntarily engaging yet non-taxing, allowing the body's physiological recovery from arousal. This process is multisensory; the fragrant smell of natural materials or the tactile encounter with the sea can transport an individual back to happy memories, enabling emotional integration and a sense of being away. The cognitive evaluation of these experiences results in a transformative learning process, where individuals develop new goals and attitudes based on their bodily insights. Ultimately, the psychological dimension of embodiment is about claiming identity and finding meaning through the body's natural intelligence (Aartun et al., 2020; Basu et al., 2019; Lefèvre et al., 2025; Skulmowski & Rey, 2018).

The difference between self-awareness and body-awareness is central to this psychological flourishing. While self-awareness often involves an externalized, evaluative view of the body, embodied self-awareness is an internal, experiential state that fosters self-acceptance. Activities like yoga and dance encourage this interoceptive awareness, helping individuals to listen to the body and move toward eudaemonic behavior. This shift reduces bodily dissociation and improves life satisfaction by anchoring the individual in their "original intent" and physical potential. In this way, recreation provides an experiential alternative to traditional therapy, using the body as play to cultivate mental health (Candia-Rivera et al., 2024; González-Grandón et al., 2024; Koncz et al., 2023; Mahindru et al., 2023; Rosado et al., 2025; Zafeiroudi et al., 2025).

Social and Cultural Dimensions

Recreation serves as a vital arena for the formation of social cohesion" and collective identity, where shared bodily practices build social capital. The concept of "habitus" is essential for understanding this cultural dimension, as individuals acquire durable dispositions and body techniques through socialization that guide their leisure choices. In the field of serious leisure, these techniques are used to read the social status of others and to signal one's own identity through bodily intentionality. For example, a backpacker habitus involves internalizing specific postures and aesthetic rejections of mainstream consumerism, expressing identity through a sentient and mobile presence. These shared rituals and interactions build a group mind, where the synchronization of emotions and movements enhances the collective resilience of a community (Alford & Bennett, 2021; Aria & Pedlar, 2003; Kuentzel, 2000; Şahin et al., 2025; Weber, 2025; Veal, 2022;).

The body in recreation also acts as a socially readable surface where identity is performed and social positioning is established. For marginalized groups, including individuals with disabilities or trans individuals, leisure-scapes can become sites of radical defiance where nonnormative bodies reclaim joy and challenge hegemonic ideals. Through methods like body mapping, these individuals can express their lived realities and navigate the power dynamics that often exclude “fat,” “mad,” or “queer” bodies from traditional fitness spaces. These body-reflexive pleasures marry visceral sensations with social discourses, allowing participants to reconstruct identities that were previously suppressed. This socio-political dimension of embodiment proves that recreation is not just about health; it is a quest for social justice and the right to belong in space (Barras & Frith, 2023; Gotfredsen & Linander, 2023; Potvin & Niblett, 2023).

Furthermore, the leisure-social positioning-identity chain suggests that recreational choices are deeply embedded in the habitual dwelling of the individual. For individuals living with dementia, social recreational settings provide a means of identity confirmation, where being recognized as a person through shared activity facilitates social citizenship. These relational interactions are cornerstones of the embodied experience, where social habits are formed through the exchange of equipment or group photo-taking. This connectivity to others acts as a buffer against stigma and social isolation, reinforcing the idea that embodiment is fundamentally intercorporeal an interplay of responsiveness and otherness. In this way, recreation facilitates a form of emplacement where the individual feels rooted in both their body and their community (Kontos et al., 2017; Owen et al., 2024; Peoples et al., 2022; Russell et al., 2022; Russell et al., 2022; Sun et al., 2019; Sun et al., 2022).

The social transmission of bodily knowledge is another key mechanism by which culture is embodied through leisure. Novices learn by observing the gestures and body techniques of experts, a process that involves assigning social meaning to movements. This observational learning is critical across the whole experience, as experts also observe novices to evaluate their performance and assign social recognition. The sensorial production of the social means that group identities are built through shared sounds, smells, and tactile encounters that store cultural values in the collective body. Ultimately, recreational embodiment is a social practice that allows individuals to “walk the walk” of their culture, making leisure a primary site for the negotiation of self and society (Kontos, 2005; Owen et al., 2024; Russell et al., 2022).

Transformative and Therapeutic Effects

Recreational activities possess significant transformative potential, providing embodied healing mechanisms that help individuals navigate traumas or biographical disruptions. For those living with chronic illness or spinal cord injuries, voluntarily engaging in physical challenges offers a sense of control and an alternative to the sick body narrative. This healing capacity is grounded in therapeutic landscapes green and blue spaces where environmental qualities work in tandem with individual practice to store wellness in the body. Immersions in water, often described as place rapture, allow for the release of negative emotions and the creation of deep, resilient connections with the natural world. These transformative sensations are often triggered by repetitive movements and multisensory input, which slow the body down and enable a state of total immersion (Aaby et al., 2025; Chun et al., 2022; Kleiber et al., 1995; Le Hénaff & Héas, 2019).

The therapeutic value of these encounters is articulated through therapeutic accretions, where repeated sedimented encounters build resilient well-being over time. Like the layering of nacre in a pearl, these accretions involve the layering of body knowledge, memory, and place encounters to build a mobile crust that protects against psychological adversity. The rhythm and repetition of activities such as a daily walk or a weekly dance class allow skills to move from conscious effort into the unconscious intelligence of the body, freeing the mind for deeper reflection. These situated rhythms support long-term mental health by providing a "therapeutic salve" to the wounded body-self through the simple act of doing. Furthermore, for individuals with trauma exposure, mindful movement facilitates empowerment by increasing interoceptive awareness and emotional expression (Bell et al., 2017; Foley, 2024; Molteni et al., 2024; Zafeiroudi et al., 2025)

Repetitive movement also anchors embodied memory, where the body understands and recalls sensations even when cognitive memory is compromised. For individuals with dementia, visiting familiar landscapes can transform their ability to interact with the world, revealing deep-seated lay geographies of past experiences. Similarly, nostalgic olfactory and tactile triggers such as the smell of hay or the touch of soft cotton transport individuals back to happy childhood memories, facilitating emotional integration and personhood. This phenomenological continuity allows individuals to maintain a sense of self-existence through the body's natural intelligence, proving that the embodied mind remains a mind in motion even in the face of cognitive decline (Fuchs, 2020; Kontos & Martin, 2013; Margot-Cattin et al., 2021; Petherbridge, 2025)

The transformative power of recreation is also visible in its ability to facilitate personal evolution and identity reconstruction. For migrant women, nature-based leisure becomes an emotional outlet for letting go of past negative emotions tied to relationship loss, facilitating a metamorphosis toward an identity of their own choosing. This process is bottom-up, as the physical act of being close to nature and experiencing activities purifies the mind and self-motivates the individual toward flourishing. The sensational learning points during these activities become critical turning points that change an individual's worldview, demonstrating that embodiment is not static but a dynamic journey of becoming. Ultimately, the therapeutic effects of recreation prove that the body is a place of opportunities for discovery and self-reclamation (Campbell, 2023; Fullagar, 2008; Ridgway, 2022; Ono et al., 2021).

Integrated Theoretical Model: The Dynamic Recursivity Model of Recreational Embodiment

To integrate these findings, we propose the Dynamic Recursivity Model of Recreational Embodiment (DRMRE). This conceptual model explains how structural catalysts interact with somatic processes to produce transformative outcomes through specific causal pathways. The logical pathway of this model is recursive rather than linear: identity and well-being outcomes provide the necessary feedback loop to motivate further participation, while somatic learning informs future modes of sensorimotor attunement. The mediators are essential because they explain how and why a physical act becomes a psychological resource: it occurs through the neuronal model-making and the translation of sensory signals into lived meanings (Cohen & García, 2008; Kimmel et al., 2024; Reilly et al., 2016; Tymoszuk et al., 2019; Walsh et al., 2020)

This model advances the existing literature by explicitly integrating phenomenological embodiment, neurobiological plasticity, and socio-cultural habitus into a single recursive framework. Unlike linear models that treat leisure outcomes as static consequences of participation, the DRMRE conceptualizes recreational experience as a dynamic, self-reinforcing process in which bodily engagement continuously reshapes perception, identity, and well-being. In doing so, it offers a more comprehensive explanation of how recreational practices become enduring psychological and social resources.

Within the DRMRE framework, recreational experience is structured through a dynamic interaction between three core components. First, structural catalysts such as activity complexity, environmental affordances, and engagement patterns shape the conditions under which individuals encounter and interact with recreational contexts. Second, these conditions are processed through embodied mechanisms, including sensorimotor attunement, somatic learning, and psychological flow, which enable individuals to translate physical engagement into meaningful lived experience. Finally, these processes give rise to a range of outcomes, including resilient well-being, identity reconstruction, and socio-cultural integration, reflecting the cumulative and transformative impact of embodied participation in recreation. Importantly, these components do not operate in isolation but function recursively, continuously reshaping one another over time (Fancourt et al., 2021; Huang et al., 2024; Kimmel et al., 2024; Liu et al., 2021; Qiu et al., 2025; Soria et al., 2022; Takiguchi et al., 2022).

Integrative Perspectives and Implications

The synthesis of empirical data and theoretical perspectives presented in this chapter confirms that recreational embodiment serves as a foundational pathway to psychological regulation, resilience, and holistic flourishing. Referring back to the proposed Dynamic Recursivity Model of Recreational Embodiment (DRMRE**)**, it is evident that the quality of human experience is not merely an outcome of isolated variables but an emergent property of the recursive interaction between structural catalysts and somatic processes. The model posits that structural affordances such as activity complexity and the material cues of the leisure-scape initiate a cycle where sensorimotor attunement and body awareness function as critical mediators. This logic challenges reductionist, top-down models of mental health that prioritize cognitive monitoring, suggesting instead that movement-based formats offer essential alternative routes to well-being through bottom-up sensorimotor and affective pathways. By recognizing the body as the primary standpoint from which we perceive, act, and become, the DRMRE model provides a unified framework for understanding how physical leisure is transformed into psychological and social resources through the translation of sensory signals into lived meanings (Biassoni et al., 2023; Davids et al., 2016; Fuchs, 2020; Sanna, 2025; Kempermann, 2022; Kimmel et al., 2024)

From a critical standpoint, a primary theoretical contribution of this investigation is the conceptualization of recreation as a skillful performance where the body is the primary site of knowledge production and existential verification. This perspective refutes the poverty of embodied cognition claim by demonstrating that embodiment theory provides scientifically valuable insights into the fundamental experiences of cognitive life, particularly in the domains of sports, nature engagement, and aging. For example, the direct link established between movement (such as aerobic exercise) and cognitive functions specifically hippocampal expansion and neuroplasticity supports the life-mind continuity thesis, proving that the embodied mind is fundamentally an embodied mind in motion. Furthermore, the integration of Drew Leder's (1990) concepts of dys-appearance and eu-appearance within the DRMRE model clarifies how the transition from monitoring effort to experiencing flow allows the participant to are their body in more assertive and joyful ways, even amidst the challenges of illness or aging (Castro-Alonso et al., 2024; Dzwiza-Ohlsen & Kempermann, 2023; Farina, 2020; Groven & Zeiler, 2018; Kempermann, 2022; Zeiler, 2010;).

The analysis also reveals critical socio-political implications, as the leisure-scape is often stratified by power dynamics and normative restrictions that shape who is allowed to feel at home in recreational environments. While most models of recreation prioritize pleasure, it is vital to acknowledge the darker side of therapeutic landscapes where fat, disabled, neurodivergent, or trans bodies face hostility or structural inaccessibility. The use of visual methods like body mapping represents a transformative contribution to the field, offering marginalized groups a platform for radical defiance to reclaim joy and reconstruct identities that were previously suppressed by societal messaging. This necessitates an intersectional approach to leisure studies that challenges the "universality of normative bodies" and advocates for more inclusive and equitable tourism and recreation systems. However, it is important to recognize that embodied recreational experiences are not universally accessible or equally meaningful across all social groups, as structural inequalities and cultural norms continue to shape who can participate, how participation is experienced, and what forms of embodiment are considered legitimate (Allison, 2000; Mielke et al., 2021; Spaaij et al., 2015; Watson & Scraton, 2013).

Practical and policy implications derived from the DRMRE model suggest that destination managers, event planners, and healthcare providers must regard sensory and emotional experiences as fundamental objectives. The creation of event environments characterized by multi-sensory engagement and emotional resonance points has the potential to foster long-term loyalty and elevated satisfaction. Policy makers should emphasize the potential pleasures and body-reflexive pleasures of physical activity rather than solely focusing on its clinical medical benefits, as the experience of joy is a more potent driver of sustained health behaviors. For older adults and people living with dementia, embedding nature-based programs within community infrastructures facilitates phenomenological continuity and social citizenship, allowing these individuals to maintain a sense of personhood through the body's natural intelligence (Collins et al., 2023; Nyman & Szymczyńska, 2016; Owen et al., 2024; Toubøl et al., 2024).

Future research directions should prioritize bridging the disciplinary silos between neurobiology, geography, and leisure sciences to further map the lots of mechanisms by which leisure affects health on individual and societal levels. Further inquiry into offline cognition and embodied imagination is warranted to understand how recreational memories support long-term mental health even when physical participation is restricted. Additionally, the role of technology embodiment in virtual and digital leisure requires deeper investigation to see how artificial environments can facilitate ownership and agency for diverse populations. Addressing the ambiguity of pleasure and pain in challenging activities remains a crucial area for understanding the "somatic learning" involved in becoming a committed "outdoor person (Day et al., 2021; Owen et al., 2024; Sharma et al., 2024; Takiguchi et al., 2022; Tussyadiah et al., 2018).

In conclusion, this chapter argues that recreational embodiment should be understood as an active and transformative dimension of leisure experience rather than a simple consequence of participation. Bodily movement, sensory perception, emotional regulation, social interaction, and personal meaning operate together to shape how individuals experience recreation and how these experiences contribute to well-being. The Dynamic Recursivity Model of Recreational Embodiment offers a conceptual lens for explaining this process by showing how the body, activity context, environment, and lived experience continually influence one another. Through this perspective, recreation extends beyond conventional interpretations that define it only through health benefits, enjoyment, or participation outcomes. It becomes a meaningful embodied process through which individuals strengthen resilience, develop a sense of belonging, negotiate identity, and experience psychological growth. The chapter also underlines the importance of creating recreational settings that are inclusive, accessible, emotionally engaging, and responsive to different bodily experiences. Overall, the model provides a useful foundation for future research and professional practice by emphasizing that the body is not merely involved in recreation, but is the primary medium through which recreational experience gains psychological, social, and existential significance.

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ECORECREATION AND URBANIZATION

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1. Introduction

In the contemporary world, the relationship between individuals and nature has become increasingly fragile—arguably more so than at any previous point in history. The process of urbanization, which originated with industrialization and has accelerated markedly in recent decades, has not only transformed physical living environments but has also profoundly reshaped individuals' everyday experiences, patterns of time use, and modes of interaction with their surroundings. Particularly in densely populated urban centers, prevailing lifestyles have led to a growing physical detachment from nature, while simultaneously altering the meaning and quality of human–nature relationships. In this respect, urbanization should be understood not merely as a spatial transformation, but as a multifaceted process that weakens the fundamental bond between humans and the natural environment.

One of the most salient manifestations of this transformation is observed in the ways individuals engage with their leisure time. Traditionally, recreational activities were characterized by outdoor settings, direct contact with nature, and rich social interaction. However, such activities are increasingly being relocated to digital environments. While digitalization affords greater flexibility in terms of time and space, it simultaneously transforms the nature of leisure, steering it toward more passive, screen-based, and individualized forms. This shift necessitates a critical re-examination of the physical, social, and psychological dimensions of recreation. In particular, the diminishing connection with nature emerges as a significant concern, especially in relation to individual well-being.

The combined effects of urbanization and digitalization have thus contributed to an increasing detachment from both the physical environment and the natural rhythms of life. Prolonged exposure to screens, heightened cognitive load, and the predominance of artificial environments exert substantial influences on individuals' mental and emotional processes. Within this context, recreational approaches that facilitate renewed contact with nature transcend being mere leisure preferences; rather, they represent a vital necessity for supporting

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holistic well-being. At this point, eco-recreation emerges as an approach that enables individuals to reconnect with nature through nature-based recreational activities. Eco-recreation is not merely a practice that supports individual well-being; it also serves an important function in developing environmental awareness and promoting sustainable lifestyles. However, considering the realities of the digital age, it does not seem sufficient to address recreational experiences solely within either a nature-based or a fully digital framework. Therefore, there is a need for new approaches that integrate nature-based recreation with digital technologies.

This study aims to examine the effects of urbanization and digitalization on individuals' relationships with nature and their leisure experiences, while elucidating the role of ecorecreation within this context. Furthermore, it advances a conceptual proposition eco-digital (hybrid) recreation—to capture the experiential intersection between digital recreation and ecorecreation, which have predominantly been addressed as distinct domains in the existing literature.

Accordingly, the subsequent sections first delineate the concepts of recreation and ecorecreation, followed by a critical discussion of the theoretical frameworks that underpin this field. Building upon this conceptual and theoretical foundation, the study then analyzes the implications of urbanization processes for recreation and human–nature relationships, and evaluates the individual, social, and environmental contributions of ecorecreation from a multidimensional perspective.

2. Conceptual and Theoretical Framework

2.1. The Concept and Scope of Recreation

Throughout human history, work and rest have emerged as two complementary modes of existence. The intrinsic human inclination to recover from the burdens of daily life, regain vitality, and seek meaning constitutes the foundation of activities that are conceptualized in the modern era as recreation.

Definitions of recreation in the literature reflect the inherently multidimensional nature of the concept. Recreation has been examined through sociological, psychological, economic, and ecological lenses, with each discipline emphasizing its own priorities. Karaküçük (2014) conceptualizes recreation as a form of leisure engagement that supports individual well-being, strengthens social bonds, and promotes harmony with the natural environment. Within this framework, recreation extends beyond mere rest, encompassing processes of physical, mental, and social renewal. Similarly, Hazar (2022) defines recreation as a set of freely chosen activities undertaken outside of work time that provide participants with enjoyment and satisfaction.

The scope of recreation has expanded significantly over time. Initially associated primarily with physical rest, the concept has progressively incorporated cultural, artistic, environmental, and social dimensions. Today, recreation encompasses a broad spectrum of activities, including sporting, cultural, social, and nature-based practices. Within this classification, outdoor recreation holds particular significance due to its direct engagement with the natural environment. Karaküçük and Akgül (2016) emphasize that nature-based recreational activities perform a dual function by simultaneously supporting individual health and contributing to environmental sustainability. This dual function constitutes one of the foundational reference points for the concept of ecorecreation, which will be elaborated in subsequent sections (Akgül & Karaküçük, 2024).

The relationship between leisure and recreation also represents a recurrent theme in the literature. While leisure refers to the time available to individuals beyond obligatory responsibilities, recreation denotes the intentional and restorative use of this time. From this perspective, not all leisure activities can be classified as recreational. Voluntary participation, intrinsic motivation, and the capacity to facilitate renewal emerge as key criteria in defining an activity as recreational (Kelly, 1989; Kraus, 1971).

2.2. The Concept of Ecorecreation

Ecorecreation refers to the organization and practice of recreational activities in ways that respect ecological values and the functioning of ecosystems, while prioritizing the conservation of natural resources within a sustainability-oriented framework. Karaküçük and Akgül (2016) define ecorecreation as the implementation of all leisure-related activities, policies, and practices with a strong commitment to environmental protection and sustainability. This definition highlights two fundamental axes: the balance between individual benefit and environmental conservation. Beyond constituting a mere category of activity, *ecorecreation* embodies a distinct ethical stance and a sense of responsibility. Karaküçük and Akgül (2019) characterize ecorecreation as “a message,” thereby underscoring its function in foregrounding environmental protection and ecological sensitivity. From this perspective, ecorecreation encompasses all forms of recreational experience that are conducted without disrupting ecological balance, altering natural systems, or causing harm to living organisms.

The emergence and consolidation of the concept have been closely linked to the intensification of global environmental challenges. Ecological problems—deepened by processes of industrial development—such as deforestation, air and water pollution, biodiversity loss, and climate change have reached a level that threatens the very foundations of human existence. Within this context, alongside concepts such as ecotourism, eco-cities, and eco-energy, ecorecreation has gained prominence as a means of enhancing environmental awareness and embedding ecological sensitivity into everyday life practices.

Although ecorecreation partially overlaps with the concept of *outdoor recreation*, it also diverges from it in significant ways. While outdoor recreation broadly encompasses all activities conducted in open-air environments, ecorecreation emphasizes that such activities must be carried out with ecological awareness and responsibility (Karaküçük & Akgül, 2016). This distinction reveals the normative dimension of the concept: ecorecreation is defined not only by where activities take place, but also by how they are conducted.

Within this framework, the notion of the *ecorecreationist* also gains analytical significance. Individuals who participate in ecorecreational activities and are expected to demonstrate a high level of environmental consciousness—referred to as ecorecreationists—engage with nature through responsible and conservation-oriented practices (Karaküçük & Akgül, 2019). Such individual orientations contribute, in turn, to the broader societal construction of environmental awareness.

2.3. Theoretical Approaches

2.3.1. The Biophilia Hypothesis

The *biophilia hypothesis* constitutes a theoretical framework proposing that humans possess an innate affinity for other living organisms and the natural world, shaped through biological evolution. Although the philosophical roots of the concept can be traced back to ancient Greek thought, modern discussions of biophilia are primarily associated with two key figures. The German psychoanalyst Erich Fromm (1992) initially defined biophilia as a passionate love for life and all living things, conceptualizing it as a psychological orientation. Subsequently, the American biologist Edward O. Wilson rearticulated the concept within a biological–evolutionary framework in his seminal work *Biophilia* (1993).

Wilson (1984) defines biophilia as the human tendency to focus on life and life-like processes. From this perspective, the human–nature connection is not merely a cultural construct but rather a biologically grounded predisposition shaped over hundreds of thousands of years of evolutionary history. The human mind evolved in response to the conditions of natural environments characteristic of the Paleolithic era; consequently, the artificial settings imposed by urbanization exist in a persistent state of tension with this inherent biological inclination (Kellert & Wilson, 1993; Wilson, 1993). Although urbanization may attenuate biophilic tendencies, it does not eliminate them entirely (Wilson, 1993).

The edited volume *The Biophilia Hypothesis* by Kellert and Wilson (1993) significantly expanded the interdisciplinary scope of the concept. In this work, biophilia is not reduced to an aesthetic appreciation of nature; rather, it is conceptualized as a multidimensional relationship encompassing cognitive, emotional, spiritual, and symbolic dimensions of human engagement with the natural world. Moreover, this body of work interrogates the tension between biophilia and technology, raising the question of whether technology represents an evolutionary extension of biophilic tendencies or, conversely, a force that weakens the human–nature connection.

The biophilia hypothesis has also received empirical support through meta-analytic research. For instance, Gaekwad et al. (2022) demonstrated that exposure to natural environments significantly enhances positive affect while reducing negative emotional states. These findings are interpreted as empirical validation of the biophilia hypothesis. Similarly, Gullone (2000) reported that a wide range of studies across disciplines consistently supports the central proposition of the hypothesis, indicating that exposure to natural elements contributes to improved psychological well-being.

The relationship between ecorecreation and biophilia represents a particularly productive conceptual intersection. While the biophilia hypothesis underscores an inherent human inclination toward nature, ecorecreation reflects the practical manifestation of this inclination through ecologically responsible engagement in everyday life. In other words, ecorecreation defines a domain of activity in which the innate need for connection with nature is fulfilled in alignment with cultural awareness and environmental responsibility. This form of responsible interaction not only satisfies the biologically grounded desire for reconnection with nature but also contributes to the broader goal of ecological sustainability.

2.3.2. Attention Restoration Theory (ART)

Contemporary urban life imposes sustained and intensive demands on individuals' cognitive resources. Traffic noise, prolonged screen exposure, multitasking requirements, and the overabundance of information collectively create an environment in which attentional capacities are continuously depleted. *Attention Restoration Theory* (ART), developed by Rachel Kaplan and Stephen Kaplan and systematized in 1989, provides a comprehensive framework for understanding the restorative effects of natural environments on cognitive functioning.

According to Kaplan and Kaplan (1989), human attention can be differentiated into two primary forms. *Directed attention* is intentional, effortful, and involves the active inhibition of distracting stimuli. This form of attention corresponds closely to the demands of modern life and is inherently susceptible to fatigue with prolonged use. In contrast, *involuntary attention* operates effortlessly and is spontaneously engaged by inherently interesting stimuli. ART posits that natural environments activate this latter attentional mechanism, thereby facilitating the restoration of depleted cognitive resources.

For an environment to exert a restorative effect, the theory identifies four essential properties. The first is *being away*, referring to the subjective sense of psychological distance from everyday demands and stressors. The second is *extent*, indicating that the environment should present a coherent and sufficiently rich experiential world. The third is *soft fascination*, whereby elements such as sunsets, rustling leaves, and flowing water effortlessly capture attention without cognitive strain. The fourth is *compatibility*, denoting the alignment between environmental affordances and an individual's intrinsic motivations and experiential expectations (Stephen Kaplan, 1995).

Natural environments exemplify settings in which these four properties co-occur. In contrast to the overstimulation characteristic of urban and digital environments, nature offers stimuli that are inherently engaging yet cognitively undemanding, thereby creating optimal conditions for alleviating mental fatigue. A systematic review by Ohly et al. (2016) provides robust evidence for the restorative effects of natural environments on directed attention. Similarly, a recent review by Cheng et al. (2024) highlights the growing interdisciplinary momentum in attention restoration research and underscores the increasing interest in nature-based environmental design.

ART offers a particularly illuminating theoretical lens for interpreting the relationship between ecorecreation and urbanization. Given the chronic cognitive load imposed by urban living, nature-based ecorecreational activities should be understood not merely as forms of leisure or entertainment, but as functional mechanisms for cognitive restoration. Activities such as walking in natural settings, spending time in botanical gardens, or participating in outdoor experiences in natural environments represent practical manifestations of the restorative processes described by ART. In this context, the theoretical convergence between ART and the biophilia hypothesis becomes especially salient, as both frameworks address the human–nature relationship from distinct yet complementary perspectives (Barbiero, 2021).

2.3.3. Sustainability and the Ecological Approach

The concept of *sustainability* acquired its contemporary meaning with the publication of the report *Our Common Future* by the Brundtland Commission in 1987 (Gro Harlem Brundtland, 1987). The report defines sustainable development as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." This definition necessitates a holistic perspective that extends beyond economic growth within the environment–development nexus to include dimensions of social equity and ecological balance.

Ecorecreation establishes strong and multidimensional linkages with the framework of sustainability. Fundamentally, ecorecreational activities are grounded in principles that prioritize the conservation and responsible use of natural resources, as well as the maintenance of ecological balance. Karaküçük and Akgül (2016) emphasize that ecorecreation foregrounds the protection and sustainable use of natural resources alongside individual development and well-being, often positioning these considerations above purely economic objectives. This perspective transcends a narrow focus on individual benefit and integrates the principle of intergenerational equity into recreational behavior.

From an ecological standpoint, ecorecreation encompasses a broad spectrum of responsibilities, including conducting activities without disrupting ecosystem processes, preserving biodiversity, minimizing ecological footprints in natural areas, and utilizing environmentally sustainable materials. Kement et al. (2021), in their study on the model of ecorecreational attitudes and behaviors, found that environmental concern, environmental knowledge, environmental awareness, and environmental beliefs significantly predict participation in ecorecreational activities. These findings underscore that the internalization of ecological values constitutes a fundamental condition for ecorecreational engagement.

Adopting a holistic perspective on the relationship between individual well-being and environmental sustainability represents one of the defining characteristics that structurally distinguishes ecorecreation from other forms of recreation. The interconnection between nature-based recreation and sustainability has also attracted increasing attention in the international literature. Buckley (2019) demonstrates that outdoor recreation and nature-based tourism contribute to sustainability across individual, societal, and ecological dimensions. Similarly, Høyem (2020) documents that participants in outdoor recreational activities tend to develop stronger pro-environmental attitudes over time, reinforcing the link between recreational engagement and environmentally responsible behavior.

3. The Relationship Between Urbanization And Ecorecreation

3.1. Urbanization and Urbanism

Urbanization can be defined, in its most basic sense, as the process by which rural populations concentrate in urban areas and urban settlements expand in terms of population, spatial extent, and economic activity. However, such a narrow demographic definition fails to adequately capture the multidimensional nature of the process. Urbanization should instead be understood as a comprehensive form of societal transformation, intertwined with economic restructuring, spatial reorganization, cultural change, and increasing ecological pressures (Keleş, 2015).

Although the concepts of *urbanization* and *urbanism* are often used interchangeably in practice, a meaningful distinction exists between them. While urbanization primarily refers to a spatial and demographic phenomenon, urbanism denotes the process through which individuals and communities internalize urban values, lifestyles, and behavioral patterns (Karaküçük & Gürbüz, 2007). The mere physical presence of individuals or groups in urban settings does not necessarily imply the realization of urbanism. Indeed, Tekeli (2004) emphasizes that, in the case of Türkiye, one of the essential preconditions for controlling unplanned urbanization and improving quality of life is the establishment of a genuine process of urbanism.

Urbanization is accelerating rapidly on a global scale. According to projections by the United Nations, approximately 68% of the world's population is expected to reside in urban areas by 2050 (Southall et al., 2020). This figure underscores that urbanization is no longer merely a demographic preference, but has become a structural necessity with far-reaching environmental, social, and health-related implications.

Türkiye is among the countries closely following this global trend at a rapid pace. While the proportion of the urban population was approximately 25% in the 1950s, it has risen to around 80% in recent years, reflecting a profound transformation in settlement patterns and modes of living.

3.2. Unplanned Urbanization and Ecological Impacts

When the pace of urbanization exceeds the capacity for spatial planning and the provision of adequate infrastructure, it gives rise to a phenomenon commonly referred to as *unplanned urbanization*, the consequences of which are both profound and far-reaching. Urban growth that unfolds in an uncontrolled and unregulated manner creates conditions that facilitate the degradation of green spaces, the destruction of wetlands, habitat fragmentation, and the disruption of natural cycles. Although the specific manifestations of these impacts may vary across cities, the underlying patterns remain remarkably consistent.

The trajectory of urbanization in Türkiye provides a compelling illustration of the ecological costs associated with unplanned urban growth. In particular, informal and unregulated development occurring along the peripheries of major cities has led to the conversion of agricultural land into built environments, the contraction of forested areas, and the degradation of river systems. Within this context, the findings of Altıntaş (2020) indicate that urbanization in Türkiye contributes to increased CO_2 emissions in both the short and long term. These results offer empirical support for the structural relationship between urbanization and environmental pollution in the Turkish context.

The ecological consequences of urbanization extend well beyond rising emission levels. The fragmentation of natural habitats during urban expansion constitutes one of the most critical threats to biodiversity. As natural areas are converted for development, many species experience significant habitat loss, while the urban heat island effect alters local climatic conditions. The reduction of green spaces, coupled with increasing air and water pollution, disrupts the ecological balance of cities, exacerbates social inequalities, and diminishes overall quality of life. Moreover, transformations occurring along the rural–urban fringe represent a critical dimension of this process. The erosion of rural and traditional lifestyles, the degradation of natural and cultural assets, and the disruption of ecological integrity constitute tangible outcomes of this transition (Aşıcı et al., 2025).

3.3. The Ecological Costs of Urban Living

Urban living profoundly transforms individuals' relationships with nature. Urban residents spend a substantial portion of their daily lives in artificial environments, enclosed spaces, and in front of screens. This condition systematically undermines the innate need for connection with the natural environment emphasized by the biophilia hypothesis. At the individual level, the ecological cost of urbanization thus begins with this form of biological and psychological deprivation.

A growing body of research increasingly demonstrates the detrimental effects of urban living on mental health. Evidence indicating a higher prevalence of mental health disorders among urban populations calls into question the relationship between urbanization and well-being. A comprehensive meta-analysis published in Nature Cities (Li et al., 2025), based on a systematic review of 449 studies and a meta-analysis of 78 field experiments, reveals that exposure to urban nature produces significant positive effects on multiple health outcomes, including reductions in anxiety and depression and improvements in overall mental health. In this context, urban green spaces emerge as critical bridges between individual psychological well-being and urban sustainability.

The ecological costs of urban living extend well beyond the individual dimension. Cities constitute focal points of global energy consumption and carbon emissions, where natural cycles are substantially disrupted and anthropogenic ecological pressures are most intensely experienced. Consequently, the challenge of urbanization occupies a central position in debates on sustainable development. As emphasized by Tekeli (2004), in the context of Türkiye, addressing unplanned urbanization and improving urban quality of life are not merely matters of planning; rather, they represent priority areas of intervention for societal health and ecological balance.

The contraction of recreational spaces under the pressure of urbanization constitutes another tangible dimension of this ecological cost. Access to parks, forested areas, and open public spaces is closely associated with income level, neighborhood characteristics, and social position. This condition reflects not only an issue of welfare but also a structural problem that must be addressed within the framework of environmental inequality. Ensuring equitable access to ecorecreational opportunities thus represents a crucial component of a sustainable and ecologically resilient model of urban development.

4. Contributions of Ecorecreation

4.1. Psychological and Physiological Effects

The effects of ecorecreation on individual health have become a focal point of an expanding body of research in recent years. From a psychological perspective, nature-based recreational activities are consistently supported by robust empirical evidence demonstrating their effectiveness in reducing stress, alleviating symptoms of anxiety and depression, and enhancing overall mental well-being. For urban residents whose cognitive systems operate under chronic cognitive load, ecorecreational activities conducted in natural environments provide valuable opportunities for restoration and psychological equilibrium.

A substantial number of studies conducted in forest environments in Japan have shown that time spent in natural settings significantly reduces heart rate, blood pressure, and cortisol levels compared to urban environments. Notably, these physiological benefits are not limited to direct engagement such as forest walking; even passive exposure to natural imagery can elicit similar effects. Research involving working populations further indicates that participation in nature-based activities for ninety minutes, twice per week, positively influences visual processing speed, attentional capacity, and cortisol regulation, while simultaneously reducing symptoms of burnout (Kobayashi et al., 2017; Park et al., 2010; Qing Li, 2022).

Ecorecreation also offers substantial contributions to physical health. Activities such as hiking, cycling, rock climbing, rafting, nature photography, and botanical observation support cardiovascular health, strengthen the musculoskeletal system, reduce the risk of obesity, and contribute positively to immune function. A systematic review and meta-analysis examining the effects of physical activity in urban green spaces (Hu et al., 2025) reveals that green exercise holds significant potential as a non-pharmacological intervention for reducing symptoms of anxiety and depression. The study further identifies session duration and intervention frequency as significant moderating factors influencing the magnitude of these effects.

Research focusing on the measurement of restorative environments also provides compelling support for the relationship between ecorecreation and individual well-being. Bitiş et al. (2022), in a study examining the physical and spatial landscape characteristics associated with positive affect, mindfulness, and relaxation in urban green spaces, demonstrate that the qualitative attributes of natural environments play a decisive role in shaping individual psychological experiences. These findings offer an objective basis for prioritizing the allocation of spaces designed for ecorecreational functions within planning and design processes.

4.2. Social and Societal Impacts

Beyond its contributions to individual health, ecorecreation also exerts significant effects in strengthening social life. Activities conducted collectively in natural settings facilitate the formation of social bonds, reinforce community cohesion, and mitigate social fragmentation in urban environments (Kiliçarslan & Ayyıldız Durhan, 2023; Kiliçarslan & Özant, 2024). In a study examining the mental health impacts of structured activities in public green spaces, Weekes et al. (2019) found that participation in nature conservation and citizen science projects produces significant positive effects on both affective states and sense of purpose. In parallel, research on physically active individuals has demonstrated a positive association between regular physical activity and overall quality of life, reinforcing the broader psychosocial benefits attributed to recreational participation (Akarsu et al., 2018).

At the community level, civic ecology practices represent another important dimension of ecorecreation. Activities such as habitat restoration, urban agriculture, and the collective management of green spaces enable local communities to benefit from natural capital while simultaneously fostering social cohesion, education, and economic opportunities. Davids et al. (2021) demonstrate that civic ecology initiatives implemented in low-income urban communities not only enhance the quality of natural habitats but also strengthen social cohesion and generate new employment opportunities.

From the perspective of social equity, access to ecorecreational opportunities in urban contexts is often unevenly distributed in ways that may reinforce class-based disparities. Individuals residing in proximity to green spaces and enjoying ease of access are more likely to benefit from the individual and societal advantages associated with ecorecreation. Addressing these inequalities necessitates structural interventions, including informed urban planning decisions, the establishment of green space standards, and the development of equitable transportation infrastructure. For the societal benefits of ecorecreation to be fully realized, the principles of accessibility and inclusivity must be systematically integrated into planning and policy processes.

4.3. Environmental Awareness

Ecorecreation provides a unique experiential context for the development of environmental awareness through individuals' direct and embodied engagement with the natural environment. Time spent in nature enables abstract knowledge about ecological processes, the value of biodiversity, and human-induced environmental pressures to acquire concrete and personally meaningful significance. This experiential dimension differs qualitatively from information conveyed in classroom settings or through digital media.

A growing body of empirical research supports the role of nature-based recreation in fostering environmental awareness. A recent study published in Frontiers in Psychology (Zhang, 2025) demonstrates that place identity and the diffusion of pro-environmental behavior serve as mediating factors in the relationship between perceived recreational landscapes and environmentally responsible behavior. This finding suggests that nature-based experiences shape environmental awareness not passively, but through active processes of identity formation and meaning-making.

A particularly noteworthy insight in this literature is that environmental awareness is not merely an indirect outcome of exposure to nature; rather, it is the product of specific recreational experiences and active engagement (Lawrence, 2012). Individuals who actively spend time in natural environments encounter environmental issues such as pollution and ecological degradation more directly, and this confrontation reinforces their environmental sensitivity (Durhan et al., 2023). Studies examining the relationship between participation in sport and leisure activities and environmental awareness, as well as green consumption behaviors, further corroborate these findings (Niu et al., 2024).

Eco-digital (hybrid) recreation practices introduce an additional layer to the environmental awareness dimension. These hybrid forms, which integrate digital tools with nature-based experiences, can play a distinctive role—particularly in fostering environmental sensitivity among younger generations. In the following subsection, this intersection between environmental awareness and digital–nature interaction is examined in greater detail.

Ecodigital (Hybrid) Recreation: A New Conceptual Approach

A novel and distinctive form of recreational experience is emerging at the intersection of digital recreation and ecorecreation, which have traditionally been examined as separate domains in the literature. This study introduces the concept of *eco-digital (hybrid) recreation* to conceptualize these intersecting experiences. Eco-digital recreation refers to hybrid recreational practices in which individuals engage with nature while simultaneously utilizing digital tools. These experiences, characterized by the integration of nature-based activities and digital technologies, embody the distinctive qualities of both domains.

Within this conceptual framework, a range of practices can be identified, including GPS-supported nature walks, augmented reality-based games (e.g., Pokémon GO), plant and animal identification via mobile applications, nature-based exercise supported by activity tracking systems, and the digital sharing of nature experiences. Such activities enable individuals to sustain their interaction with nature while enriching and interpreting their experiences through digital mediation.

Empirical research examining the effects of location-based games and eco-digital applications on nature connectedness and well-being highlights the significant potential of this emerging field. Puhakka (2025), in a longitudinal study conducted in Finland, found that a ten-day participation in location-based activities such as geocaching and Pokémon GO significantly increased adolescents' perceived well-being and their sense of connection to nature. These findings suggest that hybrid recreational experiences can facilitate processes of reconnecting with the natural environment.

A recent study investigating the relationship between location-based games such as Pokémon GO and sustainability-oriented behaviors (Kordyaka et al., 2026) indicates that only specific deep-engagement-oriented game design features are associated with positive pro-environmental behaviors, while no significant effects were observed on negative behaviors. This finding underscores that the impact of eco-digital recreational practices on environmental awareness is contingent upon design variables, highlighting the need for more nuanced research in this area.

Studies exploring how technology can be leveraged to enhance nature connectedness also provide important insights. Research advocating the reframing of technology as a facilitator of outdoor engagement (Livingston, 2022) demonstrates that applications inspired by the momentum of Pokémon GO—such as local plant identification tools—can effectively increase nature engagement, particularly among younger, digitally oriented generations. This intersection between technology and nature interaction provides a robust foundation for expanding both the conceptual and applied research agenda of eco-digital recreation.

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RECREATIONAL STRATEGIES FOR CAMPUS SUSTAINABILITY: A MULTIDIMENSIONAL APPROACH

Ferhat Kılıçarslan[1]

Introduction

Sustainability is a multifaceted concept. Universities, networks, rankings, and evaluation tools typically define and frame this concept by bringing together environmental, social, economic, and intergenerational concerns, each from its own perspective. From the perspective of this study's central thesis, however, it is important to clarify the meaning universities ascribe to this concept. From the universities' perspective, the prevailing definition is human-centered (focused on human needs, well-being, and justice) rather than eco-centered (viewing nature as valuable in and of itself) (Harvey et al., 2022). These definitions are rhetorically flexible and contingent on institutional goals and contexts. This situation also exhibits a similar "adaptability and fluidity" to political discourse (Weisser, 2017). Uncertainty is frequently cited and viewed as an obstacle to coordinated action.

Sustainability is viewed as an integrated institutional paradigm for higher education institutions—one that is not limited to environmental sensitivity or resource efficiency alone, but rather transforms the processes of education, research, governance, social contribution, and campus life collectively (Lozano et al., 2015). The contribution of higher education institutions to sustainable development gains meaning not only through the production of knowledge but also through the transfer of that knowledge to environmental, social, and economic spheres of influence (Findler et al., 2019). Universities are positioned as strategic actors in integrating sustainable development goals into institutional policies, curricula, research agendas, and on-campus practices (Serafini et al., 2022). The sustainable campus approach, meanwhile, is viewed as a practical field of higher education where this institutional positioning manifests itself at the levels of physical space, social life, learning experiences, and behavioral transformation (Evans et al., 2015).

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The concept of a sustainable campus is viewed as an integrated management and living space model encompassing multidimensional processes such as energy management, waste reduction, water usage, transportation planning, green space design, healthy living facilities, stakeholder participation, and behavioral transformation (Lozano et al., 2015). The impact of campuses on sustainable development is considered not only in terms of the environmental performance of institutional operations but also in conjunction with educational outcomes, social participation, quality of life, and the capacity to generate social impact (Findler et al., 2019). In this context, the concept of a sustainable campus demonstrates that sustainable development goals must be concretized in higher education institutions not only through policy documents but also through daily life practices and campus experiences (Serafini et al., 2022).

In the context of sustainability, recreational activities serve as a functional interface between environmental awareness, healthy living, social interaction, and experiential learning (Dustin et al., 2017). Campus recreation is viewed as a multidimensional participatory space that enables students to engage their free time through physical, social, cultural, mental, and nature-based activities (Sim et al., 2026). Outdoor recreation programs are regarded as a complementary educational framework that supports experiential learning, connection with nature, physical activity, and lifelong development processes within higher education institutions (Dustin et al., 2017). Since university students' patterns of participation in campus recreation programs are linked to individual, social, environmental, and institutional factors, recreation services are positioned not merely as a provider of activities but as a strategic area in terms of campus health and a culture of sustainable living (Sim et al., 2026).

One of the most significant areas of focus regarding campus recreation in the context of sustainability is the impact of green spaces on students' health, well-being, and quality of life (Hipp et al., 2016). The active and passive use of green spaces by university students has been found to be associated with variables such as health, well-being, quality of life, and perceived stress levels (Holt et al., 2019). Academic green spaces demonstrate that campus landscaping is not merely an aesthetic or environmental element, but can function as a daily therapeutic environment, a space for social interaction, and a venue for recreational renewal for students (Foellmer et al., 2021). Perceived campus greenery and restorative environmental features are considered among the key spatial and psychosocial indicators influencing how students experience campus life (Hipp et al., 2016).

Recent systematic reviews examining the relationship between the campus environment and student health outcomes have shown that the built and natural environmental characteristics of higher education campuses are associated with physical activity, walkability, mental health, and quality of life (Ding et al., 2024). Access to green spaces, the availability of open spaces, walkable campus design, and the placement of recreational infrastructure are considered key environmental variables that influence students' daily activity levels and campus experiences (Holt et al., 2019). In sustainable campus initiatives, social impact, student experience, and well-being indicators must be considered alongside environmental performance indicators (Findler et al., 2019). In this regard, the recreational dimension creates a functional space that bridges environmental sustainability and social sustainability, directly engaging with the daily behaviors of campus users (Ding et al., 2024).

Campus recreation is viewed not merely as a service area that increases student participation in physical activity, but as an institutional development area linked to student learning outcomes, social engagement, and psychosocial well-being (Lower-Hoppe et al., 2020, Türkmen & Akgül, 2025). Recreational sports experiences are among the complementary learning opportunities that develop outside of academic programs in higher education but support students' personal, social, and professional development processes (Ayyıldız Durhan et al., 2021; Dustin et al., 2017). Recent studies conducted on post-secondary students indicate that participation in physical recreation is associated with indicators of psychosocial well-being and that this relationship may vary depending on students' mental health status (deJonge et al., 2025). Campus recreation is therefore positioned as a strategic component of higher education that must be evaluated in conjunction with the agendas of a healthy campus, inclusive participation, student engagement, and a culture of sustainable living (Sim et al., 2026). Within this framework, the ecorecreation perspective provides a conceptual basis for positioning recreational practices as environmentally responsible, nature-sensitive, and sustainability-oriented leisure experiences (Akgül, 2024; Karaküçük & Akgül, 2016;).

The existing literature indicates that studies on sustainable higher education are primarily addressed through the lens of institutional policy, educational programs, research capacity, environmental operations, and alignment with sustainable development goals (Serafini et al., 2022). Studies evaluating the impact of higher education institutions on sustainable development reveal that indicators are generally structured around institutional performance, operational processes, and governance mechanisms (Findler et al., 2019). However, the sustainability performance of recreational practices on campuses, when considered alongside dimensions such as behavioral transformation, student well-being, and social participation, appears to be a relatively limited area of research (Sim et al., 2026). This limitation indicates that studies examining sustainable campus practices from a recreational perspective need to be further developed both theoretically and practically (Dustin et al., 2017).

This section aims to examine the recreational dimension of sustainability initiatives implemented on campuses and to conceptually situate these initiatives within the sustainability mission of higher education institutions (Evans et al., 2015). The study aims to classify campus-based recreational initiatives along the axes of environmental sustainability, social sustainability, physical activity, healthy living, student engagement, and institutional sustainability (Holt et al., 2019). In this regard, the section aims to develop an integrated evaluation framework linking campus life, student well-being, nature-based activities, and behavioral transformation by re-examining the sustainable campus literature through a recreational lens (Lozano et al., 2015).

2.1 Sustainable Campus Strategies

A sustainable campus is not merely a collection of environmentally friendly buildings. In the literature, this concept is defined as a university-wide approach that integrates sustainability into administrative activities, teaching, research, and campus culture, and strikes a balance among environmental, social, and economic goals. According to Sugiarto (2022), a sustainable campus is an environmentally focused campus that integrates environmental science into policies, management, and academic activities, as well as into all managerial dimensions and best practices of sustainable development. Some campuses prioritize environmental activities, while others focus on social issues, institutional sustainability, or curriculum reform. Truly sustainable campuses, however, aim for a holistic integration that encompasses the entire institution (Fissi et al., 2021; Hernandez-Diaz et al., 2021; Scahill and Bligh, 2025). Therefore, a sustainable campus is a university that systematically aligns its teaching, research, administrative activities, governance, and culture with the long-term principles of environmental protection, social well-being, and economic responsibility.

Sustainable campuses play a significant role in supporting sustainable approaches among all users—students and staff alike—in harmony with both the natural and built environments. According to studies in the literature, sustainability-based initiatives have been found to significantly increase students' awareness of sustainable development and their ability to take initiative (Biancardi et al., 2023; Kılıçarslan & Özant, 2024a; Oliveira & Proença, 2025). Sustainable campuses support many Sustainable Development Goals (such as poverty, health, gender equality, climate action, and strong institutions) by shaping the mindsets and behaviors of future leaders and professionals (Abo-Khalil, 2024; Christou et al., 2024). In this regard, it can be said that universities are not merely institutions that produce and process knowledge, but also generate practices oriented toward life.

In Türkiye, the sustainable campus approach is increasingly becoming a prominent area of evaluation through national monitoring indicators, international ranking systems, and institutional reporting mechanisms developed at the university level. The inclusion of indicators such as zero waste, green campus, environmentalism, green space ratio, and smoke-free zones in YÖK's General Report on University Monitoring and Evaluation demonstrates that sustainable campus practices are being tracked as institutional performance indicators within Türkiye's higher education system (YÖK, 2025a). At the international level, UI GreenMetric evaluates campus sustainability through indicators such as campus and infrastructure, energy and climate change, waste, water, transportation, education, and governance, thereby enabling a comparative assessment of sustainable campus performance (UI GreenMetric, 2025). According to the 2025 UI GreenMetric results, the inclusion of 139 universities from Türkiye in the rankings, Türkiye's rise to the position of the country with the highest number of universities represented in Europe, and the fact that Istanbul Technical University, Yıldız Technical University, Erciyes University, Ege University, Özyeğin University, and Yeditepe University all ranking within the top 100 globally, demonstrates that sustainable campus practices have become a widespread agenda in higher education at the national level (YÖK, 2025b).

The literature on sustainable campus assessment tools emphasizes that such systems should not be limited to environmental indicators alone but should be considered in conjunction with criteria such as data quality, data collection methods, implementation levels, dimensions of sustainability, university functions, and contextual differences (Gutiérrez-Mijares et al., 2023). It is noted that campus sustainability assessment tools must be strengthened through inclusive decision-making, context-sensitive indicator selection, and stakeholder participation, indicating that sustainability assessment in universities requires a standardized yet flexible framework (Dawodu et al., 2022). Recent studies indicate that higher education institutions must integrate the Sustainable Development Goals not only into specific units but across the entire institutional framework and develop measurement tools that can be adapted to different university structures (Basheer et al., 2024). In Türkiye, Erciyes University's production of data, policies, and evidence documents for UI GreenMetric, THE Impact Rankings, QS Sustainability, and YÖK Monitoring and Evaluation Criteria through its Sustainability Coordination Office demonstrates that sustainability reporting is linked to institutional data management (Erciyes University, 2025). The inclusion of indicators such as open sports areas, walking trails, healthy campus improvements, and the proportion of buildings accessible to people with disabilities in Niğde Ömer Halisdemir University's sustainable campus target cards suggests that the sustainable campus approach can be directly linked to recreation, healthy living, accessibility, and the use of open spaces (Niğde Ömer Halisdemir University, 2025).

2.2. The Relationship Between Campus Recreation and Sustainability

Campus recreation can be defined as an institutional service area that enables students in higher education institutions to make the most of their free time through physical, social, mental, and nature-based activities, while also generating multidimensional outcomes such as health, well-being, a sense of belonging, community spirit, and student success (Özant et al., 2025; Wilson, 2025; Zaytzev et al., 2022). Campus recreation centers and programs are not merely structures that provide spaces for sports or exercise; they are important social spaces that facilitate interaction, collaboration, social integration, and the formation of a campus community among students (Dalgarn, 2001; Henchy, 2011). In this regard, campus recreation is regarded as a strategic component of higher education that supports students' adaptation to university life, strengthens campus belonging, and enriches the student experience (Soria et al., 2022; Pilgreen, 2018). The digital transformation of leisure practices also indicates that campus recreation should be considered not only through physical spaces but also through virtual and hybrid recreational participation patterns (Akgül et al., 2024).

The role of campus recreation in higher education extends beyond health and physical activity outcomes to encompass areas such as psychosocial well-being, resilience, a sense of belonging, student engagement, learning outcomes, and academic success (Ayyıldız Durhan, 2020; Forrester, 2015; Morales-Giner et al., 2025). Outdoor recreation programs offer functional contributions in terms of reducing stress among students, supporting physical and mental health, fostering environmental awareness, and facilitating the transition to university (André et al., 2017; Dustin et al., 2017). Evidence from recreational sport contexts also indicates that outdoor and informal sport participation may contribute to sustainable activity awareness through physical, psychological, and social benefits (Arslan et al., 2024; Kılıçarslan & Özant, 2024b). The fact that participation in recreational activities is associated with meaning, belonging, escape-renewal, and subjective well-being indicates that these programs should be designed not merely as activity-based initiatives but as experiential learning environments that support student development (Makubuya et al., 2020; Twilley et al., 2022).

Campus recreation is also an important tool for fostering an inclusive and sustainable campus life. It is noted that the physical environment, service atmosphere, and accessible program design are key factors in international students' participation in campus recreation, indicating that recreational spaces must be addressed in conjunction with inclusive campus policies (Cavan &

Hums, 2025; Önal & Biricik, 2025). Similarly, for domestic students, diverse sociocultural groups, and student groups vulnerable in terms of mental health, recreational programs hold the potential to foster social connections, facilitate campus adaptation, support psychosocial well-being, and enhance student retention (deJonge et al., 2025; Van Dyk & Weese, 2019;). In this context, campus recreation can be positioned as a central area of practice within a sustainable campus approach due to its capacity to foster healthy living, social inclusion, active participation, environmental awareness, and a student-centered campus experience (Morales-Giner et al., 2025; Snelgrove et al., 2022;).

Campus recreation is positioned as a key component of the sustainable campus approach, as recreational programs not only aim to increase participation in physical activity but also support the social and behavioral dimensions of sustainability, such as student well-being, social engagement, environmental awareness, inclusive participation, and the quality of campus life (Henchy, 2011; Puhakka, 2021). The sustainable campus literature addresses campus development activities through behavioral transformation, learning-education tools, and physical facilities; this framework demonstrates that recreational spaces provide a functional platform for both environmental and social sustainability (Ayyıldız Durhan, 2022; Sugiarto et al., 2022). The characteristics of campus open spaces—such as vegetation, natural water features, accessibility, safety, comfort, and aesthetic quality—are considered key variables influencing students' recreational preferences and perceptions of socio-cultural sustainability (Manahasa et al., 2025; Wang et al., 2021;). In this regard, recreational areas are not merely spaces for leisure time on campuses but integrated living spaces that support students' connection with nature, stress management, social interaction, and capacity to develop sustainable behaviors (André et al., 2017; Krasny & Delia, 2015).

The importance of campus recreation within a sustainable campus approach is directly linked to policies promoting a healthy campus, an inclusive campus, and environmental responsibility. It is noted that participation in recreation centers and programs supports students' social belonging, campus engagement, and integration into university life, demonstrating that recreation is an area that generates institutional value in terms of social sustainability (Cavan & Hums, 2025; Miller, 2011; Özant & Ayyıldız Durhan, 2024;). While open-space recreation programs are associated with multidimensional outcomes such as academic success, university adaptation, mental and physical health, stress reduction, and environmental awareness among students, studies on sustainable sports facilities reveal that these structures can generate environmental, ethical, educational, operational, and economic benefits (Dustin et al., 2017; Stinnett & Gibson, 2016). Studies examining sustainable campuses and sports facilities in the Turkish context indicate that sports areas on university campuses can be linked to sustainability policies regarding healthy living, environmental awareness, and student participation (Çalışkan & Çelik, 2024). In this regard, campus recreation can be considered a strategic component that integrates environmental infrastructure, healthy living, student engagement, social inclusion, and corporate responsibility within a sustainable campus approach (Durão et al., 2025; Menon & Suresh, 2020).

The fundamental principle in planning recreational activities on sustainable campuses is to consider the dimensions of physical space, student experience, environmental sensitivity, and governance collectively (Sugiarto et al., 2022). In the planning of recreational spaces, user perception, satisfaction, public participation, and students' expectations regarding their experiences of learning, living, enjoying, and relaxing must be taken into account (Sun et al., 2025). The adequacy, accessibility, safety, comfort, and physical quality of campus open spaces are among the key indicators for creating a socio-culturally sustainable recreational environment (Manahasa et al., 2025). To enhance recreational preferences, the proportion of green spaces, vegetation continuity, natural water features, aesthetic quality, and opportunities for interaction with nature should be incorporated into the planning process (Wang et al., 2021). The biophilic design approach is an important methodology that should be considered in the spatial design of sustainable recreational areas, as it supports campus users' connection with nature and fosters experiences of creativity and renewal (Abdelaal, 2019). In addition, activity type and recreational leadership should be considered as experience-design variables, since they may shape participants' flow experience and behavioral engagement (Özant & Ayyıldız Durhan, 2024).

Sustainable campus recreation should not be limited to environmental protection alone but must be planned in conjunction with social equity, economic feasibility, managerial integration, performance evaluation, and stakeholder collaboration (Cerveny, 2022; Kara, 2025). While the sustainable development of recreational facilities has the potential to generate environmental, educational, ethical, operational, and economic benefits, limitations such as cost, maintenance, and institutional capacity must also be considered during the planning process (Stinnett & Gibson, 2016). Therefore, recreational activity planning in sustainable campuses should be structured around a model that is accessible, inclusive, nature-based, low-impact, student-centered, measurable, and aligned with institutional strategy (Dalton et al., 2018; Dawodu et al., 2022).

3. Method

3.1. Research Model

This study is designed as a document analysis based on a qualitative research approach aimed at examining the recreational dimension of sustainable campus practices. Document analysis is a qualitative research method that involves the systematic examination, classification, and interpretation of written and digital documents related to the research topic (Bowen, 2009). Accordingly, this study evaluated university sustainability reports, green campus webpages, strategic planning documents, international sustainability rankings, and relevant academic studies as primary data sources. The research aims to describe sustainable campus practices through the documents obtained, focusing on the dimensions of recreational space use, green spaces, active transportation, open sports areas, healthy living, social participation, and accessibility. In this regard, the study is structured as a descriptive and classificatory research model that examines the relationship between the sustainable campus approach and campus recreation based on existing documents (Bowen, 2009; Merriam & Tisdell, 2016).

3.2. Data Sources

The data sources for this study consist of open-access institutional and academic documents related to sustainable campus initiatives. In this context, the study examined universities' sustainability reports, green campus pages, strategic plans, activity reports, sustainability coordination documents, international ranking data such as UI GreenMetric, YÖK monitoring and evaluation reports, as well as academic studies addressing campus recreation, green space usage, active transportation, open sports areas, healthy living, and social participation. In selecting data sources, care was taken to ensure that the documents were up-to-date, accessible, officially published by the institutions, and directly relevant to the study's objectives. Accordingly, the study was structured using written and digital sources that enable the evaluation of the recreational dimension of sustainable campus practices.

3.3. Data Collection

The data were collected through a systematic review of open-access institutional and academic documents identified in line with the study's objectives. During this process, universities' sustainability, green campus, and environmental management webpages, sustainability reports, strategic plans, activity reports, UI GreenMetric, and YÖK monitoring reports were examined. Additionally, academic studies addressing campus recreation, open space use, active transportation, green spaces, healthy living, and social participation were included in the evaluation. The selection of documents was based on criteria such as recency, accessibility, institutional validity, and direct relevance to the study's focus on recreational sustainability. The information obtained was recorded by considering the university name, type of initiative, sustainability dimension, and level of recreational relevance.

3.4. Data Analysis

The documents obtained in the study were examined using a descriptive analysis approach. Descriptive analysis is a qualitative analysis approach that enables the organization, classification, and interpretation of data within the framework of predefined themes. In this context, sustainable campus practices were evaluated under the themes of green space usage, active transportation, outdoor sports areas, healthy living, social participation, accessibility, and environmental awareness, taking into account their recreational dimensions. During the analysis process, each practice was classified based on the sustainability dimension it pertained to and its relationship with campus recreation. Thus, the aim was to evaluate practices at different universities not only in terms of environmental performance indicators but also in terms of student participation in campus life, opportunities for physical activity, social interaction, and well-being outcomes.

4. Findings

4.1. Examples of Sustainable Campus Initiatives at Universities

Under this heading, selected examples of sustainable campus practices in the contexts of Türkiye, Europe, the Americas, and Asia are presented. The tables include only those practices where a meaningful link can be established between the sustainable campus approach and recreational value. For this reason, practices such as energy, waste, or carbon management—which have limited direct recreational benefits—have been evaluated only to the extent that they are related to green spaces, active transportation, open space use, healthy living, social participation, or the student experience.

Table 1. Sustainable Campus Initiatives and Recreational Values in Türkiye

University / Context	Sustainable Campus Initiative	Recreational Value	Sustainability Dimension	Source
Universities in Türkiye ranking high in UI GreenMetric	Integrated assessment of sustainable university campuses and sports facilities	Sports areas, healthy living, student participation	Environmental and social sustainability	Çalışkan & Çelik, 2024
Universities in Ankara	Green campus initiatives, sustainable transportation, energy efficiency, and environmental visibility activities	Campus mobility, environmental awareness, outdoor space use	Environmental and managerial sustainability	Güngör et al., 2025
Istanbul Sabahattin Zaim University	Green campus, education, research, and community-engagement-based sustainability initiatives	Community participation, campus life, student awareness	Social and institutional sustainability	Bulut, 2021

Middle East Technical University	Integrated solid waste management, recycling, and composting practices	Ecological awareness and environmental responsibility in campus life	Environmental sustainability	Bahçelioğlu et al., 2020
Izmir Katip Çelebi University, Çiğli Campus	Rethinking the transportation network through ecological design principles	Pedestrian- and bicycle-oriented active transportation, physical activity	Environmental sustainability and healthy living	Kalaycı Önaç et al., 2021
Campuses in Türkiye and the United States	Restorative potential of campus green spaces	Rest, psychological restoration, quality of life	Social sustainability and well-being	Gulwadi et al., 2019
Çanakkale Onsekiz Mart University	Assessment of sustainable green campus and landscape opportunities for students with disabilities	Accessible outdoor space use and inclusive recreation	Social sustainability and accessibility	Alkan, 2022
Bursa Uludağ University	Seed balls, ecological gardens, waste-to-art projects, and social sustainability activities	Nature-based participation, social interaction, environmental volunteering	Social and environmental sustainability	Salihoğlu & Turhan, 2023

Examples from Türkiye indicate that sustainable campus initiatives are particularly focused on environmental sustainability. Sports facilities, green campus initiatives, active transportation, landscape design, ecological gardens, and waste management practices hold the potential to generate recreational value (Çalışkan & Çelik, 2024). A study on universities in Ankara reveals that visibility and institutional communication levels vary in sustainable campus initiatives, indicating that sustainable campus practices in Türkiye are not only related to implementing these practices but also to the challenge of making them visible (Güngör et al., 2025). In the case of İzmir Katip Çelebi University, linking the pedestrian and bicycle-focused transportation network to ecological design principles demonstrates that active transportation is a strategic component from both environmental sustainability and recreational mobility perspectives (Kalaycı Önaç et al., 2021).

Another key finding in the Turkish context is that sustainable campus practices can be linked to student well-being, inclusivity, and social participation. The evaluation of landscape facilities for students with disabilities at Çanakkale Onsekiz Mart University demonstrates that the sustainable campus approach is directly related to accessibility and the dimension of inclusive recreation (Alkan, 2022). At Bursa Uludağ University, projects such as ecological gardens, seed balls, and "art from waste" that generate social contributions demonstrate that recreational activities can be used as tools for environmental awareness and social integration (Salihoğlu & Turhan, 2023). Within this framework, the recreational aspects of sustainable campus practices in Türkiye are most clearly evident in the areas of open-space use, active transportation, sports facilities, green spaces, social participation, and environmental awareness.

Table 2. Sustainable Campus Initiatives and Recreational Values in Europe

University / Context	Sustainable Campus Initiative	Recreational Value	Sustainability Dimension	Source
University of Copenhagen, University of Nottingham, and Middle East Technical University	Energy efficiency, green spaces, waste management, environmental education, carbon reduction, and sustainable transportation	Student well-being, environmental awareness, campus experience	Environmental and social sustainability	Sütünç, 2025
University of Florence	Sustainable green university strategies and institutional sustainability initiatives	Community participation, campus life, environmental awareness	Institutional and environmental sustainability	Fissi et al., 2021
European higher education institutions	Impact of waste and transportation policies on environmental perception	Active transportation, environmental awareness, campus behaviors	Environmental sustainability	Puertas et al., 2023
University open spaces	Landscape services in campus open spaces, including rest, social meetings, and transition-space functions	Rest, socialization, outdoor recreation	Social sustainability and well-being	Tudorie et al., 2020
Finnish university campuses	Energy efficiency, mobility, biodiversity, and campus transformation	Place attachment, mobility, outdoor space use	Environmental and social sustainability	Komarzyńska-Świeściak et al., 2025
A university in Germany	Effects of academic green spaces on well-being	Recreation, attention restoration, social interaction, identity formation	Social sustainability and healthy campus	Föllmer et al., 2020
European higher education	Sustainability practices in campus infrastructure with a focus on SDG 11	Urban quality of life, accessible campus, outdoor space experience	Environmental, social, and managerial sustainability	Popowska & Sady, 2025

European examples demonstrate that the sustainable campus approach is linked not only to operational environmental management but also to the quality of campus life, the experience of open spaces, and student well-being. A comparative study on the University of Copenhagen, the University of

Nottingham, and METU reveals that practices such as energy efficiency, green spaces, waste management, and sustainable transportation can not only reduce environmental impact but also support student well-being and environmental awareness (Sütünç, 2025). The example of the University of Florence, meanwhile, demonstrates that a sustainable green university approach must be integrated with institutional strategy, education, research, and campus management (Fissi et al., 2021).

In the European context, recreational value is particularly evident through campus open spaces and academic green spaces. The fact that campus open spaces serve functions such as rest, socialization, transit, and meeting with friends demonstrates that these areas are not merely landscape elements but fundamental spaces for students' daily recreational experiences (Tudorie et al., 2020). In the case of a university in Germany, the association of academic green spaces with recreation, attention restoration, social interaction, and identity formation highlights that green spaces in sustainable campuses hold strategic value in terms of psychosocial well-being (Föllmer et al., 2020). In Finland's campus transformations, the integrated consideration of energy, mobility, and biodiversity themes demonstrates that recreational value is directly linked to the campus's physical planning (Komarzyńska-Świeściak et al., 2025).

Table 3. Sustainable Campus Initiatives and Recreational Values in the Americas

University / Context	Sustainable Campus Initiative	Recreational Value	Sustainability Dimension	Source
Universities in the United States	Development of campus sustainability after 1970 around environmental management and social change	Campus culture, environmental behavior, social participation	Environmental and social sustainability	Washington-Ottombre et al., 2018
Universities in the United States	Sustainable transportation framework based on bike-share programs	Active transportation, physical activity, campus mobility	Carbon reduction and healthy living	Enow et al., 2025
University natural areas	Natural area stewardship as part of campus sustainability	Contact with nature, sense of place, mental well-being	Environmental and social sustainability	Krasny & Delia, 2015
Campuses in Türkiye and the United States	Restorative potential of campus green spaces	Rest, restoration, quality of life	Social sustainability and well-being	Gulwadi et al., 2019
Collegiate recreational sports facilities	Sustainable facility development practices in sports facilities	Sport, physical activity, educational awareness	Environmental, ethical, operational, and economic sustainability	Stinnett & Gibson, 2016

Universities in Brazil	Green campus initiatives and students' perceptions of sustainable development	Student awareness, proactive participation, campus life	Social and environmental sustainability	Ribeiro et al., 2021
Higher education institutions in Latin America	Mapping sustainability initiatives and integrating them into campus operations	Campus participation, environmental responsibility, social learning	Environmental and institutional sustainability	Leal Filho et al., 2021
Intercollegiate sport events	Recycling and environmental fan engagement in sport spectators	Sport-event-based environmental behavior	Environmental awareness and social participation	Casper et al., 2020

In the American context, sustainable campus practices have historically developed, particularly in the United States, around the axes of environmental management, campus culture, and social change. Evaluations of campus sustainability in the U.S. indicate that the process initially progressed primarily through ecological and voluntary initiatives, but over time has become more comprehensive, incorporating institutional policy, environmental management, and social transformation dimensions (Washington-Ottombre et al., 2018). Bicycle-sharing programs and sustainable transportation frameworks, meanwhile, demonstrate that carbon reduction, mobility, and healthy living goals can be addressed together on campuses (Enow et al., 2025). In this regard, active transportation initiatives are one of the sustainable campus components that most clearly highlight recreational value in American examples.

In American examples, campus natural areas, recreational sports facilities, and sports events are notable application areas in terms of sustainability. It is noted that the conservation of natural areas may influence students' sense of place, mental well-being, and conservation behaviors, highlighting the potential of nature-based recreation on campus to foster environmental behaviors (Krasny & Delia, 2015). Sustainable facility development practices in recreational sports facilities demonstrate that a sustainable campus approach can be integrated with sports and recreation infrastructure due to their capacity to generate environmental, ethical, educational, operational, and economic benefits (Stinnett & Gibson, 2016). Studies in the Brazilian and Latin American context, meanwhile, show that green campus initiatives can foster sustainability knowledge, awareness, and proactive participation among students (Leal Filho et al., 2021; Ribeiro et al., 2021).

Table 4. Sustainable Campus Initiatives and Recreational Values in Asia

University / Context	Sustainable Campus Initiative	Recreational Value	Sustainability Dimension	Source
Higher education institutions in Asia	Regional comparison of sustainability practices	Campus life, environmental awareness, student participation	Environmental, social, and institutional sustainability	Leal Filho et al., 2021
Hong Kong Sustainable Campus Consortium	Inter-university sustainable campus consortium	Shared campus culture, social participation, sustainability awareness	Managerial and social sustainability	Xiong & Mok, 2020
Public universities in Malaysia	Green campus implementation, challenges, and solutions	Campus open spaces, environmental awareness, student participation	Environmental and managerial sustainability	Muhiddin et al., 2023
Universiti Malaya	Green campus investments focused on waste management and external stakeholder collaboration	Community participation, campus awareness, student experience	Environmental and institutional sustainability	Wang et al., 2025
Southeast Asian campuses	Sustainable and inclusive campus planning and design approaches	Student well-being, outdoor space use, campus experience	Social and environmental sustainability	Mansor et al., 2023a
Southeast Asian campuses	Sustainability analysis based on environment, social development, buildings and layout, and governance	Campus life, accessibility, social interaction	Social and managerial sustainability	Mansor et al., 2023b
Higher education campus environments	Relationship between natural environment and active transportation infrastructure and student health	Physical activity, mental health, walkability	Healthy campus and environmental sustainability	Ding et al., 2023
Central Asian universities	Institutionalization of green transition management and sustainable campus practices	Campus culture, environmental awareness, student participation	Managerial and environmental sustainability	Olzhebayeva et al., 2024

Examples from Asia demonstrate that sustainable campus practices exhibit a regionally heterogeneous structure. It is noted that sustainability practices are more prominent in East and Southeast Asia, particularly in the contexts of Malaysia, Indonesia, Thailand, and Hong Kong (Leal Filho et al., 2021). The example of the Hong Kong Sustainable Campus Consortium demonstrates that the sustainable campus approach can be implemented not only at the individual university level but also through inter-university collaboration and a consortium framework (Xiong & Mok, 2020). Examples from Malaysian public universities and Universiti Malaya, meanwhile, reveal that green campus initiatives are addressed in conjunction with waste management, stakeholder collaboration, campus investments, and administrative capacity (Muhiddin et al., 2023; Wang et al., 2025).

In the Asian context, recreational value is particularly evident in the areas of campus planning, open space use, student health, and active transportation. The Southeast Asian campus planning literature indicates that sustainable and inclusive campus design is associated with student well-being, academic achievement, and environmental responsibility (Mansor et al., 2023a). A systematic review on the campus environment and student health reveals that the natural environment, active transportation infrastructure, and campus design are linked to students' physical activity and mental health outcomes (Ding et al., 2023). The fact that green transition management in Central Asian universities requires institutionalization and external support demonstrates that sustainable campus practices are driven not only by physical arrangements but also by management capacity, strategic planning, and stakeholder participation (Olzhebayeva et al., 2024).

5. Conclusion

Examples from Asia demonstrate that sustainable campus practices exhibit a regionally heterogeneous structure. It is noted that sustainability practices are more prominent in East and Southeast Asia, particularly in the contexts of Malaysia, Indonesia, Thailand, and Hong Kong (Leal Filho et al., 2021). The example of the Hong Kong Sustainable Campus Consortium demonstrates that the sustainable campus approach can be implemented not only at the individual university level but also through inter-university collaboration and a consortium framework (Xiong & Mok, 2020). Examples from Malaysian public universities and Universiti Malaya, meanwhile, reveal that green campus initiatives are addressed in conjunction with waste management, stakeholder collaboration, campus investments, and administrative capacity (Muhiddin et al., 2023; Wang et al., 2025). Campus recreation strategies may also be strengthened through university-local government collaborations, particularly in the planning of open sport areas, community-based recreation programs, and active living policies (Kurtipek, 2019; Kurtipek & Yenel, 2018;).

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THE EFFECTS OF SEDENTARY BEHAVIOUR AND PHYSICAL ACTIVITY ON LIFETIME HEALTH

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Introduction

One of the most notable changes in modern life is the gradual decline in the role of physical activity within daily life and the consequent increase in sedentary behaviour. Technological advancements, urbanisation, digitalisation and the shift towards desk-based work have significantly reduced individuals' energy expenditure and made prolonged sitting a routine part of daily life. Sedentary behaviour refers to activities typically performed in a sitting or lying position and characterised by low energy expenditure (≤1.5 MET) (Tremblay et al., 2017). This is considered an independent risk factor, separate from physical activity, and is currently regarded as a major public health issue (Owen et al., 2010).

The rise in sedentary lifestyles places a significant burden not only on individual health but also on public health and healthcare systems. Globally, physical inactivity is recognised as one of the leading causes of premature death and is strongly associated with cardiovascular diseases, type 2 diabetes, obesity and certain types of cancer (Lee et al., 2012). According to reports published by the World Health Organisation, approximately 27% of adults worldwide fail to meet the recommended levels of physical activity. This proportion is particularly higher in developed and increasingly urbanised societies (WHO, 2020). Consequently, reducing sedentary behaviour, raising public awareness and promoting physical activity are among the priority objectives of global health policies.

When the effects of sedentary behaviour are assessed from a life-course perspective, they vary according to the individual's developmental stages. In childhood, insufficient physical activity is associated with delayed motor development, particularly increased screen time and a heightened risk of obesity (Carson et al., 2016), whilst a marked decline in physical activity levels is observed during adolescence (Dumith et al., 2011). In adulthood, occupational sedentary behaviour comes to the fore, with desk-based jobs and shift work

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systems significantly reducing individuals' daily activity levels (Church et al., 2011). In old age, reductions in physical activity are associated with a decrease in muscle mass (sarcopenia) and a decline in functional capacity (Booth et al., 2012). Furthermore, alongside reductions in bone mineral density during old age, the increased risk of falls and the resulting fractures lead to longer periods of bed rest, which in turn causes serious health problems. Given all these factors, the effects of sedentary behaviour must be addressed through a holistic approach.

Recent studies have demonstrated that sedentary behaviour is associated not only with health issues at the macro level but also with haematological and biochemical parameters. It has been demonstrated that physical activity has regulatory effects on haemoglobin levels, white blood cell count (WBC), red blood cell count (RBC) and inflammatory markers (Pedersen and Saltin, 2015). This suggests that physical activity is not merely a factor that enhances performance and fitness levels, but also serves as an intervention tool that exerts multifaceted effects on systemic health.

In this chapter of the book, the concepts of sedentary behaviour and physical activity will be examined within the context of lifelong health; the effects observed during childhood, adolescence, adulthood and old age will be analysed using a holistic approach. Furthermore, the physiological and biochemical effects of physical activity will be assessed in the light of current literature, drawing attention to the multidimensional effects of a sedentary lifestyle on health. The aim of this chapter is to highlight the importance of physical activity across different age groups and to establish a scientific framework for the adoption of a lifelong active lifestyle. It should not be forgotten that physical activity forms the foundation of the concept of healthy ageing.

Conceptual Framework

Physical activity encompasses all bodily movements produced by skeletal muscles that result in energy expenditure, whilst sedentary behaviours refer to waking behaviours performed during the day that require low energy expenditure (≤1.5 MET), such as sitting, lying down or reclining (Tremblay et al., 2017). These include watching TV, playing video games, using a computer, driving a car and reading a book (Gonzales et al., 2017). Even if an individual exercises regularly, they may still be considered sedentary if they spend a large part of the day sitting. This highlights the need to consider sedentary behaviour as an independent risk factor, distinct from physical activity (Owen et al., 2010).

Although the terms 'sedentary behaviour' and 'physical inactivity' are often used interchangeably, they carry distinct meanings in the literature. Physical inactivity refers to a situation where an individual fails to meet recommended levels of physical activity (Tremblay et al., 2017). The importance of this distinction stems from the fact that even if an individual's physical activity level is sufficient, spending a large portion of the day in a sedentary state can still pose independent health risks (Owen et al., 2010). Consequently, the concepts of 'being active' and 'sitting less' should be regarded as complementary behaviours with distinct objectives.

One of the most commonly used measures for the quantitative assessment of physical activity is the Metabolic Equivalent (MET) concept. MET is a unit that expresses the energy cost of physical activities by taking an individual's resting energy expenditure as a reference. 1 MET corresponds approximately to 3.5 ml/kg/min oxygen consumption. This value represents resting metabolism (Ainsworth et al., 2011). Physical activities are generally classified as low (<3 MET), moderate (3–6 MET) and high (>6 MET) intensity activities. This classification provides an important framework for prescribing exercise and assessing individuals' levels of physical activity.

International guidelines on physical activity specify minimum activity levels according to age groups and recommend limiting sedentary behaviour. According to the latest guidelines published by the World Health Organisation, adults are advised to engage in at least 150–300 minutes of moderate-intensity or 75–150 minutes of vigorous-intensity aerobic physical activity per week (WHO, 2020). For children and adolescents, at least 60 minutes of moderate-intensity physical activity per day is recommended. However, it is emphasised that merely achieving the recommended level of physical activity is insufficient; prolonged periods of uninterrupted sitting must also be limited.

When the effects of sedentary behaviour on health are examined, it is observed that such behaviour has adverse effects on energy balance, metabolic processes and cardiovascular function. Prolonged sitting behaviour is associated with a decrease in lipoprotein lipase activity , impaired glucose metabolism and reduced insulin sensitivity (Hamilton et al., 2007). These mechanisms contribute to the role of a sedentary lifestyle in the development of chronic diseases such as obesity, metabolic syndrome, type 2 diabetes and cancer.

On the other hand, regular physical activity is a key factor that counterbalances these adverse effects and plays a protective role in health. It has been reported that regular physical activity has positive effects on the cardiovascular, musculoskeletal and immune systems; furthermore, by enhancing psychological well-being, it reduces the risk of depression and anxiety (Warburton and Bredin, 2017). Furthermore, various studies have demonstrated that participation in recreational activities and physical activity has significant effects on individuals' psychological well-being, life satisfaction and overall perception of health (Türkmen et al., 2021). For this reason, reducing the sedentary tendencies brought about by modern life and encouraging individuals towards an active lifestyle is recognised as one of the fundamental components of preventive health approaches.

In line with this conceptual framework, it is becoming increasingly important to examine the effects of sedentary behaviour and physical activity on individual health from a life-course perspective. In particular, the assessment of physical activity levels across different age groups and specific populations (such as adolescents and the elderly) contributes to a better understanding of the effects of these behaviours on both physiological and functional outcomes. Consequently, the age-specific assessments to be addressed in the following sections aim to highlight the multidimensional effects of a sedentary lifestyle.

Sedentary Behaviour and Physical Activity in Childhood

A child is an individual who has not yet attained physical, mental and social maturity. The Convention on the Rights of the Child states: 'Every human being under the age of eighteen years is considered a child, unless the law applicable to the child provides for an earlier age of majority' (United Nations, 1989, Article 1). According to the World Health Organisation, childhood is defined as the period before the age of 10, whilst adolescence spans the ages of 10 to 19. Legally, adolescence ends at the age of 18 and adulthood begins; in other words, an individual is considered a child in legal terms until the age of 18 (Bülbül, 2004).

Childhood is a critical developmental stage during which physical, cognitive and psychomotor development occurs most rapidly; lifestyle habits acquired during this period significantly influence an individual's health behaviours in later life. Physical activity plays a fundamental role in children's musculoskeletal development, cardiovascular fitness levels and the development of motor skills (Janssen and LeBlanc, 2010). However, a decline in children's physical activity levels and an increase in sedentary behaviour are currently being observed. In particular, urbanisation, the decline in safe play areas and the widespread use of digital technologies are causing children to move away from active play (Gray et al., 2015).

One of the most prominent indicators of sedentary behaviour in childhood is increased screen time. Time spent watching television, using computers, and on tablets and smartphones reduces children's daily energy expenditure and limits the time allocated to physical activity. Furthermore, the increasing habit of consuming fast and ready-made meals can also lead to adverse health outcomes. Studies have shown significant associations between high screen time and increased body mass index (BMI), obesity risk, and low levels of physical fitness (Tremblay et al., 2011). Furthermore, it is noted that prolonged sedentary behaviour may have adverse effects not only on physical health but also on attention span, academic performance and social development (Carson et al., 2016).

Insufficient physical activity during childhood leads to critical consequences, particularly in terms of motor development. Fundamental movement skills (running, jumping, balance, object control, etc.) are acquired during this period, and the inadequate development of these skills can lead to reduced participation in physical activity in later years (Lubans et al., 2010). It is linked to a key mechanism known as the 'motor competence–physical activity cycle', which influences an individual's ability to maintain an active lifestyle. Consequently, encouraging physical activity during childhood determines not only current health status but also lifelong physical activity habits.

The rise in sedentary behaviour during childhood also has adverse effects on energy balance, thereby paving the way for the development of obesity. As physical activity decreases, energy expenditure falls; conversely, the prevalence of high-calorie dietary habits increases the risk of obesity. The observed increase in childhood obesity worldwide is attributed to the combined effect of these two factors (WHO, 2020). It is known that obesity developing during childhood is highly likely to persist into adulthood and constitutes a significant risk factor for cardiometabolic diseases (Sahoo et al., 2015).

The positive effects of physical activity on children's health are not limited to physical parameters alone. It has been reported that regular physical activity increases bone mineral density, enhances muscle strength and improves cardiovascular fitness; it also supports psychosocial development, thereby having positive effects on self-confidence, social skills and emotional well-being (Janssen and LeBlanc, 2010). Furthermore, it has been reported that participation in leisure-time activities is associated with individuals' levels of physical activity and general health behaviours (Türkmen et al., 2020). Encouraging children to adopt a physically active lifestyle from an early age is of critical importance for both short- and long-term health outcomes.

According to the physical activity guidelines recommended by the World Health Organisation, children and adolescents aged 5–17 are advised to engage in at least 60 minutes of moderate-to-vigorous physical activity daily (WHO, 2020). Furthermore, limiting screen time and reducing prolonged sitting behaviour are also key components of these recommendations. To implement these recommendations, multi-faceted interventions are required at the family, school and community levels.

Consequently, reducing sedentary behaviour and increasing physical activity during childhood is one of the key factors determining an individual's lifelong health status or well-being. One of the most effective approaches to increasing physical activity in childhood is school-based intervention programmes. As schools are settings where children spend a significant portion of their day, they provide a critical environment for fostering physical activity habits. Interventions implemented in this context include structured physical education lessons, active play periods, active learning methods, and out-of-school physical activity activities (Dobbins et al., 2013).

It has been reported that programmes combining nature-based activities, group games and physical activity with social interaction are more effective in increasing children's participation in physical activity (Erwin et al., 2012). Furthermore, it is emphasised that multi-component interventions involving family participation are important for the sustainability of behavioural change. Such initiatives not only increase levels of physical activity but also contribute to children developing environmental awareness, social skills and lifelong healthy habits. Movement habits acquired during childhood have lasting effects not only on physical health but also on cognitive and social development. Examples of interventions carried out in this context demonstrate that school-based recreational activities are an effective tool for increasing children's participation in physical activity. It is of great importance that interventions targeting childhood are initiated at an early age and made sustainable.

Sedentary Behaviour and Physical Activity in Adolescence

Adolescence is a critical developmental stage encompassing the transition from childhood to adulthood, characterised by intense biological, psychological and social changes. Behavioural patterns established during this period play a significant role in determining an individual's lifelong health habits. However, studies have shown that levels of physical activity decrease significantly during adolescence compared to childhood (Dumith et al., 2011). This decline is particularly associated with the increased academic workload, social media use and the digitalisation of leisure activities that accompany the adolescent period (Guthold et al., 2020).

One of the key determinants of sedentary behaviour in adolescents is the increase in screen-based activities. The rise in time spent on smartphones, computers and social media platforms leads to a reduction in time allocated to physical activity. Studies have shown significant associations between high screen time and low levels of physical activity, increased risk of obesity, and poor cardiovascular fitness (Carson et al., 2016). Furthermore, it is noted that prolonged sedentary behaviour has negative effects on sleep quality and that this situation may create a chain reaction of effects on both physical and psychological health (LeBlanc et al., 2015).

It is known that a decline in physical activity during adolescence is not limited to physical health alone, but also affects psychological and cognitive processes. It has been reported that regular physical activity reduces symptoms of depression and anxiety, boosts self-confidence, and positively influences cognitive performance (Biddle and Asare, 2011). Conversely, an increase in a sedentary lifestyle is associated with social isolation, low self-efficacy, and elevated stress levels. This situation highlights the need to assess adolescents' health holistically, rather than focusing solely on their physical health. Furthermore, the literature emphasises that participation in physical activity among adolescents is associated with psychological well-being, motivation and life satisfaction (Türkmen et al., 2021).

From a physiological perspective, a decrease in physical activity levels during adolescence has adverse effects on metabolic health. Low levels of physical activity are associated with insulin resistance, increased body fat, and an adverse lipid profile, a situation that increases the risk of cardiometabolic diseases in later life (Hallal et al., 2012). It is emphasised that sedentary habits acquired during this period tend to carry over into adulthood, and therefore early intervention is critical.

According to the physical activity guidelines recommended by the World Health Organisation, adolescents are advised to engage in at least 60 minutes of moderate-to-vigorous physical activity daily (WHO, 2020). Furthermore, limiting screen time and reducing sedentary behaviour are also key components of these recommendations. However, global data indicate that a significant proportion of adolescents do not meet these recommendations.

In conclusion, adolescence represents a 'turning point' in terms of whether sedentary behaviours become established or are broken. School-based programmes, peer-supported activities, family involvement and technology-supported interventions (e.g. mobile apps and wearable devices) are among the effective strategies for increasing physical activity levels (Van Sluijs et al., 2011). Maintaining and increasing physical activity levels during this period directly affects not only current health status but also the risk of chronic diseases in adulthood. Therefore, interventions targeting adolescents must be initiated at an early stage and supported by approaches that take individual differences into account. Furthermore, planning activities that are tailored to individuals' interests, enjoyable and sustainable is of critical importance for increasing participation in physical activity during this period.

Sedentary Behaviour and Physical Activity in Adults

Adulthood is a life stage characterised by increased professional responsibilities, where a significant portion of daily life is spent in the workplace, and consequently, physical activity levels vary considerably. Modern working life, particularly with the rise of desk-based jobs, leads to individuals being exposed to prolonged sitting behaviour. This situation is recognised as one of the primary reasons for the increasing prevalence of sedentary behaviour in the adult population (Church et al., 2011). A reduction in physical activity in daily life disrupts energy balance and paves the way for the development of various chronic diseases in the long term.

In some workplaces, although individuals may be standing or moving during work, the fact that these movements often lack sufficient intensity and continuity can prevent them from fully benefiting from the protective effects of physical activity on health. The shift work system is a significant factor influencing physical activity habits. In particular, night shifts disrupt individuals' circadian rhythms, negatively affecting sleep patterns, and this contributes to a reduction in physical activity levels (Proper et al., 2016). Insufficient sleep, combined with increased fatigue and a lack of motivation, leads to reduced participation in physical activity; this, in turn, reinforces a sedentary lifestyle. Furthermore, when combined with irregular eating habits, the adverse effects on metabolic health become even more pronounced.

The rise in sedentary behaviour among adults is associated with cardiovascular diseases, type 2 diabetes, obesity and certain types of cancer, and is regarded as a significant public health issue (Lee et al., 2012). It has been demonstrated that prolonged sitting behaviour can increase the risk of mortality, independent of physical activity levels (Ekelund et al., 2016). Therefore, not only exercising but also reducing the amount of time spent being sedentary during the day is of critical importance for maintaining health.

The positive effects of physical activity on adults are multifaceted. Regular physical activity improves cardiovascular fitness, enhances muscle strength, improves metabolic health and supports psychological well-being (Warburton and Bredin, 2017). Furthermore, it has been reported that simple interventions aimed at increasing physical activity in the workplace (such as active break schemes, standing work arrangements and short walking breaks) are effective in reducing sedentary behaviour (Neuhaus et al., 2014).

Physical activity guidelines published by the World Health Organisation recommend that adults engage in at least 150–300 minutes of moderate-intensity physical activity per week (WHO, 2020). However, current data indicate that many adults do not meet these recommendations. This situation highlights the need to raise individual awareness and to promote workplace-based interventions.

Consequently, reducing sedentary behaviour and increasing physical activity during adulthood is of critical importance for maintaining an individual's health and reducing the risk of chronic diseases. Particularly among groups with intense and irregular working conditions, such as night or shift work, the development of strategies to encourage physical activity is considered a vital necessity for both individual health and the sustainability of healthcare services.

Sedentary Behaviour and Physical Activity in Old Age

Old age is a life stage characterised by a natural decline in physiological functions and a marked reduction in an individual's physical capacity. During this period, a decrease in physical activity levels and an increase in sedentary behaviour have multifaceted adverse effects on health. A sedentary lifestyle is associated with a decline in functional capacity, a reduction in independent living skills, and a negative impact on quality of life in older adults (Booth et al., 2012).

One of the most significant physiological changes in old age is sarcopenia. Sarcopenia is defined as the age-related loss of muscle mass and muscle strength, and physical inactivity is one of the key factors accelerating this process (Cruz-Jentoft et al., 2010). The reduction in muscle mass makes it difficult for individuals to carry out their daily activities and leads to loss of balance, thereby increasing the risk of falls. This situation contributes to an increase in fractures, hospital admissions and mortality rates among older adults.

Another significant consequence of sedentary behaviour in older adults is its adverse effects on cardiovascular and metabolic health. A reduction in physical activity is associated with impaired glucose metabolism, insulin resistance and increased body fat, which in turn increases the risk of type 2 diabetes and cardiovascular disease (Paterson and Warburton, 2010). Furthermore, it has been reported that a sedentary lifestyle contributes to the development of chronic diseases by increasing inflammation levels.

However, the positive effects of regular physical activity on older adults are quite evident. Physical activity increases muscle strength, improves balance and coordination, maintains bone density, and reduces the risk of falls (Chodzko-Zajko et al., 2009). Furthermore, it has been demonstrated that aerobic exercise improves cardiovascular fitness and has positive effects on cognitive function. In this context, physical activity plays a critical role in older adults not only in terms of disease prevention but also in maintaining functional independence.

According to the physical activity guidelines recommended by the World Health Organisation, older adults are advised to engage in at least 150 minutes of moderate-intensity physical activity per week (WHO, 2020). Furthermore, performing balance and muscle-strengthening exercises at least 2–3 days a week is important for reducing the risk of falls. Furthermore, it is recommended to reduce sedentary time and to break up prolonged sitting behaviour at regular intervals.

Increasing participation in physical activity during old age is not limited to individual motivation alone but is also closely linked to environmental and social factors. Safe walking areas, social support mechanisms and the provision of suitable exercise programmes are among the key factors that increase older adults' participation in physical activity (Paterson and Warburton, 2010). Therefore, interventions targeting older adults must be addressed through a holistic approach encompassing individual, social and environmental dimensions, and the necessary policies must be developed.

In conclusion, reducing sedentary behaviour and increasing physical activity during old age is a fundamental component of healthy ageing. During this period, physical activity plays a critical role not only in the prevention of diseases but also in improving quality of life, maintaining independence and supporting active ageing.

Physiological and Biochemical Effects

The effects of physical activity and sedentary behaviour on health are assessed not only at the macro level but also through physiological and biochemical parameters. Recent studies have demonstrated that regular physical activity exerts regulatory effects on haematological, metabolic and inflammatory processes. Conversely, it has been reported that a sedentary lifestyle creates adverse effects on these systems, thereby paving the way for the development of various diseases (Pedersen and Saltin, 2015).

When assessed in terms of haematological parameters, physical activity has significant effects, particularly on haemoglobin (Hb), red blood cell (RBC) and white blood cell (WBC) levels. It is noted that regular exercise can increase haemoglobin levels by stimulating erythropoiesis and improve oxygen-carrying capacity (Hu and Lin, 2012). This is considered a key mechanism, particularly in terms of enhancing aerobic capacity and improving physical performance. Conversely, it is stated that haematological parameters may be at lower levels in sedentary individuals, and that this situation may have adverse effects on general health.

From the perspective of the immune system, physical activity is seen to have a modulatory effect on immune functions. It is reported that regular moderate-intensity exercise strengthens the immune system, increases resistance to infections, and balances inflammatory processes (Nieman and Wentz, 2019). These effects, particularly when assessed through white blood cell (WBC) levels and inflammatory markers (such as C-reactive protein), highlight the role of physical activity in systemic health. Conversely, it is known that prolonged sedentary behaviour is associated with low-grade chronic inflammation, and that this increases the risk of cardiometabolic diseases.

From a metabolic perspective, physical activity has significant effects on glucose metabolism and insulin sensitivity. Regular physical activity reduces insulin resistance by increasing glucose uptake in muscle tissue and lowers the risk of type 2 diabetes (Colberg et al., 2016). It has been reported that sedentary behaviour negatively affects these mechanisms, thereby contributing to the development of metabolic syndrome. Furthermore, it has been demonstrated that physical activity has positive effects on the lipid profile; it increases HDL cholesterol levels whilst reducing LDL cholesterol and triglyceride levels.

From a musculoskeletal perspective, physical activity plays a critical role in maintaining and increasing muscle mass, supporting bone mineral density, and enhancing functional capacity. In particular, it is known that resistance exercises prevent muscle loss and reduce the risk of sarcopenia by increasing muscle protein synthesis (Phillips and Winett, 2010). A sedentary lifestyle, on the other hand, is associated with muscle atrophy, a decrease in bone density and a decline in functional capacity.

However, the physiological effects of physical activity may vary depending on the intensity and duration of the exercise, as well as the individual's baseline fitness level. It is noted that moderate and regular physical activity has the most positive effects on health; whereas excessively intense and prolonged exercise may, in some cases, have temporary suppressive effects on the immune system (Nieman and Wentz, 2019). For this reason, it is important to plan physical activity in a manner suited to individual characteristics.

The physiological and biochemical effects of physical activity and sedentary behaviour are multifaceted, and these effects directly influence an individual's overall health status. Assessed across a broad spectrum ranging from haematological parameters to metabolic processes, these effects demonstrate that physical activity serves not only as a performance-enhancing tool but also as a preventive and therapeutic intervention. In particular, the planning of interventions targeting physical activity in sedentary individuals is of great importance for improving health indicators. In this regard, investigating the effects of short-term exercise programmes on haematological and metabolic parameters in sedentary individuals emerges as a significant area of research for future studies.

Conclusion

The topics addressed in all these sections clearly highlight the need to evaluate the effects of sedentary behaviour and physical activity on individual health from a lifelong perspective. It is observed that physical activity habits established in childhood continue into adolescence, adulthood and old age; conversely, sedentary behaviours also exhibit similar continuity. Furthermore, the increasing prevalence of a sedentary lifestyle presents a significant public health issue on a global scale. This situation demonstrates that behavioural patterns acquired at an early age play a decisive role in lifelong health outcomes (Telama, 2009).

A decline in physical activity levels and an increase in screen-based sedentary behaviour during childhood and adolescence affect not only current health status but also the risk of chronic diseases in adulthood. Research indicates that physical activity habits developed during these periods are sustainable and directly influence an individual's lifestyle in later years (Dumith et al., 2011). The widespread implementation of school-based programmes, increased family involvement, and encouraging children towards an active lifestyle are of great importance. The development and implementation of early intervention strategies for this situation are of paramount importance.

In adulthood, sedentary behaviour is seen to be more closely linked to occupational factors. In particular, it is noted that participation in physical activity is limited and sedentary time increases among individuals with demanding and irregular working conditions. This situation increases health risks for individuals and, in the long term, contributes to the burden of chronic diseases. However, it has been reported that workplace-based interventions and awareness-raising programmes are effective in increasing levels of physical activity (Neuhaus et al., 2014).

In later life, a decline in physical activity is associated with significant health issues such as reduced functional capacity, loss of muscle mass and decreased bone mineral density. During this period, physical activity plays a critical role not only in disease prevention but also in maintaining independent living (Chodzko-Zajko et al., 2009). Consequently, the promotion of physical activity throughout life is regarded as a fundamental strategy for supporting the process of healthy ageing.

Findings at the physiological and biochemical levels demonstrate that physical activity has a broad scope of influence, ranging from haematological parameters to metabolic processes. In particular, changes assessed through parameters such as haemoglobin, red blood cells (RBCs) and white blood cells (WBCs) highlight the systemic effects of physical activity. This demonstrates that physical activity is not merely a behavioural variable, but also an intervention tool with measurable biological effects (Pedersen and Saltin, 2015).

When the findings are considered together, it becomes apparent that strategies aimed at reducing sedentary behaviour and increasing physical activity must be addressed at the individual, environmental and policy levels. Research highlights that single-dimensional interventions yield limited effects; conversely, multi-component and sustainable approaches produce more successful outcomes. In this context, the development of comprehensive policies supporting lifelong physical activity is of great importance.

Accordingly, it is recommended that future studies incorporate multidisciplinary approaches that jointly examine the biological, psychological and social effects of physical activity and sedentary behaviour across different age groups. Furthermore, increasing the number of long-term intervention studies and supporting these with objective measurement methods will enhance the reliability of the findings.

In conclusion, reducing sedentary behaviour and increasing physical activity should be among the priority objectives for both individual and public health. Adopting an active lifestyle throughout life is an indispensable element not only for the prevention of diseases but also for maintaining a productive, high-quality life and fostering healthy societies.

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EXERCISE INDUCED MYOKINES: MOLECULAR MECHANISMS PERFORMANCE EFFECTS

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Introduction

Skeletal muscle, traditionally recognized for its contractile properties, has emerged as a significant endocrine organ that secretes a diverse array of signaling molecules known as myokines (Picciotto et al., 2024). These myokines facilitate critical inter-organ crosstalk, influencing various physiological processes locally and systemically (Magliulo et al., 2021). This paradigm shift recognizes skeletal muscle as an active participant in metabolic regulation, immune function, and tissue regeneration, extending beyond its mechanical role (Jia et al., 2023). Initially, Interleukin-6 was identified as the first myokine, establishing the concept of muscle as an endocrine organ (Picciotto et al., 2024; Steensberg et al., 2000). Subsequent research has broadened this understanding, identifying a multitude of exerkines—bioactive molecules released from various organs like the heart, liver, adipose tissue, brain, and gut in response to exercise—that collectively mediate many of the cardiometabolic benefits of physical activity (Jin et al., 2024). While myokines are a specific subset of exerkines originating from muscle tissue, the broader classification of exerkines encompasses molecules released from diverse organs, such as hepatokines from the liver and adipokines from adipose tissue, underscoring the systemic molecular response to physical activity (Magliulo et al., 2021; Robbins & Gerszten, 2023). This molecular response involves a wide array of signaling molecules, including cytokines, lipids, metabolites, and nucleic acids, many of which are transported via extracellular vesicles that facilitate inter-organ communication (Verboven & Vechetti, 2023; Walzik et al., 2024). A comprehensive understanding of the various hormones involved in the mobilisation of these mediators during exercise, and the complex interactions between them, is vital for uncovering the full scope of the physiological adaptations induced by exercise and their therapeutic potential. mobilization (Magliulo et al., 2021).

Among exercise-related processes, the dynamics of myokine release and cellular signaling are influenced by exercise stimuli and are associated with the

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regulation of exerkine secretion and signaling pathways (Walzik et al., 2024; Whitham et al., 2018). The release of myokines during exercise is regulated by contraction-induced cellular signaling pathways and associated metabolic responses in skeletal muscle, and this process may vary depending on the type, intensity, and duration of exercise as well as muscle recruitment patterns (Pedersen & Febbraio, 2012; Whitham et al., 2018). This complexity underscores the intricate interplay between mechanical stimuli, bioenergetic demands, and paracrine/endocrine signaling that orchestrates systemic adaptations to physical activity (Chow et al., 2022; Walzik et al., 2024; Zhao et al., 2024). Long-term resistance and endurance exercise can induce distinct molecular responses through exercise-specific signaling pathways, thereby modulating myokine secretion patterns (Raimondo et al., 2017). Different exercise modalities, including continuous and interval-based protocols, have been shown to differentially influence gene expression and the release of exercise-induced factors, contributing to variability in the skeletal muscle secretome (Magliulo et al., 2021). High-intensity interval training particularly promotes the rapid release of myokines such as irisin, while the effects of IL-6 on tissue repair and adaptation are shaped depending on the duration of the training and its chronic application. (Chow et al., 2022; Zhou et al., 2024). Among the currently known myokines are various molecules such as FGF-21, IL-6, IL-8, IL-15, irisin, BDNF, ANGPTL4, LIF, FSTL-1, and myostatin (Pedersen & Febbraio, 2008, 2012; Steensberg et al., 2000; Trovato et al., 2019). These myokines, many of which are recognized as exerkines, collectively orchestrate systemic physiological responses, modulating metabolic homeostasis, inflammatory pathways, and tissue remodeling (Leuchtmann et al., 2021; Magliulo et al., 2021; Raimondo et al., 2017; Trovato et al., 2019). Their expression levels in skeletal muscle are typically low at rest but significantly increase during muscle contraction, with specific exercise protocols influencing their secretion patterns and concentrations (Pinto et al., 2024; Trovato et al., 2019).

The present review systematically examines the molecular mechanisms governing myokine release, their multifaceted effects on exercise performance, and their significant clinical implications for health and disease management. Specifically, this paper aims to delineate the intricate signaling pathways that orchestrate myokine secretion in response to varying exercise intensities and durations. Additionally, it will explore the pleiotropic effects of prominent myokines, such as Interleukin-6, Irisin, Myostatin, and Brain-Derived Neurotrophic Factor, on metabolic homeostasis, exercise adaptations, and systemic health (Jin et al., 2024; Leuchtmann et al., 2021).

1. Skeletal Muscle as an Endocrine Organ

The recognition of skeletal muscle as an endocrine organ represents a paradigm shift from its traditional role as merely a contractile tissue to a dynamic secretory gland integral to systemic physiological regulation.

This understanding is rooted in the muscle's capacity to synthesize and secrete signaling molecules, termed myokines, that exert autocrine, paracrine, and endocrine effects on various tissues and organs (Farrash et al., 2021). This secretory function facilitates crucial inter-organ communication, influencing metabolism, inflammation, and cellular proliferation across distant sites (So et al., 2014; Trettel et al., 2023). Over 600 potential myokines have been identified, including cytokines, growth factors, and hormone-like proteins, enriching our understanding of muscle's role in whole-body metabolism, inflammation regulation, and energy homeostasis (Cui et al., 2025). For instance, IL-6, a well-studied myokine, is involved in stimulating lipid oxidation, glucose uptake, and hepatic neoglucogenesis (Laurens et al., 2020). This discovery has led to the broader concept of "exerkines," encompassing all exercise-induced signaling molecules from various organs, with myokines representing a significant subset derived from skeletal muscle that profoundly impacts metabolic regulation (Jin et al., 2024; Laurens et al., 2020; Zhou et al., 2024). Indeed, the release of IL-6 from skeletal muscle in response to contractile activity is a pivotal mechanism for exercise-induced metabolic adaptations, influencing glucose metabolism and insulin sensitivity in various peripheral organs (Carson, 2017; Lin et al., 2023). Beyond IL-6, other myokines contribute to systemic health benefits, including enhanced substrate oxidation and the reduction of both subcutaneous and visceral fat (Hoffmann & Weigert, 2017). This endocrine function of skeletal muscle provides a conceptual basis for understanding how muscular activity communicates with other tissues and organs to modulate systemic metabolism and health (Pedersen, 2009). This comprehensive interplay highlights how muscle contraction directly translates into systemic effects, positioning exercise as a potent modulator of overall physiological well-being (Rad & Panahzadeh, 2023; Severinsen & Pedersen, 2020). This endocrine role underscores the profound impact of skeletal muscle not only in locomotion but also as a critical regulator of whole-body energy metabolism and systemic health (Iizuka et al., 2014; Kim & Kim, 2020). This conceptualization thereby offers a mechanistic explanation for the protective effects of regular physical activity against a wide array of chronic diseases, such as type 2 diabetes, cardiovascular disease, and certain cancers (Pedersen, 2009; Tabone, 2025). The extensive network of myokines released by skeletal muscle during contraction facilitates cross-talk between muscle and other organs, including the brain, adipose tissue, bone, liver, and gut, influencing diverse physiological processes such as cognition, lipid and glucose metabolism, and bone formation (Severinsen

& Pedersen, 2020). Specifically, the secretion of IL-6 by contracting human skeletal muscles significantly contributes to the exercise-induced elevation of plasma IL-6, establishing a direct link between muscle activity and systemic metabolic regulation (Pedersen & Febbraio, 2005; Rad & Panahzadeh, 2023; Robbins & Gerszten, 2023). This myokine functions both locally, by increasing glucose uptake and fatty acid oxidation within the muscle, and systemically, by stimulating adipocyte lipolysis and hepatic gluconeogenesis to enhance fuel availability (Safdar & Tarnopolsky, 2017). Elevated IL-6 levels resulting from muscle contraction further improve glucose uptake and fatty acid oxidation, thereby playing a critical role in energy mobilization during physical exertion (Sanchez et al., 2025). Moreover, IL-6 has been shown to increase insulin-stimulated glucose disposal and promote GLUT-4 translocation to the plasma membrane in myotubes, further highlighting its role in glucose homeostasis (Foudi & Legeay, 2021).

2. Classification of Myokines

This classification typically organizes myokines based on their structural characteristics, receptor interactions, and the primary physiological pathways they influence, thereby facilitating a more granular understanding of their diverse roles in maintaining systemic equilibrium. For instance, some myokines act as pro-inflammatory cytokines, while others mediate anti-inflammatory responses, illustrating their multifaceted roles in immune regulation (Iizuka et al., 2014). Furthermore, myokines can be categorized by their predominant mode of action, such as those primarily involved in metabolic regulation, angiogenesis, or neurogenesis, reflecting the broad spectrum of physiological processes influenced by skeletal muscle activity. Beyond this, myokines can be further delineated by the specific cellular signaling cascades they activate, such as the AMP-kinase or PI3-kinase pathways, which are critical for glucose uptake and fat oxidation within the muscle itself (Forcina et al., 2022). This intricate classification scheme underscores the complexity of myokine biology and their widespread impact on systemic physiology (Капилевич et al., 2017). The ongoing discovery of new myokines further refines this classification, revealing more nuanced interactions and specialized functions that contribute to the overall adaptive response to exercise (Eckel, 2019). However, classifying myokines often presents challenges due to their pleiotropic effects, where a single myokine can exert multiple, sometimes opposing, biological functions depending on the target tissue and physiological context. For example, while IL-6 is often characterized as a pro-inflammatory cytokine, its exercise-induced systemic increase can generate an elevation of plasma anti-inflammatory cytokines and inhibit the production of pro-inflammatory TNF-α, thus exhibiting context-dependent anti-inflammatory properties (Pedersen & Febbraio, 2008; Petersen & Pedersen, 2005). Therefore, a more comprehensive classification system should account for the dynamic interplay between myokine concentration, tissue-specific receptor expression, and the broader physiological milieu to accurately delineate their functional roles. Despite these complexities, current understanding broadly categorizes myokines based on their primary effects, such as those involved in metabolic regulation (e.g., FGF-21, irisin), inflammation modulation (e.g., IL-6, IL-15), or tissue remodeling (e.g., myostatin) (Eckel, 2019; Severinsen & Pedersen, 2020). Indeed, IL-6 exemplifies this complexity, functioning both as a pro-inflammatory mediator in certain contexts and exhibiting anti-inflammatory properties when secreted during exercise, particularly by inducing anti-inflammatory factors and inhibiting pro-inflammatory cytokines (Villar-Fincheira et al., 2021). This pleiotropic nature of myokines, particularly IL-6, highlights the intricate regulatory mechanisms governing exercise-induced physiological adaptations and their therapeutic potential in mitigating chronic inflammatory conditions (Eldomiaty et al., 2019). This context-dependent functional duality necessitates a nuanced approach to myokine classification, moving beyond simplistic categorizations to embrace their dynamic and multifaceted biological activities (Felice et al., 2020). Consequently , accurate classification requires consideration of the specific physiological state and the precise molecular pathways engaged by each myokine to fully elucidate its role in exercise physiology and therapeutic intervention (Eckel, 2019; Pedersen & Febbraio, 2008). Further research endeavors are crucial to meticulously characterize the mechanisms underpinning these context-specific functional shifts, thereby facilitating the development of targeted interventions for diverse health conditions (Leal et al., 2018; Lightfoot & Cooper, 2016).

3. Molecular Mechanisms of Myokine Release

Molecular mechanisms of myokine release encompass a sophisticated interplay of intracellular signaling pathways that are activated in response to mechanical stress, metabolic perturbations, and neurohormonal cues experienced during muscle contraction. These pathways integrate various signals to orchestrate the transcription, translation, and secretion of these diverse signaling molecules, ultimately influencing systemic physiological adaptations. The intensity, duration, and type of exercise significantly modulate the secretion of myokines, reflecting the intricate regulatory mechanisms governing their release (Zhou et al., 2024).

3.1 Contraction-Induced Signaling Pathways: Muscle contraction initiates a cascade of intracellular events, including alterations in calcium handling, energy status, and reactive oxygen species production, which collectively activate specific signaling molecules such as AMPK, MAPK, and NF-κB, thereby upregulating the expression of various myokines. For instance, exercise-induced nitric oxide production has been hypothesized to be an important signaling event for the expression of myokines like IL-6 and IL-8, with its inhibition leading to significant reductions in their mRNA expression (Dyakova et al., 2015). Furthermore, the activation of calcium-calmodulin-dependent kinases following muscle contraction plays a pivotal role in regulating the transcription of numerous myokines by influencing transcription factors such as MEF2 and CREB (Lightfoot & Cooper, 2016). These intricate pathways, in turn, modulate the expression of genes encoding myokines, which are subsequently translated and secreted via both conventional endoplasmic reticulum-Golgi pathways and unconventional vesicle-mediated mechanisms. However, a comprehensive understanding of the specific types and volumes of contraction required to optimize the release of these regulatory molecules for therapeutic applications, such as the prevention and treatment of type 2 diabetes, remains an area requiring further investigation (Carson, 2017). While the precise mechanisms governing myokine secretion are still being elucidated, it is evident that muscle contraction itself, independent of cellular damage, is a potent stimulus for their release (Furuichi et al., 2018). Specifically, the mechanical tension and metabolic stress induced by muscle contraction lead to morphological adaptations within the muscle through protein biosynthesis and myokine secretion (Torregrosa et al., 2022). This process involves the activation of various signaling molecules, including AMPK and p38/MAPK, which are crucial for mediating the adaptive responses to exercise and promoting myokine transcription (Ahsan et al., 2022; Lin et al., 2023). Indeed, the AMPK pathway plays a crucial role in exercise-induced myokine expression, as evidenced by reduced IL-15 production in skeletal muscle lacking specific AMPK subunits (Капилевич et al., 2017). The interplay between AMPK activation and myokine secretion is bidirectional, with myokines such as SPARC influencing AMPK activity and vice versa, underscoring the complex regulatory network governing exercise adaptations (Ahsan et al., 2022). Further research has explored the relationship between IL-8 and AMPK, with studies suggesting that specific concentrations of IL-8, similar to post-exercise interstitial levels, can activate the AMPK pathway and increase glucose uptake in muscle cells (Ahsan et al., 2022; Carson, 2017). Moreover, increased intracellular calcium flux, rather than muscle contraction per se, appears to be a critical determinant for acute myokine secretion during electrical stimulation (Takada et al., 2022). In summary, the release of myokines is a highly regulated process involving diverse intracellular signaling cascades, including AMPK, MAPK, and calcium-dependent pathways, which are responsive to the specific physiological demands of muscle contraction and play a critical role in mediating systemic metabolic and adaptive responses (Ahsan et al., 2022; Pedersen & Febbraio, 2008).

3.2 Role of Exercise Intensity and Duration: The magnitude and temporal dynamics of myokine release are critically dependent on the intensity and duration of physical activity, influencing their subsequent systemic and local effects. For instance, high-intensity and long-duration exercise protocols typically elicit more pronounced increases in circulating myokine levels compared to moderate or low-intensity activities, reflecting a dose-response relationship between exercise stimulus and secretory output (Hoffmann & Weigert, 2017). This dose-response relationship is further modulated by factors such as training status, age, and nutritional status, which can influence the sensitivity of muscle cells to exercise stimuli and their capacity for myokine production. Different exercise modalities, such as aerobic and resistance training, also induce distinct myokine expression profiles, highlighting the specificity of muscular adaptations to various forms of physical exertion (Bettariga et al., 2024). For example, acute bouts of aerobic exercise stimulate the secretion of Sparc, which then regulates glucose metabolism by activating AMPK pathways (Faraldi et al., 2022). Conversely, resistance exercise has been shown to preferentially increase levels of myostatin, a myokine known to inhibit muscle growth, while reducing its expression during recovery (Laurens et al., 2020). However, myostatin synthesis and secretion are generally decreased during exercise, leading to reduced muscle differentiation and protein accretion (Torregrosa et al., 2022). The acute exercise-induced reduction in myostatin promotes muscle hypertrophy, contributing to improved insulin sensitivity and glucose uptake (Hoffmann & Weigert, 2017). The specific types of myokines stimulated also vary based on the mode of training, with resistance training being a powerful stimulus for myokine release (Zunner et al., 2022). Specifically, interval resistance training, particularly at high intensities, has been shown to modulate myokine changes and metabolic risk factors (Ataeinosrat et al., 2022). Chronic exercise-induced myokine responses, on the other hand , are associated with sustained adaptations in metabolic regulation and tissue remodeling, reflecting cumulative physiological adjustments to consistent physical activity over time (Ringleb et al., 2026). Moreover, the variability in individual myokine responses to different exercise types, such as high-intensity interval training versus resistance training, underscores the need for personalized exercise prescriptions to optimize cardiometabolic benefits (He et al., 2018). This variability highlights the complexity of discerning optimal training paradigms for targeted myokine secretion, particularly given that the specific influence of diverse training variables on this response often remains inadequately characterized (He et al., 2019). This complexity is further compounded by emerging evidence suggesting fiber-type specific myokine secretion patterns, where glycolytic fibers may preferentially secrete certain myokines like FGF21, while oxidative fibers are more associated with others, such as irisin

(Piccirillo, 2019). Additionally, the temporal dynamics of myokine secretion can vary significantly across different training modalities and intensities, with some myokines peaking immediately post-exercise while others exhibit delayed responses lasting several hours or even days (Bettariga et al., 2024). For instance, myostatin levels can transiently increase immediately post-exercise before gradually decreasing to baseline levels within 72 hours, irrespective of the training mode (He et al., 2018). Briefly , while resistance training often leads to a more sustained elevation of certain myokines, reflecting its distinct anabolic signaling pathways (He et al., 2018). Aerobic training, characterized by high metabolic demand, primarily influences myokine expression related to metabolic and immune functions, with changes moderated by factors such as exercise duration, intensity, and training status (Ringleb et al., 2026).

4. Key Myokines and Their Functions

With regard to key myokines and their functions, understanding the individual roles and interplay of these muscle-derived signaling molecules is crucial for elucidating their systemic effects on health and disease. This section will delineate the specific functions of prominent myokines, exploring their molecular mechanisms and physiological implications in modulating metabolism, inflammation, and tissue regeneration. These key myokines, including Interleukin-6, Irisin, Myostatin, and Brain-Derived Neurotrophic Factor, exert pleiotropic effects on various organ systems, thereby contributing to the comprehensive health benefits of physical activity.

4.1 Interleukin-6 (IL-6): Interleukin-6 is arguably the most extensively studied myokine, recognized for its pivotal role in mediating muscle-to-organ crosstalk and systemic metabolic regulation during and after exercise (Tabone, 2025). It acts as a multifaceted cytokine, influencing glucose and lipid metabolism, inflammatory responses, and energy homeostasis, often in an autocrine, paracrine, or endocrine fashion (Leal et al., 2018). Its acute release from contracting skeletal muscle is highly sensitive to exercise intensity and duration, peaking within hours following exertion and playing a crucial role in post-exercise immune modulation and energy substrate mobilization (Trettel et al., 2023). This rapid increase in circulating IL-6 levels is distinct from chronic inflammation, as exercise-induced IL-6 primarily functions as an energy sensor, promoting glucose uptake and fat oxidation in distant tissues rather than solely contributing to inflammatory processes (Morais et al., 2024). Specifically, IL-6 has been shown to enhance energy metabolism by increasing glucose uptake and fatty acid oxidation through the activation of signaling pathways like 5'-adenosine monophosphate-activated protein kinase (Faraldi et al., 2022). Beyond its metabolic roles, IL-6 also contributes to muscle growth and repair processes, particularly through its involvement in satellite cell activation and differentiation, crucial for muscle regeneration and adaptation to training stimuli. The ubiquitous expression of its co-receptor gp130, in conjunction with the limited expression of the IL-6 receptor, allows for diverse cellular responses, which are further modulated by soluble IL-6R released through ADAM10 and ADAM17 activity (Lombardi et al., 2017). Furthermore, exercise-induced IL-6 exhibits anti-inflammatory effects by suppressing pro-inflammatory cytokines and stimulating anti-inflammatory mediators, thereby contributing to systemic immune regulation (Aryana et al., 2018). Indeed, IL-6 has been shown to induce the production of IL-10, a potent anti-inflammatory cytokine, from immune cells, fostering an anti-inflammatory state (Marques et al., 2021). This intricate interplay distinguishes exercise-induced IL-6 from pathological inflammation, redirecting its metabolic and immunomodulatory functions towards beneficial physiological adaptations (Ringleb et al., 2023). It functions through autocrine, paracrine, and endocrine pathways, signaling via the gp130Rβ/IL-6Rα homodimer to activate AMPK, which subsequently enhances glucose uptake and fatty acid oxidation within skeletal muscle (Karsenty & Mera, 2017). The total plasma level of IL-6 can also be partially altered by immunological cells from both the innate and adaptive immune systems, depending on the training stimulus, which induces transient pro-inflammatory effects followed by an anti-inflammatory response (Rogeri et al., 2020). Moreover, IL-6 has been implicated in enhancing glucose disposal and uptake in skeletal muscles by stimulating glucose transporter 4 translocation, in addition to promoting fatty acid uptake and lipolysis (Minafra et al., 2022). While high levels of IL-6 are associated with insulin resistance in obesity, exercise-induced IL-6 is crucial for improving insulin sensitivity and glucose disposal, partly by stimulating glucose uptake via AMPK and phosphatidylinositol-3-kinase signaling pathways (O'Neill, 2013; Smith, 2018).

4.2 Irisin: Irisin, a cleavage product of fibronectin type III domain-containing protein 5, is another prominent myokine secreted in response to muscular contractions (O'Neill, 2013). This myokine plays a significant role in mediating the beneficial metabolic effects of exercise, particularly through its browning effect on white adipose tissue and its influence on energy expenditure (Darkwah et al., 2021). Irisin facilitates the conversion of white adipocytes into more metabolically active beige adipocytes, thereby increasing thermogenesis and overall energy expenditure (Jee, 2021). Furthermore, irisin enhances mitochondrial biogenesis and oxidative phosphorylation in skeletal muscle, contributing to improved metabolic flexibility and endurance capacity (Lombardi et al., 2019). Beyond its direct impact on adipose tissue and skeletal muscle, irisin also exerts neurotrophic effects, contributing to cognitive function and neurogenesis in the brain (Leal et al., 2018). Its endocrine functions extend to various other tissues, including bone, where it promotes bone formation, and the cardiovascular system, where it exhibits cardioprotective effects (Liu et al., 2025). The systemic actions of irisin underscore its potential as a therapeutic target for metabolic disorders and age-related decline. However, the precise quantification of irisin has presented methodological challenges, with some studies indicating elevated serum irisin levels following sustained exercise at moderate to high intensities or resistance training over extended periods (Gallo-Villegas & Calderón, 2023). However, accurate measurement of irisin levels is complicated by factors such as assay variability and diurnal fluctuations, necessitating standardized methodologies for reliable quantification in research and clinical settings (Ludovico et al., 2024). Despite these complexities, irisin's multifaceted roles in metabolism, neuroprotection, and tissue remodeling highlight its critical importance in mediating exercise-induced physiological adaptations and its potential as a therapeutic agent for various chronic diseases (Arhire et al., 2019; Paoletti & Coccurello, 2024; Rashidlamir et al., 2017). First identified by Bostrom et al. in 2012, irisin is derived from the proteolytic cleavage of fibronectin type III domain-containing protein 5 (Khan, 2018; Norman et al., 2022). This myokine, with its 112-amino-acid polypeptide structure, is secreted into the bloodstream by both muscle and adipose tissues, where it is instrumental in modulating metabolic processes and cardiovascular health (Khalil et al., 2025). Its therapeutic potential is being actively investigated for conditions such as metabolic disorders, obesity, type 2 diabetes, and neurodegenerative diseases (Norman et al., 2022; Paoletti & Coccurello, 2024). Irisin's physiological role in inducing thermogenic beige fat genesis to control energy metabolism was initially described by Spiegelman (Liu et al., 2022). This crucial function positions irisin as a key mediator in energy balance and whole-body metabolism, primarily through its ability to enhance muscle-adipose communication and insulin sensitivity (Paoletti & Coccurello, 2024). Its ubiquitous presence in various tissues like the brain, liver, heart, and kidneys further highlights its broad impact on systemic metabolic regulation and inter-organ crosstalk (Khalil et al., 2025; Zhao, 2022). Its role in maintaining metabolic homeostasis makes it a promising target for interventions aimed at preventing and treating metabolic dysregulation (Khalil et al., 2025).

4.3 Myostatin: This multifaceted myokine also plays a critical role in skeletal muscle plasticity, promoting muscle growth and regeneration while also influencing bone structure and strength (Planella-Farrugia et al., 2019). Myostatin, a member of the transforming growth factor-beta superfamily, primarily functions as a negative regulator of muscle growth and differentiation (Picciotto et al., 2024). Conversely, irisin has been shown to downregulate myostatin expression, thereby promoting muscle growth and hypertrophy (Bonanni et al., 2022; Ladang et al., 2023). This antagonistic relationship between irisin and myostatin highlights a complex regulatory mechanism governing muscle mass accrual and maintenance, underscoring irisin's anabolic potential (Bonanni et al., 2022). The synthesis of irisin, specifically the proteolytic conversion of FNDC5, is largely influenced by peroxisome proliferator-activated receptor-γ coactivator-1α (PGC-1α) transcriptional activity, which is upregulated by exercise (Jia et al., 2023; Paoletti & Coccurello, 2024). This transcriptional regulation underscores the intricate molecular control of irisin production in response to physical activity and its subsequent impact on muscle anabolism (Muñoz et al., 2018; Rashidlamir et al., 2017). Beyond its direct effects on muscle, irisin is pivotal in inducing the browning of white adipose tissue and activating thermogenesis, processes mediated by the upregulation of peroxisome proliferator-activated receptor gamma coactivator-1-alpha (PGC-1α) (Zhang et al., 2023). This mechanism consequently enhances energy expenditure and improves metabolic health (Mohammed et al., 2025). Additionally, irisin enhances insulin sensitivity in muscle and liver tissues, promotes β-cell proliferation and survival under gluco- and lipotoxic conditions, and contributes to metabolic homeostasis by increasing autophagy (Mizera et al., 2021). Moreover, irisin has been identified as a significant regulator of bone metabolism, influencing osteogenesis and bone mineral density (Magliulo et al., 2021). Global deletion of myostatin in animal models results in significant muscle hypertrophy, reduced adiposity, and enhanced insulin sensitivity, further supporting the intricate interplay between myostatin and metabolic regulation (Bonewald, 2018). Conversely, therapeutic strategies for sarcopenia frequently target the myostatin/activin signaling pathway to counteract muscle fiber atrophy (Faienza et al., 2023). Myostatin's antagonistic influence extends to bone morphogenetic protein 7-induced adipogenesis, thereby inhibiting the differentiation of bone marrow mesenchymal stem cells into adipocytes (Yi et al., 2025). This inhibition further solidifies myostatin's role in regulating the delicate balance between osteogenesis and adipogenesis within the bone marrow microenvironment. Furthermore, myostatin signaling has been implicated in the pathogenesis of various metabolic diseases, including type 2 diabetes and obesity, through its modulation of adipogenesis and insulin sensitivity (Pervin et al., 2021). Consequently, targeting myostatin or its downstream signaling components represents a promising therapeutic avenue for addressing not only muscle wasting disorders but also metabolic dysregulation associated with these conditions. Moreover, the suppression of myostatin has been demonstrated to promote adipose browning and improve insulin signaling, suggesting a broader metabolic impact beyond its canonical role in muscle growth inhibition (Pervin et al., 2021). This is further supported by evidence that myostatin signaling regulates FNDC5 expression and adipose browning via upregulation of miRNA-34a (Pervin et al., 2019). The canonical cellular changes induced by active myostatin and activin A are mediated through the activin receptor type II B and subsequent intracellular Smad signaling cascades (Omosule & Phillips, 2021). However, myostatin can also signal through activin type IIA receptor, and the incomplete blockade of myostatin signaling by targeting only the type IIB receptor may not fully reveal its direct role in adipocyte metabolism (Ge et al., 2016). While myostatin is critical for muscle mass regulation, its multifaceted roles extend to adipogenesis and overall energy homeostasis, with myostatin-deficient mice exhibiting reduced total body fat and improved glucose metabolism (Grafe et al., 2017; Suh & Lee, 2020).

4.4 Brain-Derived Neurotrophic Factor (BDNF): Brain-Derived Neurotrophic Factor is a neurotrophin primarily recognized for its critical roles in neuronal survival, growth, and synaptic plasticity within the central and peripheral nervous systems. This neurotrophic factor, however, is not exclusively confined to neural tissues; it is also expressed and secreted by skeletal muscle, functioning as a myokine to mediate various systemic effects, particularly in the context of exercise (Tencerová & Kassem, 2016). The release of BDNF from skeletal muscle during physical activity contributes to improvements in cognitive function, neurogenesis, and metabolic regulation, thus highlighting its role in inter-organ crosstalk between muscle and brain (Pedersen & Febbraio, 2012). BDNF also plays a role in energy expenditure by promoting the browning of white adipose tissue and increasing uncoupling protein 1 expression, thereby enhancing thermogenesis (Chen et al., 2023). Furthermore, BDNF activates AMPK and acetyl-CoA carboxylase in skeletal muscle, which increases fatty acid oxidation and contributes to metabolic health and energy balance (Zhou et al., 2024). The systemic effects of muscle-derived BDNF extend to the regulation of glucose homeostasis and insulin sensitivity, establishing a crucial link between muscle activity and whole-body metabolic health. BDNF levels are known to increase after both moderate and high-intensity aerobic exercise in diverse populations, further underscoring the exercise-induced systemic effects of this myokine (Meiliana et al., 2024). Additionally, both Cathepsin B and irisin, also released from muscle, have been shown to cross the blood-brain barrier, stimulating BDNF production and promoting hippocampal neurogenesis (Severinsen & Pedersen, 2020). The ability of these myokines to traverse the blood-brain barrier and modulate BDNF expression highlights a significant mechanism by which skeletal muscle contributes to brain health and cognitive function (Kostka et al., 2024; Pedersen, 2019). Indeed, cathepsin B, an exercise-induced myokine, is essential for improvements in memory and adult neurogenesis through its ability to elevate hippocampal BDNF levels (Leuchtmann et al., 2021; Pedersen, 2019). Remarkably, despite the physiological induction of BDNF by endurance exercise, muscle-specific genetic ablation of BDNF has been shown to enhance running performance, potentially by fostering neuromuscular junction remodeling and a myosin heavy chain-IIB to MyHC-IIX fiber type transition (Leuchtmann et al., 2021). However, the precise mechanisms governing the interplay between muscle-derived BDNF and exercise adaptation, particularly in the context of fiber type specification and neuromuscular junction integrity, warrant further elucidation (MIKI et al., 2024). Moreover, the complex interplay between different cellular sources of BDNF, including myofibers, satellite cells, motoneurons, and endothelial cells within the skeletal muscle, further complicates the understanding of its systemic impact (Cefis et al., 2023; Kwatra et al., 2021). This complexity is further compounded by the observation that while muscle-derived BDNF contributes to systemic effects, its autocrine function within the muscle, particularly concerning neuromuscular junction physiology and metabolic flexibility, is also critically important (Rentería et al., 2022). Further research is necessary to fully delineate the specific contributions of each cellular source to circulating BDNF levels and their differential impact on brain function and metabolic regulation (Cefis et al., 2023). Understanding these nuanced contributions is crucial for developing targeted interventions that leverage the therapeutic potential of myokines for neurological and metabolic disorders. This is particularly relevant given that other neuroactive myokines, such as MCP-1, IL-6, and myostatin, also exhibit pleiotropic effects on brain health and neuroplasticity (McNeish et al., 2025). Thus, investigating the synergistic effects of these various myokines in concert, rather than in isolation, may provide a more comprehensive understanding of their collective impact on cognitive function and neurodegenerative disease progression (Gao et al., 2024).

In summary, muscle-derived myokines function as essential systemic mediators orchestrating a complex inter-organ communication network. IL-6 acts as a primary metabolic sensor, stimulating hepatic glucose production and adipose lipolysis while fostering a systemic anti-inflammatory environment. Irisin enhances metabolic rate by inducing the browning of white adipose tissue and supports skeletal integrity by promoting bone mineral density. Myostatin serves as a critical negative regulator of muscle hypertrophy, maintaining proteostatic balance, whereas BDNF facilitates the muscle-brain axis by promoting neurogenesis and cognitive plasticity alongside intramuscular fatty acid oxidation. Collectively, these signaling molecules integrate metabolic homeostasis, tissue regeneration, and neuroprotection.

Effects of Myokines on Exercise Performance

The intricate interplay of myokines released during physical activity significantly influences an individual’s capacity for exercise, encompassing aspects such as endurance, strength, and recovery (Farrash et al., 2021). This influence is mediated through diverse mechanisms, including the modulation of energy substrate utilization, angiogenesis, muscle fiber type transitions, and the systemic adaptation to exercise-induced stress. For instance, myokines such as IL-6 and irisin have been implicated in optimizing energy metabolism during prolonged exertion, influencing substrate partitioning and mitochondrial biogenesis, which are critical for sustained performance (Laurens et al., 2020). Additionally, the modulation of muscular force generation and fatigue resistance is a critical aspect influenced by myokine activity, thereby directly impacting an athlete's physical output and recovery kinetics. Furthermore, certain myokines contribute to muscle hypertrophy and regeneration processes, thereby facilitating adaptation to training stimuli and accelerating post-exercise recovery (Gao et al., 2024). For example, myostatin, a potent inhibitor of muscle growth, plays a critical role in regulating muscle mass and strength, with its suppression leading to enhanced hypertrophic responses and improved force production (Hałoń et al., 2019; Lee & Jun, 2019). Conversely, irisin has been shown to positively affect muscle mass and strength, acting in opposition to myostatin via the IGF-1/Akt/mTOR pathway (Śliwicka et al., 2021). This multifaceted role of myokines underscores their potential as therapeutic targets for enhancing athletic performance, mitigating muscle wasting conditions, and accelerating recovery from exercise-induced muscle damage (Severinsen & Pedersen, 2020; Vasyukova et al., 2021). Their diverse roles highlight the nuanced endocrine function of skeletal muscle, influencing systemic physiology and adaptation to physical stressors (Kostka et al., 2024). Acutely, both endurance and resistance exercise trigger the systemic release of a plethora of bioactive molecules, including proteins, metabolites, and microRNAs, that maintain metabolic homeostasis and coordinate the body's response to physical activity (Leuchtmann et al., 2021). These exercise-induced factors, collectively termed exerkines, are intricately regulated by the intensity, type, and duration of the physical activity, thereby orchestrating a complex physiological interplay (Zhou et al., 2024). This broad classification of exerkines encompasses myokines, hepatokines, and adipokines, among others, reflecting the multi-organ systemic response to exercise (Jin et al., 2024; Magliulo et al., 2021). Specifically, myokines are primarily derived from skeletal muscle and encompass a diverse array of molecules, including cytokines, growth factors, and peptides, which mediate autocrine, paracrine, and endocrine effects on various target organs (Picciotto et al., 2024). For example, myokines such as irisin, interleukin-6, and myostatin have been identified as key regulators of metabolic homeostasis, inflammatory responses, and skeletal muscle development (Borer et al., 2024; Zhou et al., 2024). Despite this comprehensive classification, the precise tissue sources of many exercise-induced plasma biochemicals remain unclear, even as research endeavors aim to localize exerkines more definitively (Robbins

& Gerszten, 2023). Elucidating these distinct tissue origins is paramount for understanding their specific roles in exercise physiology and their potential as therapeutic targets for various conditions (Pedersen & Febbraio, 2008). Their diverse roles highlight the nuanced endocrine function of skeletal muscle, influencing systemic physiology and adaptation to physical stressors. These exerkines, including those originating from skeletal muscle, adipose tissue, and other organs, collectively contribute to the multifaceted benefits of exercise, impacting cardiovascular health, cognitive function, and metabolic regulation (Chow et al., 2022; Walzik et al., 2024). This sophisticated network of inter-organ communication, mediated by these diverse exerkines, underscores the pervasive and systemic impact of physical activity on overall physiological resilience and disease prevention (Lu et al., 2025). Specifically, these organokines, including circulating microRNAs, lipids, and extracellular vesicles, facilitate intricate crosstalk between various tissues, such as the gut, immune system, and nervous system, thereby influencing a wide array of physiological processes (Magliulo et al., 2021; Verboven & Vechetti, 2023). The continuous discovery of novel exerkines and the elucidation of their complex signaling pathways represent a critical frontier in exercise physiology, promising to refine our understanding of exercise-induced adaptations and to identify new therapeutic targets for chronic diseases (Jia et al., 2023; Jin et al., 2024; Walzik et al., 2024).

The ongoing discovery of novel exerkines—now numbering in the hundreds and originating from diverse tissues such as skeletal muscle, adipose, liver, and others—and the elucidation of their intricate, multi-organ signaling pathways represent a pivotal frontier in exercise physiology (Jin et al., 2024; Robbins & Gerszten, 2023). This rapidly advancing field promises to profoundly refine our understanding of exercise-induced adaptations, including metabolic regulation, anti-inflammation, and tissue regeneration, while identifying novel therapeutic targets for chronic diseases like obesity, type 2 diabetes, neurodegeneration, and osteoarthritis (Jia et al., 2023; Jin et al., 2024; Pedersen & Febbraio, 2008; Severinsen & Pedersen, 2020; Vasyukova et al., 2021; Walzik et al., 2024). A comprehensive understanding of these organokines and their cargo systems is crucial for deciphering the mechanistic insights behind inter-organ communication and formulating targeted preventive or therapeutic strategies (Magliulo et al., 2021; Zhou et al., 2024). However, despite significant progress, the functional allocation of many myokines in humans remains limited, necessitating further research into fiber type-specific myokine signatures and their autocrine and paracrine actions (Eckel, 2019). Furthermore, investigating the systemic transport mechanisms of these exerkines, including their carriage via extracellular vesicles, is essential for a complete understanding of their distal effects and the intricate crosstalk between distant organs (Magliulo et al., 2021). This includes detailed analysis of their spatiotemporal release patterns and their interactions with various receptor systems to fully delineate their physiological impact (Magliulo et al., 2021). Indeed, extracellular vesicles have emerged as crucial mediators of intercellular communication, transporting a diverse cargo of proteins, nucleic acids, and lipids between cells and playing a significant role in the systemic responses to acute exercise bouts (Robbins & Gerszten, 2023; Verboven & Vechetti, 2023). These vesicles, particularly exosomes, are hypothesized to facilitate interorgan cross-talk by delivering specific exerkines to distant tissues, thereby coordinating systemic adaptations to endurance exercise (Safdar & Tarnopolsky, 2017). Many of these exerkines are indeed contained within exosomes and other microvesicles, which further highlights their role in promoting inter-organ communication and systemic benefits of exercise (Safdar & Tarnopolsky, 2017). The existing, albeit scant, data suggest that exosomes and small microvesicles are released into circulation in response to acute endurance exercise in an intensity-dependent manner, carrying many of the currently reported myokines and exerkines (Safdar & Tarnopolsky, 2017). This exercise-rich exosomal cargo, which increases with exercise intensity, can potentially modulate metabolic health and mitigate inflammation across various tissues (Huang et al., 2024; Zhou et al., 2024). Consequently, exploring the intricate mechanisms governing exerkine encapsulation within extracellular vesicles and their subsequent targeted delivery to distant tissues will be crucial for deciphering the full spectrum of exercise-induced systemic adaptations (Fischetti et al., 2023). Furthermore, the identification of the source tissue for these exerkines has become increasingly feasible due to methodological advances in untargeted and targeted mass spectrometry, metabolomic, proteomic, and lipidomic analyses (Walzik et al., 2024). Future research should focus on leveraging these advanced "omics" platforms to profile the complex alterations in exerkine compositions and extracellular vesicle cargo in response to diverse exercise modalities, thereby moving beyond the study of singular factors to a more holistic understanding of inter-organ communication (Chow et al., 2022; Robbins & Gerszten, 2023). This comprehensive approach will enable a more precise characterization of existing and novel exerkines, including their sources, targets, transport mechanisms, and biological roles, across varied populations, exercise frequencies, intensities, times, and types (Magliulo et al., 2021). This comprehensive characterization is vital for defining the optimal "FITT" paradigm of exercise training to achieve consensus about exerkine regulation and to develop patient-oriented, evidence-based interventions (Magliulo et al., 2021). However, limitations still exist in fully characterizing the global exerkine dynamics and their interactions with various target tissues, especially concerning the effects of aging and chronic metabolic diseases on exosome biology and circulating exosomal biomarkers (Safdar & Tarnopolsky, 2017; Walzik et al., 2024). Hence, further investigation into the dynamic interplay between exercise, aging, and exosome profiles is warranted to unlock the full therapeutic potential of exercise mimetics (Magliulo et al., 2021; Pinto et al., 2024).

5. Clinical and Practical Applications

The burgeoning understanding of exerkines offers substantial promise for developing innovative diagnostic, prognostic, and therapeutic strategies across a spectrum of health conditions. For instance, modulating exerkine levels could offer targeted interventions for cardiometabolic disorders, neurological impairments, and even cancer cachexia, where direct tissue measurements and a broader exploration of exerkines like GDF15 are recommended (Hekmatikar et al., 2023). Given its role as a stress-responsive cytokine and its association with cardiovascular disease and metabolic improvement following aerobic exercise, GDF-15 may emerge as a significant therapeutic target or biomarker (Magliulo et al., 2021). However, challenges remain in translating these findings, as many promising results from rodent studies have not been replicated in humans due to environmental factors, sex differences, and evolutionary biology (Robbins & Gerszten, 2023). Thus, despite compelling preclinical evidence, the direct application of exerkine-based therapies in clinical settings necessitates rigorous validation in human cohorts to confirm efficacy and safety (Walzik et al., 2024). Using exercise-derived exerkines or their mimetics as therapeutic agents requires careful evaluation of optimal dosages, delivery methods, and potential off-target effects. Consequently , large human studies across diverse populations and exercise modalities are crucial to validate the clinical utility of exerkines and overcome current limitations in translational research (Robbins & Gerszten, 2023).

Conclusion

In conclusion, the emerging field of exerkine research has profoundly reshaped our understanding of skeletal muscle as a dynamic endocrine organ, orchestrating systemic physiological adaptations to physical activity.

This evolving paradigm highlights the intricate molecular mechanisms by which muscle contraction initiates a complex cascade of inter-organ communication, influencing metabolism, inflammation, and cellular homeostasis throughout the body. While some myokines like IL-15 have demonstrated anabolic effects and roles in modulating adipose tissue, suggesting their classification as potential myokines involved in muscle-fat cross-talk, others like growth differentiation factor 15 have been identified as exerkines, yet their primary source may not always be skeletal muscle, pointing to a broader inter-organ secretome (Magliulo et al., 2021; Pedersen & Febbraio, 2008). Further investigation into the precise cellular origins and target tissues of these diverse exerkines is essential for fully delineating their individual and synergistic contributions to exercise-induced health benefits (Laurens et al., 2020). Moreover, while IL-15 has multifaceted functions, including resistance to diet-induced adiposity and increased bone mineral content in genetic overexpression models, and a clear role in attenuating skin aging via mitochondrial biogenesis, a direct mechanistic link between exercise-induced IL-15 secretion and reductions in human fat mass is still largely underexplored (Walzik et al., 2024). Further studies are warranted to bridge the gap between observed effects in animal models and human physiology, particularly to delineate the specific mechanisms by which IL-15 influences adipose tissue metabolism in humans (Laurens et al., 2020). Furthermore, while interleukin-6 remains the most extensively studied myokine, with clear evidence of its exercise-induced secretion and pleiotropic effects, the precise molecular pathways governing its release and subsequent systemic actions warrant further comprehensive elucidation (Carey & Kingwell, 2009).

Despite their relatively recent emergence in the literature, myokines—and more broadly, exerkines—are poised to revolutionize exercise sciences by expanding our understanding of skeletal muscle as an endocrine organ that orchestrates inter-organ communication, while enabling innovative diagnostic, prognostic, and therapeutic strategies across diverse health conditions (Chow et al., 2022; Pedersen & Febbraio, 2008; Robbins & Gerszten, 2023).

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ENHANCING QUALITY OF LIFE THROUGH PHYSICAL ACTIVITY IN INDIVIDUALS WITH INTELLECTUAL DISABILITIES

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Introduction

Children with intellectual disabilities are children who cannot use their ability to perceive the stimuli in their environment, evaluate what is perceived, conceptualize, think, learn, and make connections between what is learned and experiences, and try to live in their own world (Kurt et al., 2008). Intellectual disability is also defined by an inability in the individual's ability to adapt to his or her environment and perform daily living skills. This includes social skills, communication and activities of daily living. Intellectual disability occurs during the developmental period, i.e. from birth to approximately 18 years of age (Borthwick-Duffy, 2001; Sapna, 2019). Intellectual disability can result from a variety of causes, including genetic disorders, environmental influences, lack of prenatal care and toxic exposures (Chelly et al., 2006). These individuals with learning disabilities face difficulties in areas such as adaptation to society, communication, social relations and daily living skills (Chyzhyshyn, 2022).

Trainings implemented to overcome the difficulties experienced by individuals with intellectual disabilities are of great importance in terms of improving the quality of life of these individuals and ensuring their better integration into society (Aller et al., 2023; Kelley et al., 2023). Trainings for individuals with intellectual disabilities can improve their quality of life by supporting their cognitive and behavioral development. These trainings help individuals to become more independent in daily life and improve their social skills, while also providing important benefits for families and support staff. For trainings to be effective, a personalized and continuous approach should be adopted (Danielsson et al., 2015; Roording-Ragetlie et al., 2023).

Physical activity is recognized as a beneficial intervention that improves individuals with intellectual disabilities. Participation in physical activity and sports reduces behavioral and emotional problems, improves executive functions, increases overall quality of life, improves general health, improves

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self-efficacy and quality of life, and improves social skills and self-perception (Jakubowska et al., 2024; Su et al., 2022).

In this chapter, the effects of physical activity on the cognitive, social and emotional development of individuals with intellectual disabilities and its contributions to their quality of life will be discussed comprehensively. In the light of the existing literature, the effects of physical activity on the psychosocial adaptation processes, executive functions and general well-being of these individuals will be evaluated; in addition, suggestions for increasing the effectiveness of this process will be discussed.

Intellectual Disability

Intellectual disability can be defined as an individual's performance significantly below average in cognitive functions, which leads to permanent limitations in areas such as daily life skills, social interaction, adaptation, health and safety. This situation, which emerges with the interaction of environmental, genetic and social factors, can affect the individual's ability to adapt to new and complex situations, to remember what they have learned and to solve problems (Bertelli et al., 2022).

Individuals with intellectual disabilities may face various difficulties in the process of meeting the expectations of the society, as is the case with individuals belonging to other disability groups. These individuals may have difficulty in adapting to the requirements of daily life not only in the cognitive field but also physically. This situation may create various obstacles in their interactions with the social environment and their adaptation to society, making their adaptation difficult (İlhan & Esentürk, 2015).

Classification of Intellectual Disability

Classifying individuals with intellectual disabilities and identifying their differences is important for determining the support services they will receive and gaining the necessary life skills (Kurt, 2020). International classification systems such as DSM-5 and ICD-11 classify intellectual disability under different categories. These systems consider intellectual disability together with other psychiatric disorders, allowing it to be evaluated in a broader context (Ullah et al., 2020).

Scientifically, people with intellectual disabilities are categorized into 4 categories: mild, moderate, severe and profound intellectual disabilities. In this categorization, the level of disability of people with intellectual disabilities is determined according to IQ (Intelligence Quotient) test scores (Kayrak, 2014). As the intelligence scores of individuals with intellectual disabilities decrease, their level of intellectual disability increases. For this reason, it becomes difficult to integrate individuals with low intelligence scores into living conditions and integration into society. The mental disability classifications of these individuals according to their intelligence scores are given in the table below.

Table 1: Classification of intellectual disability according to intelligence level

Disability Group	Intelligence Score
Mild intellectual disabilities	69-50
Moderately intellectually disabled	49-35
Severe intellectual disability	34-20
Profound (very severe) intellectual disability	19-0

Causes of İntellectual Disability

The causes of intellectual disability are based on a variety of factors, including genetic, environmental and infectious factors. These factors can have different proportions of influence in different types and degrees of severity of intellectual disability. Most people experience mild intellectual disability and in this group a specific biological cause is less likely to be identified. However, in cases of severe and profound intellectual disability, specific biological causes such as genetic abnormalities, metabolic disorders and brain malformations are more common (Patel et al., 2020).

In the literature, the main factors that cause intellectual disability are explained as follows.

- ✓ Hereditary factors,
- ✓ Chromosomal disorders such as Down syndrome, metabolic disorders such as phenylketanuria and some genetic disorders,
- ✓ Unconscious use of drugs, drugs, alcohol and smoking by the mother during pregnancy,
- ✓ Infectious diseases such as rubella, toxoplasma and exposure to radiation during pregnancy,
- ✓ Poisoning of the mother during pregnancy, inadequate nutrition and oxygen deprivation of the baby,
- ✓ Infectious diseases that the baby has in the womb during pregnancy, blood incompatibility between the child and mother and consanguineous marriage,
- ✓ Premature or late delivery, cord entanglement, oxygen deprivation of the baby during difficult deliveries as it passes through the birth canal,
- ✓ Miscarriage of the baby, damage to the baby by birth devices, delivery in unhygienic conditions,
- ✓ Failure to provide appropriate treatment for certain diseases such as measles and whooping cough,

- ✓ Central nervous system disorders such as encephalitis, meningitis, convulsions, severe jaundice, thyroid hormone deficiency,
- ✓ Lack of adequate and balanced nutrition of the baby,
- ✓ Environmental factors such as indifference, lack of maternal love, child abuse, lack of stimuli (Şahin & Şahin, 2020).

Quality of Life in Intellectual Disabled Individuals

Quality of life is a multidimensional concept that refers to individuals' perception of their lives in relation to their goals, expectations, standards and concerns within the framework of their cultural and value systems. This concept is influenced by various factors such as physical health, psychological state, social relationships, environmental factors and spiritual beliefs (Panzini et al., 2017; Soyuer & Varol, 2019).

The quality of life in individuals with intellectual disabilities is affected by different variables compared to the general population, and especially social support, economic status, psychological health and functional abilities come to the fore (Matsumoto et al., 2024). The fact that individuals with disabilities need some services more than healthy individuals, face various disabilities and the negative effects of environmental factors can change the priorities that determine the quality of life.

In this context, the main factors shaping the quality of life of individuals with intellectual disabilities are as follows:

- ✓ Emotional well-being (feelings of happiness and confidence),
- ✓ Level of relationship with family and close friends,
- ✓ Economic conditions of the individual or their family,
- ✓ Employment and work opportunities,
- ✓ The degree of disability and the skills the individual has,
- ✓ Access to education and health services,
- ✓ Living environment and social opportunities,
- ✓ Ability to move independently in daily life,
- ✓ Opportunities to participate in social events.

A better understanding of the effects of all these factors on the quality of life of individuals with intellectual disabilities is of great importance in terms of developing effective strategies to improve the living standards of these individuals. The use of quality of life approach for individuals with intellectual disabilities has been increasing in recent years. In order to improve the quality of life of individuals with disabilities, they should be approached with empathy. Acting from the perspective of individuals with special needs, creating policies to meet their needs and providing services to reduce their difficulties in social life are very important in improving their quality of life (Öztabak, 2017).

It is important to strengthen social support systems and improve income level in order to increase the quality of life in people with intellectual disabilities. While social support positively affects quality of life by increasing social integration and psychological well-being of individuals, income level is a factor that directly affects quality of life. Individuals with low income levels may experience more difficulties in accessing health services, education and rehabilitation programs and may experience a decrease in their quality of life. Therefore, social support and economic conditions need to be improved to improve the quality of life of individuals with intellectual disabilities (Defar et al., 2023; Wu et al., 2024). Another factor that negatively affects the quality of life in these individuals is psychological and cognitive health. While depression and cognitive disorders reduce quality of life, factors such as social support and physical activity can provide positive effects. These findings emphasize the importance of targeted interventions to improve the quality of life of individuals with intellectual disabilities (Sánchez-Alcalá et al., 2024; Zahra et al., 2022).

Various strategies and interventions have been proposed to improve the quality of life of individuals with intellectual disabilities and these strategies aim to meet the physical, psychological and social needs of individuals. Studies showing that psychological support, lifestyle interventions, mindfulness-based interventions, behavioral interventions to improve daily living skills, and educational content such as regular physical activity positively affect the quality of life of these individuals are included in the literature (Egger et al., 2024; Jang et al., 2023;). Although the positive contributions of physical activity to quality of life are well documented, it is observed that it is not sufficiently prioritized in intervention programs for individuals with intellectual disabilities.

Physical Activity

Health-related quality of life is an indicator of the physical, social and mental effects of diseases on the individual, and physical activity and health are in a linear relationship. Physical activity is defined as “all body movements that occur in daily life and require energy, which occur with the contraction of skeletal muscles in the body” (Azboy, 2021).

Some sports branches that include all or part of certain body movements such as walking, running, jumping, swimming, cycling, active movements of the legs and arms, and active movements of the head and neck, dance, exercise, games and all activities in daily life are seen as part of physical activity (Azboy, 2021), and all these physical activities are a basic element that plays an important role in protecting the physical and mental health of individuals. Therefore, making physical activity an integral part of daily life is of great importance to maintain a healthy and balanced life.

For individuals with intellectual disabilities, physical activity is an important element that supports the development of both physical and cognitive functions. In order to encourage the participation of these individuals in physical activity, programs that are structured according to their individual needs should be developed and social barriers should be eliminated. Such interventions not only contribute to the improvement of motor skills and physical health, but also positively affect psychosocial well-being and general quality of life by increasing social interactions.

Relationship Between Regular Physical Activity and Quality of Life In Mentally Disabled Individuals

People with intellectual disabilities face various challenges in social, cognitive and physical domains. Social relationships and support have a significant impact on the mental health and overall quality of life of these individuals. Cognitive and physical disabilities can lead to loss of independence in activities of daily living (Ai et al., 2024; Steptoe & DiGessa, 2021). There is a relationship between gross motor function levels and independence levels of these individuals and quality of life. The level of motor functioning affects the quality of life not only of individuals but also of their caregivers (Barış & Bayram, 2020). Improving the quality of life of these individuals supports their better integration into society and personal development. Therefore, improving quality of life should be an important goal at both individual and societal levels.

In order to increase the quality of life, it is of great importance to include individuals in educational programs that will contribute to their multidimensional development instead of unidirectional approaches. Planning these programs in accordance with the needs of individuals and maintaining them regularly will be a supportive factor in their development processes. In this respect, physical activity programs can be considered as an effective educational model that contributes to both physical and cognitive, emotional and social development of individuals. The effects of physical activity on different areas of development are discussed in detail below.

The Effect Of Physical Activity On Cognitive Skills

Cognitive skills are mental abilities that enable individuals to be successful in problem solving, information processing and learning processes. These skills include various components such as acquiring and organizing information, representing problems, creating mental models, and developing cognitive strategies (Fe et al., 2020). Individuals with intellectual disabilities have significant difficulties in executive functions and cognitive processes. Poor executive functions lead to various problems in areas such as effective use of information, management of activities of daily living, social participation and behavior regulation. This situation may negatively affect the overall quality of life by making it difficult for individuals to acquire independent living skills. Therefore, interventions to support the cognitive skills of individuals with intellectual disabilities are of great importance not only for academic and social development but also for improving their quality of life by increasing their independence (Wolf et al., 2022).

Studies in the literature show that physical activity-based intervention programs can reduce behavioral problems by supporting cognitive skills in individuals with intellectual disabilities, improve working memory and visual-spatial processing, and thus positively improve daily living skills and quality of life (Koper et al., 2024; Pamuk et al., 2022).

Effects Of Physical Activity On Social Skills

Social skills are the ability of individuals to communicate and interact effectively with others. These skills enable the individual to function competently in social tasks and are often associated with communication and interaction. Social skills include various abilities such as communication, emotion regulation, cognitive skills, and social problem solving that enable individuals to be successful in social interactions (Grover et al., 2020). Social skills in individuals with intellectual disabilities are an important factor affecting their participation and adaptation to social life. Social skills deficiencies and excesses are considered to be determinants of intellectual disability, and the development of these skills can improve the quality of life of individuals.

Social skills of individuals with intellectual disabilities are more limited compared to their typically developing peers. Stereotypic and problematic behaviors negatively affect the basic components of social skills such as communication and interaction, limiting the social competence of these individuals (Matson et al., 2006). Social skills directly affect not only interpersonal relationships but also various developmental domains such as peer acceptance, academic achievement and psychological well-being (Soto Icaza et al., 2015). Another important developmental area closely related to social skills is motor skills. Motor skills play a critical role in social cognition, language development and social interaction processes and are considered as an indicator of social communication skills (Smith et al., 2018).

Programs such as physical activity and movement training have positive effects on various social skills in individuals with intellectual disabilities. These practices improve cooperation skills such as following instructions, making friends, participating in group activities and helping others. They also support self-control skills such as anger management, waiting for one's turn and a positive approach to criticism. In addition, it contributes to the reduction of externalized behaviors such as tantrums, hyperactivity, maladaptive behaviors and non-compliance with rules. Improvements in these skills reveal positive development in social skills (Hatipoğlu Özcan et al., 2024).

Some studies in the literature show that regular physical activity programs have positive effects on behavioral and emotional problems, mental health and psychosocial well-being (Borland et al., 2021); by increasing perceived control, competence and self-esteem, this supports psychological well-being by allowing individuals to have more control in their lives and provides positive effects on social functioning (Reinders et al., 2019).

Effects Of Physical Activity On Motor Skills

Motor skills refer to a person's ability to plan and perform movements. These skills improve with practice, increasing the spatial and temporal accuracy of movements (Lukman & Neviyarni, 2021). Motor skill performance is lower in individuals with intellectual disabilities compared to their typically developing peers. They experience significant deficits in skills such as running speed, balance, strength, visual motor control (Pahlevanian et al., 2012). The fact that individuals with intellectual disabilities are physically limited and there are not enough adapted sports activities causes them to stay away from sportive activities and it is thought that their quality of life is negatively affected.

Motor skills are linked to daily living skills, which have an important place in living an independent life, and poor motor skills negatively affect individuals' lives. Improved motor skills can increase the ability to fulfill daily functions and thus affect the quality of life. Thus, with the development of motor skills in individuals with intellectual disabilities, we can increase both other areas of development and quality of life (Travers et al., 2017).

Physical activity programs are one of the intervention programs that significantly improve the development of fine and gross motor skills in individuals with intellectual disabilities. These programs contribute to the development of important skills related to daily life such as strength, balance, coordination, agility and improvement of general health (Đorđević et al., 2024). There are many studies in the literature that support this information. In general, physical activity is a valuable intervention to improve motor skills in individuals with intellectual disabilities. Therefore, it is important for the quality of life of individuals with intellectual disabilities that physical activity is an indispensable part of their lives and that it becomes a lifelong philosophy.

Effects Of Physical Activity On Physical Health

Being healthy is defined as a state of complete physical, mental and social well-being and does not simply mean the absence of disease or disability. A healthy lifestyle includes habits such as a balanced diet, regular exercise, tobacco and alcohol control and psychological balance. This lifestyle accounts for 60% of the factors that significantly influence individuals' health and life expectancy (Vercammen et al., 2021).

People with intellectual disabilities face significant health problems, including obesity, cardiovascular problems and musculoskeletal problems, in addition to mental and social problems. These health problems are exacerbated by lifestyle factors, inadequate access to health services and a focus on intellectual disabilities that overshadows physical health problems.

People with intellectual disabilities are more likely to be obese than the general population due to factors such as low levels of physical activity and poor diet. This physical inactivity and obesity contributes to musculoskeletal problems that are often not adequately addressed. In addition, the fact that all these physical health factors are overshadowed by mental problems increases the rate of cardiovascular problems in these individuals (Stanley & Laugharne, 2012).

Regular physical activity or exercise programs have an important contribution to the process of preventing or improving these physical health problems in individuals with intellectual disabilities. Physical activity can help prevent obesity by reducing metabolic risk factors. This is achieved by reducing body fat and improving overall metabolic health. Regular physical activity can also reduce the risk of cardiovascular disease. This is achieved by influencing the biological and psychosocial processes that support heart health. In addition, physical activity supports musculoskeletal health and can improve mobility in these individuals. This can reduce the risk of falls by increasing muscle strength and flexibility (Stubbs, 2021).

Therefore, it is of great importance for individuals with intellectual disabilities to regularly participate in physical activity to improve their daily living skills and increase their overall quality of life. It is recommended that individuals with intellectual disabilities should be included in physical activity and exercise programs that include movement and that these programs should be regular and tailored to the individual in order to improve physical health and increase quality of life.

Conclusion

This study examined the effects of physical activity on quality of life in individuals with intellectual disabilities and revealed that regular physical activity contributes significantly to the multidimensional development of individuals. According to the findings of the study, physical activity not only improves motor skills, but also supports individuals' psychological well-being, increases their social interactions and strengthens their independent living skills. In addition, physical activity programs help individuals with intellectual disabilities to achieve emotional balance, reduce stress levels and improve their self-confidence.

Improving quality of life is not limited to physical health, but encompasses many factors such as an individual's social relationships, level of independence, emotional stability and integration into society. While physical activity enables the individual to be more active in daily life, it can contribute to economic independence by supporting participation in the workforce. At the same time, regular exercise programs can help individuals with intellectual disabilities to be more involved in social life, reducing the feeling of isolation and loneliness.

In this direction, it is seen that physical activity is an effective tool to improve the quality of life of individuals with intellectual disabilities. However, it is of great importance that these programs are planned by taking individual differences into consideration, guided by experts and implemented sustainably. The cooperation between educators, families and health professionals should be increased to make physical activity an integral part of the daily life of the individual. In conclusion, it is emphasized that physical activity should be considered as a multidimensional intervention tool to improve the quality of life of individuals with intellectual disabilities.

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ARTIFICIAL INTELLIGENCE, HUMAN–MACHINE INTERACTION, AND DIGITAL TRANSFORMATION IN DISABILITY SPORTS

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Introduction

Advances in artificial intelligence, digital technologies, and human–machine interaction systems have led to significant transformations in sports sciences and rehabilitation. Smart prostheses, wearable sensors, data analytics, and adaptive rehabilitation systems are reshaping the athletic performance and sports participation processes of persons with disabilities. In this context, disability sports have evolved beyond a solely rehabilitation-oriented field into a multidimensional domain encompassing performance, technology, psychosocial adaptation, and ethical discussions.

Artificial intelligence-supported systems provide important contributions in areas such as performance analysis, injury prevention, rehabilitation, and communication support. However, technological developments also raise issues related to competitive equity, data privacy, and ethical use. This chapter examines the historical transformation of disability sports and the role of artificial intelligence and human–machine interaction in sports performance and rehabilitation processes.

1. Historical Transformation and Paradigm Shift in Disability Sports

1.1. Historical Epistemology and Paradigm Shift

The historical development of disability sports is closely associated with epistemological transformations concerning the conceptualization of disability. This transformation has evolved from the medical model, which primarily positioned the disabled individual as "a patient requiring treatment," toward approaches that place social participation and individual capacity at the center (Oliver, 1990; Shakespeare, 2013). In this context, sport has ceased to function merely as a rehabilitative instrument; it has also become a central domain for identity construction, social visibility, and the production of elite performance (Howe, 2008).

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1.1.1. The Medical Paradigm and the Emergence of Rehabilitation

The high number of neurological and orthopedic injury cases that emerged after World War II necessitated the development of innovative approaches in rehabilitation processes. During this period, the approach developed by Ludwig Guttmann enabled the use of sport as an active rehabilitation tool in place of passive treatment methods. The studies initiated by Guttmann at Stoke Mandeville Hospital in 1944 demonstrated that sport had an impact not only on physical recovery but also on psychosocial adaptation (Guttmann, 1976).

The Stoke Mandeville Games, organized in 1948, are regarded as the origin of the modern Paralympic movement and mark the first step in transforming sport from a therapeutic instrument into a competitive structure (Bailey, 2008). During this period, the primary objectives of sport were to enhance individuals' functional capacity, support independent living skills, and improve quality of life.

1.1.2. Social Identity and Competitive Transformation

With the 1960 Rome Paralympic Games, disability sports began to transform from a rehabilitation-oriented structure into a competition-based sporting domain. This transformation contributed to the redefinition of the social roles of persons with disabilitiesand supported processes of self-efficacy, identity construction, and social visibility through sport (Brittain, 2016). In this process, sport strengthened the social participation and processes of agency formation of persons with disabilities. Simultaneously, the institutionalization of disability sports accelerated with the establishment of federations dedicated to different disability groups (Howe, 2008).

1.1.3. Elite Performance and the Scientific Transformation of Disability Sports

The establishment of the International Paralympic Committee (IPC) in 1989 constituted a major milestone in the professionalization of disability sports. During this process, athlete classification began to be based not only on the type of disability but also on functional capacity (Tweedy & Vanlandewijck, 2011).

Functional classification systems aim to enhance competitive equity by evaluating athletes through biomechanical parameters such as muscle strength, range of motion, and coordination (Vanlandewijck & Thompson, 2011). This approach has increased the significance of biomechanical and physiological performance measurements in Paralympic sports sciences.

1.1.4. Digital Transformation and Human–Machine Integration

The development of artificial intelligence and data analytics technologies after 2010 contributed to the emergence of new approaches to performance analysis in disability sports. In this process, athlete performance began to be evaluated not only through biological capacity but also through technological integration and data-driven analyses (Rum et al., 2021).

Smart prosthetic systems, through sensor fusion and machine learning algorithms, analyze the athlete's movement intention in real time and contribute to the enhancement of movement efficiency (Farina & Aszmann, 2014). The development of technological prostheses and performance-enhancing systems has sparked discussions of the "cyborg athlete" in the sports literature (Butryn, 2003). In this context, performance in sports sciences is understood as the dynamic interaction among biological, technological, and environmental factors.

2.Human–Machine Synergy in Sports and Smart Prosthetic Technologies

2.1. Definition and Technological Evolution of Smart Prostheses

While traditional prosthetic systems were designed as passive structures based on the principle of mechanical energy storage and return, modern smart prostheses have evolved into cyber-physical systems capable of dynamic adaptation through the integration of sensor data, artificial intelligence, and control systems (Farina & Aszmann, 2014; Herr & Grabowski, 2012). This transformation has moved prostheses beyond being merely "limb substitutes," turning them into adaptive performance components that continuously exchange data with the user. From a sports science perspective, this shift necessitates evaluating performance not only through biological parameters but also through human–machine interaction and technological support systems (Young & Ferris, 2016).

2.2. Neuromechanical Architecture of Smart Prostheses: "Sense–Think–Act.

Modern smart prosthetic systems consist of three fundamental layers:

2.2.1. Sensor Layer (Perceptual System)

This layer collects biological and environmental data. Electromyography (EMG) signals indicate muscle activation, while inertial measurement units (IMUs) measure angular velocity and acceleration. Force sensors determine ground reaction force (GRF). EMG signals are among the primary data sources in prosthetic control, as they reflect superficial electrical activity of motor units (Farina & Aszmann, 2014). Sensor fusion techniques enhance movement accuracy by integrating data from multiple sources (Pizzolato et al., 2017).

2.2.2. Artificial Intelligence Control Layer (Cognitive System)

This layer interprets biosignals to predict movement intention. Machine learning algorithms used in this context include pattern recognition, deep learning, and adaptive control approaches. In EMG-based control systems, pattern recognition-based models classify muscle activation patterns to enable the prosthesis to generate appropriate movements (Scheme & Englehart, 2011). In more advanced systems, brain–computer interfaces (BCIs) provide direct control through cortical signals (Lebedev & Nicolelis, 2006). This approach facilitates more direct transmission of movement commands and enhances user–prosthesis interaction.

2.2.3. Actuator Layer (Motor System)

This layer is responsible for generating mechanical movement. Microprocessor-controlled motors, hydraulic or pneumatic systems, and adaptive joint mechanisms are incorporated within this layer. These systems dynamically regulate torque and force via real-time data processing, thereby supporting biomechanical efficiency in movement and gait control (Au & Herr, 2008).

2.3. Biomechanical Optimization and Performance Analysis

The impact of smart prostheses on sports performance is primarily evaluated in terms of energy efficiency and movement symmetry.

2.3.1. Energy Storage and Return (ESR) Mechanism

Carbon fiber prostheses operate according to the principle of energy storage and return (ESR). These systems contribute to more efficient management of ground reaction forces, thereby improving step economy and reducing metabolic cost. Research indicates that appropriately designed prostheses can enhance both walking and running economy (Herr & Grabowski, 2012).

2.3.2. Asymmetry and Movement Synchronization

One of the primary determinants of performance in athletes with prostheses is bilateral movement symmetry. Data-driven analysis and adaptive control systems evaluate right–left load distribution, detect differences in joint angles, and support movement coordination. Gait asymmetries and altered load distributions are reported to be associated with long-term biomechanical complications; therefore, improving movement symmetry is considered important for enhancing performance stability and reducing injury risk (Highsmith et al., 2016).

2.4. Transformation of Intention into Mechanics: Advanced Control Systems

2.4.1. EMG-Based Machine Learning

EMG signals represent muscle contraction patterns and are classified through machine learning algorithms. These systems enable the prediction of movement intention and aim to improve classification accuracy through pattern recognition-based approaches (Scheme & Englehart, 2011).

2.4.2. Brain–Computer Interfaces (BCIs)

BCI systems directly convert signals obtained from the motor cortex into mechanical movement. This approach reduces dependence on muscle activation and enables a more direct control mechanism between the user and the prosthetic system (Lebedev & Nicolelis, 2006).

2.5. Expanding Ecosystem: Orthoses and Smart Wheelchair Systems

Artificial intelligence is not limited solely to prosthetic technologies. Robotic orthoses provide joint support and rehabilitation integration, while smart wheelchairs feature autonomous navigation, obstacle detection, and dynamic balance control. These systems contribute not only to athletic performance but also to greater independence in daily life (Cooper et al., 2008).

2.6. Ethical Dimension: Technological Doping and the Limits of Performance

The performance-enhancing potential of smart prostheses has generated significant debates in sports ethics. The concept of “technological doping” focuses on whether prostheses provide advantages compared to biological limbs (Camporesi, 2008). This debate is conducted within the framework of biomechanical advantage, metabolic efficiency, and inequalities in access to technology. Some studies suggest that prostheses may provide performance advantages under certain conditions; however, it is emphasized that this issue should be evaluated in relation to the specific sport discipline, movement pattern, and individual differences (Dyer, 2015).

3. Human–Machine Synergy and Artificial Intelligence Solutions in Rehabilitation

3.1. Epistemological Transformation in Rehabilitation: From Subjective to Objective

Traditional rehabilitation approaches have largely relied on clinical observation, manual assessment, and expert experience. Although these methods are valuable for clinical expertise, they have limitations in detecting subtle biomechanical changes in movement patterns (Liao et al., 2020).

Artificial intelligence-supported systems, however, transform rehabilitation processes from subjective evaluations into objective, measurable, and data-driven structures. This transformation strengthens the integration between performance analysis and rehabilitation processes within sports sciences (Boukhennoufa et al., 2022).

3.1.1. Comparison of Traditional and AI-Supported Approaches (Academic Model)

Parameter	Traditional Approach	AI-Supported Approach
Data Source	Clinical observation and palpation	Sensor fusion and motion analysis
Evaluation	Intermittent and subjective	Continuous and objective
Risk Detection	Post-symptom	Early pattern analysis
Decision-Making	Expert experience	Data-supported decision systems

This transformation provides significant contributions, particularly in the early detection of movement asymmetries and the evaluation of biomechanical risk factors associated with performance (Bini & Hume, 2014).

3.2. Technical Architecture of AI-Supported Rehabilitation Systems

Artificial intelligence-supported rehabilitation systems generally operate through three fundamental stages: data collection, data processing, and feedback. In the first stage, wearable sensors (IMU, EMG), optical motion analysis systems, and force platforms are used to analyze the athlete's movements with high precision (Muro-De-La-Herran et al., 2014).

In the second stage, the collected data are processed through machine learning algorithms. During this process, movement patterns are analyzed, abnormalities are detected, and performance predictions are generated. Deep learning models, in particular, can provide effective classification and pattern recognition performance in the analysis of complex biomechanical data (Liao et al., 2020).

In the final stage, visual, auditory, and haptic feedback systems are activated, enabling athletes to recognize incorrect movements in real time and supporting movement correction processes (Sigrist et al., 2013).

3.3. Virtual Reality, Biofeedback, and Adaptive Exercise

The integration of virtual reality (VR) and artificial intelligence occupies an important place in rehabilitation processes. VR-based applications support repetitive movements, thereby facilitating motor learning processes, contributing to adaptive processes associated with neuroplasticity, and assisting in the improvement of motor control. These systems have been shown to be particularly effective in neurological rehabilitation (Laver et al., n.d.).

In addition, AI-supported biofeedback systems analyze joint angles and provide real-time notifications of incorrect movements to the user, thereby supporting the learning of accurate movement patterns. Consequently, these systems may contribute to the enhancement of learning processes and movement accuracy (Sigrist et al., 2013).

Furthermore, adaptive exercise systems automatically adjust difficulty levels according to the athlete's performance, thereby contributing to the reduction of overload risk and supporting individualized rehabilitation processes. This approach is directly associated with the concept of "load management" in sports sciences.

3.4. The Use of Artificial Intelligence in Sports Injuries: The ACL Example

In anterior cruciate ligament (ACL) injuries, which constitute a major example within sports rehabilitation, biomechanical analysis and data-driven assessment systems play a critical role. These systems measure force differences between the right and left sides, analyze joint angles, and evaluate load distribution. The resulting data contribute to more reliable return-to-sport decisions (Paterno et al., 2010). Moreover, data-driven analytical approaches are increasingly being utilized for injury risk prediction and performance forecasting (Claudino et al., 2019).

Additionally, the early detection of asymmetric loading enables the development of preventive exercise programs aimed at reducing the risk of secondary injuries. This approach is considered one of the major components of injury prevention strategies in modern sports sciences.

3.5. Psychosocial Dimension: Motivation and Behavioral Adaptation

Artificial intelligence-supported systems may influence not only physical but also psychological processes. Applications such as gamification, performance tracking, and digital goal-setting can support exercise adherence and motivation (Johnson et al., 2016). According to self-determination theory, individuals' sense of competence, perception of autonomy, and ability to monitor their own progress strengthen motivational processes (Ryan & Deci, 2000).

The ability of athletes to monitor their developmental data can enhance self-efficacy and self-confidence while also supporting psychological resilience. Furthermore, community interaction facilitated through digital platforms contributes to reducing social isolation and supporting athletes' social integration processes.

3.6. Artificial Intelligence and Clinical Decision Support Processes

Artificial intelligence systems should be positioned not as replacements for expert decision-making but rather as tools that support it. These systems can provide data-driven recommendations, perform risk analyses, and contribute to the improvement of treatment processes. However, the question of who should make the final decision remains an important ethical issue. The balance between artificial intelligence and expert judgment occupies a central position in modern medical ethics (Topol, 2019).

3.7. Data Ethics and Algorithmic Limitations

The use of artificial intelligence involves various ethical and technical limitations. While the protection of biometric data is of great importance for data privacy, algorithmic bias may lead to prejudiced or erroneous outcomes due to imbalances within datasets. Furthermore, the "black box" nature of deep learning systems constitutes a major issue limiting the transparency of decision-making processes. These issues are among the critical concerns that must be carefully addressed in the clinical applications of artificial intelligence (Floridi et al., 2018).

4. Hearing Impairment Technologies, Digital Inclusivity and Ethical Vision

4.1. Communication and Technological Solutions for Hearing-Impaired Athletes

The primary factor limiting the performance of hearing-impaired athletes is not a lack of physical capacity, but rather communication barriers. Unlike Paralympic athletes, this condition constitutes a limitation primarily at the level of cognitive and environmental interaction rather than biomechanics (Stewart & Ellis, 2005). In this context, the Deaflympics presents a distinctive approach that conceptualizes disability not as a "loss of function," but as a "difference in communication." From the perspective of sports sciences, this approach highlights the importance of sensory data input in performance analysis.

Artificial intelligence-based systems developed in recent years have contributed to supporting the communication processes of hearing-impaired athletes. Sign language recognition systems can convert signs into text or speech in real time through the use of image processing and deep learning algorithms. These systems employ Convolutional Neural Networks (CNNs), computer vision techniques, and sequence modeling methods (RNN/LSTM) (Koller et al., 2016). Consequently, coach–athlete communication and tactical coordination processes can be supported, thereby contributing to the accessibility of educational and training processes.

In addition, AI-supported digital avatars can simultaneously translate spoken commands into sign language and present them visually to athletes. Such systems may contribute particularly to the enhancement of communication and coordination processes in team sports. This approach is evaluated within the framework of "multimodal communication" in the human–computer interaction literature (Turk, 2014).

Another important technology developed for hearing-impaired athletes is haptic feedback systems. These systems create an alternative communication channel by converting auditory stimuli into tactile signals. Operating through vibration patterns, pressure sensors, and wearable devices, these systems are based on the principle of sensory substitution. This principle is associated with the brain's capacity to reorganize different sensory inputs (Bach-y-Rita & Kercel, 2003). As a result, these systems may contribute to supporting athletes' environmental awareness and reaction processes.

Augmented reality (AR) technologies may also provide significant advantages for hearing-impaired athletes. These systems can integrate critical information such as scores, timing, and referee decisions into the athlete's field of vision, thereby contributing to the reduction of cognitive load and supporting decision-making processes (Azuma, 1997). Furthermore, AI-supported digital hearing systems can enhance communication quality through features such as noise filtering, sound source separation, and frequency optimization (McDermott, 2004).

4.2. Psychosocial Effects of Digital Sports Technologies

Artificial intelligence-supported sports technologies may support the participation of persons with disabilities in sports not only physically but also psychologically. Digital performance tracking systems make perceptions of achievement more tangible by visualizing individuals' developmental processes and may strengthen motivational processes. This phenomenon can be explained within the framework of self-efficacy theory (Bandura & Wessels, 1997). In addition, personalized training systems, adapted according to the individual's performance level, may contribute to reducing overload risk and supporting exercise continuity.

Digital platforms and online communities can also increase interaction among athletes, thereby contributing to the reduction of social isolation. This process particularly supports social integration among persons with disabilities and is associated with the improvement of quality of life (Seymour & Lupton, 2004).

4.3. Ethical Dimension and Technological Inequality

While technological developments provide significant opportunities in the field of sports, they also bring certain ethical concerns. The impact of AI-supported systems on performance remains a controversial issue in terms of competitive equity. In this context, the question of "technological advantage or compensatory support?" becomes increasingly important (Camporesi, 2008).

Moreover, the widespread adoption of high-cost technologies may create advantages for developed countries and influence the balance of global competition. This situation has brought discussions of equality and justice in sports ethics to the forefront. Furthermore, the protection of biometric and performance data collected by artificial intelligence systems constitutes another critical issue. The security of such data is of great importance from both ethical and legal perspectives (Floridi et al., 2018).

4.4. Future Vision

In the future, the role of artificial intelligence systems in sports is expected to increase further. These systems may analyze environmental data, provide athletes with strategic recommendations, and support performance analysis processes. Such developments may lead to a redefinition of the concept of performance within sports sciences. At the same time, the inclusive design of technology—that is, making it accessible to all individuals—may play a significant role in increasing the participation of persons with disabilities in sports.

5. Ethical Issues, Legal Framework and Future Vision

5.1. Technological Doping and Competitive Equity

The principle of fair competition, which constitutes one of the fundamental values of sport, has been reconsidered with the development of advanced prosthetic technologies and artificial intelligence-supported systems. In particular, carbon fiber prostheses and microprocessor-controlled systems possess the potential to enhance athletes' biomechanical performance (Camporesi, 2008). This situation has made the concept of "technological doping" a major topic of debate in sports ethics. The concept focuses on whether technology merely compensates for a deficiency or enhances performance beyond biological limits (Howe, 2011).

The effects of prostheses on performance are generally evaluated through biomechanical parameters such as energy storage and return (ESR), ground reaction force (GRF), and metabolic cost. Research indicates that the elastic return properties of prostheses may provide advantages over biological muscles under certain conditions (Herr & Grabowski, 2012). However, these advantages may vary depending on the sports discipline, speed, and movement mechanics involved. For this reason, international sports organizations are developing regulations concerning the use of technology in order to preserve competitive equity. These regulations encompass technical criteria related to device standardization and performance effects (Tweedy & Vanlandewijck, 2011).

5.2. Data Ethics and the Limitations of Artificial Intelligence

The widespread use of artificial intelligence systems in sports and rehabilitation has resulted in the collection of large quantities of biometric data. Data obtained from athletes, such as muscle activation (EMG), heart rhythm, and movement patterns, are highly sensitive, thereby generating significant ethical risks in terms of data privacy (Floridi et al., 2018). Furthermore, the use, storage, and sharing of these data for performance monitoring purposes remain controversial. The proliferation of wearable performance-tracking technologies has intensified debates regarding the surveillance, control, and ethical use of athlete data (Jones et al., 2016).

In addition, because artificial intelligence systems operate based on the datasets on which they are trained, algorithmic biases and systematic error risks may emerge. Imbalances within datasets may lead to inaccurate evaluations and inappropriate rehabilitation recommendations for certain disability groups (Topol, 2019). Moreover, the "black box" structure of deep learning systems—that is, the inability to fully explain decision-making processes—constitutes a significant issue for clinical trust and legal responsibility.

5.3. Human-Centered Artificial Intelligence (HCAI) and Decision-Making Processes

Although artificial intelligence is a powerful tool in sports performance and rehabilitation, it should not replace human judgment. This perspective is evaluated within the framework of human-centered artificial intelligence (HCAI) (Topol, 2019). For example, during a rehabilitation process, an AI system may predict that an athlete is ready to return to play; however, an expert may reassess this decision based on clinical risk factors. Consequently, the question of who should make the final decision becomes a significant ethical issue.

Similarly, the issue of responsibility in AI-related error cases remains controversial. The manner in which responsibility should be distributed among software developers, hardware manufacturers, and clinical practitioners is regarded as one of the fundamental elements shaping the ethical and legal framework of artificial intelligence systems (Floridi et al., 2018).

5.4. Socioeconomic Dimension and the Digital Divide

Access to artificial intelligence and advanced technologies is not equally distributed globally. While high-cost technologies are generally more widespread in developed countries, their availability may remain limited in developing countries. This situation may lead to technological inequalities in sports performance and rehabilitation processes (Van Dijk, 2020).

To address this issue, alternative solutions such as low-cost technologies, open-source software, and prosthetic systems produced through 3D printing are gaining increasing importance. Such approaches may contribute to developing a fairer, more inclusive structure in sports by enabling technology to reach broader populations (Ten Kate et al., 2017).

5.5. Future Vision and the Transformation of Sport

Developments in artificial intelligence and biotechnology are redefining the limits of human performance. Technology no longer merely compensates for deficiencies; it can also provide solutions to enhance performance. This situation is associated with the concept of human augmentation and is evaluated from a transhumanist perspective (Bostrom, 2001).

In the future, brain–computer interfaces, neural implants, and advanced prosthetic systems are expected to enable faster and more precise movement control (Lebedev & Nicolelis, 2006). As the integration of humans and machines becomes increasingly widespread, the concept of the "cyborg athlete" is likely to become more prevalent, potentially leading to the emergence of new sports categories (Howe, 2011). Furthermore, AI-supported systems are expected to play a more active role in training planning, performance analysis, and strategic decision-making processes. These developments may lead to a redefinition of the concept of human performance within sports sciences.

Conclusion

The integration of artificial intelligence and smart technologies into disability sports has created significant changes in sports performance and rehabilitation processes. Smart prostheses, sensor systems, virtual reality applications, and data-driven analysis methods support movement efficiency, injury prevention, and individualized rehabilitation processes. At the same time, these technologies strengthen athletes' motivation, communication processes, and social participation.

However, technological developments also bring important debates concerning ethical issues, data security, algorithmic bias, and competitive equity. In the future, artificial intelligence and biotechnology are expected to become increasingly integrated with sports sciences. Nevertheless, the sustainability of this transformation depends on the ethical, inclusive, and human-centered use of technology.

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ORGANIZATIONAL RESILIENCE IN SPORT ORGANIZATIONS

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Introduction

The contemporary sport ecosystem is undergoing a period of “polycrisis,” defined by the concurrent emergence of worldwide health crises, climate change-induced natural disasters, economic volatility, and cyber threats. These risks not only arise independently but also interact, producing cascading effects. Consequently, a crisis cycle emerges in which operational failures in one area can rapidly lead to financial losses and the erosion of stakeholder trust. Due to their high visibility and broad stakeholder engagement, sport organizations operate within a sensitive ecosystem where issues at a fundamental level can rapidly escalate, impacting reputation, trust, and legitimacy (Kara, 2025; Sadeqi-Arani & Ghahfarokhi, 2022). In this environment, uncertainty has become an intrinsic feature of sport management, constituting the new normal rather than an exceptional event (Evenseth et al., 2022).

The effects of uncertainty differ across sport organizations. Professional clubs typically have the capacity to absorb shocks due to diversified revenue streams, such as broadcasting rights and global sponsorships. Conversely, crises often present existential threats to amateur and lower-league clubs that depend primarily on matchday revenues and local community support (Poo et al., 2025; Wicker et al., 2013). Furthermore, many organizations must balance the dual objectives of achieving competitive success and promoting broad sport participation, underscoring the restrictions of traditional management models in addressing current disruptions (Bostock & Breese, 2023; De Bock et al., 2023).

Crises have tangible effects on daily operations. For example, a cyberattack disrupting a ticketing system on matchday can simultaneously create challenges related to security, revenue, and organizational reputation. In such cases, strategies focused solely on profit and efficiency are often insufficient to prevent systemic paralysis. Therefore, sport organizations must rapidly update operational routines and reconfigure resources (Evenseth et al., 2022; Sadeqi-

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Arani & Ghahfarokhi, 2022). This requirement has shifted the understanding of organizational resilience from a static "survival" mechanism or crisis reflex to a dynamic capacity that anticipates, adapts to, and progresses beyond environmental changes through updated routines (Duchek, 2020; Kegelaers, 2023; Vogus & Sutcliffe, 2007). As a result, resilience is now viewed as a cyclical capacity that encompasses preparation, response, and post-crisis development (Duchek, 2020; Evenseth et al., 2022). Duchek's (2020) framework conceptualizes resilience as a cyclical process comprising anticipation, coping, and adaptation (Duchek, 2020; Evenseth et al., 2022). From this perspective, resilience is a strategic capacity that enables organizations to continue making and implementing decisions under uncertainty, rather than merely a 'crisis plan'.

In sport management literature, models such as the 4R Framework (robustness, redundancy, resourcefulness, and rapidity) are also used to explain this dynamic capacity. Here, resourcefulness specifically refers to the ability to creatively reassemble available resources (bricolage) during a crisis (Wicker et al., 2013).

Resilience cannot be viewed merely as a technical or operational skill. In sport organizations, resilience is also a process closely linked to the maintenance of organizational legitimacy and social trust (Kara, 2025; Robertson et al., 2022). The strategic orientations adopted by managers during a crisis also influence this trajectory. These orientations can be classified as capitalizing on opportunities to meet rising demand, realigning resources, or repurposing through strategic moves to ensure survival (Shepherd & Williams, 2022). Consequently, building resilience in the managerial dimension of sport requires establishing a strategic balance between forms of economic, social, technological, human and political capital, and embedding learning from crises into an organizational culture (Kara, 2025; Shepherd & Williams, 2022).

This study intends to elucidate organizational resilience in sport organizations by examining its conceptual and theoretical foundations within the context of sport management. It seeks to provide a comprehensive assessment that integrates previously fragmented approaches in the literature and generates practical implications for sport organizations. In an environment where traditional management models are increasingly inadequate, resilience has emerged as a governance-oriented capacity that enables sport organizations to maintain institutional legitimacy and stakeholder trust. Accordingly, resilience will be analyzed not solely as a reactive approach to crises, but as a governance capacity that fosters sustainable performance and legitimacy amid uncertainty.

Theoretical Foundations of Organizational Resilience

Definition of Organizational Resilience

Organizational resilience, in its simplest form, is described as an institution's ability to sustain functioning in the face of unexpected shocks and disruptions, to preserve its core functions, and to rebuild itself by adapting to a changing world (Kołodziej et al., 2024). In the sport management literature, resilience can often be misinterpreted as a static personality trait; however, current approaches treat this capacity as a dynamic process that develops and is learned over time. In this respect, resilience is not limited to overcoming a blow and returning to the previous equilibrium (bouncing back); rather, it also refers to learning from crisis and evolving into a more competent structure (bouncing forward) (Duchek, 2020; Kegelaers, 2023). Especially in today's "polycrisis" environment, characterized by mutually reinforcing uncertainties, resilience enables organizations to adapt to new conditions rather than simply return to previous arrangements.

The concept's deep-rooted history across different disciplines makes it necessary to draw the boundaries of definition much more clearly in a distinctive field such as sport management. In general terms, resilience scholarship is based on three main schools. The first of these, the engineering approach, focuses on the system's absorptive capacity and speed, aiming to return to the previous performance level after disruption. The second school, the ecological approach, emphasizes the system's capacity to absorb shocks and evolve into a completely different and new state of equilibrium, that is, its capacity for transformation (Holling, 1973). The third, and perhaps the most functional for sport organizations, is the management and organization theory perspective; this approach frames resilience not as a static "feature" inherent in the organization, but as a set of competencies and capacities developed through organizational processes (Duchek, 2020; Vogus & Sutcliffe, 2007).

Considering the highly heterogeneous and multi-stakeholder structure of the sport world, reducing resilience merely to a technical "speed of recovery" would narrow the meaning of the concept. This is because resilience in sport organizations is not only about the continuity of physical facilities or digital systems, but also about the preservation, even during crisis, of relational domains such as trust, reputation, and legitimacy, which are among the institution's most valuable assets. For this reason, the managerial perspective removes resilience from mechanical resistance and defines it as a living governance ecosystem that sustains stakeholder commitment and can reproduce institutional identity under uncertainty.

Conceptual Distinctions and Conceptual Mapping

Although organizational resilience is sometimes used synonymously with crisis management or risk management in the sport management literature, it goes beyond these approaches by adopting a broader strategic time horizon (Duchek, 2020; Kołodziej et al., 2024). This distinction is important for sport organizations, because resilience is not only about "remaining standing during a crisis," but also about being able to produce trust and performance together under uncertainty (Kara, 2025; Sadeqi-Arani & Ghahfarokhi, 2022).

Crisis management focuses more on the "moment of the event": it foregrounds short-term goals such as limiting damage, stopping operational disruption, and protecting reputation. Resilience, however, even though it includes these reactive elements, centers on the capacity for anticipation, which monitors weak signals in the environment before the crisis, and the adaptation cycle, in which the system restructures itself by learning from experience after the crisis (Duchek, 2020; Evenseth et al., 2022).

Risk management is based more on identifying "known threats" and evaluating these threats through a probability–impact logic. This is valuable especially in areas that require institutional control and compliance; however, when risks cannot be fully predicted or prevented, resilience foregrounds the organization's ability to maintain its functionality. In the literature, this difference is sometimes also discussed through the need to manage "risk" and "resilience" separately (Hynes et al., 2020). At this point, resourcefulness and bricolage refer to the ability to produce creative solutions with limited available resources (Wicker et al., 2013).

The business continuity approach focuses on making critical processes functional again after disruption. Resilience, however, goes beyond operational recovery and also includes strategic orientations that can redesign the business model and resource allocation when necessary; this distinction is also clarified through the conceptual differences among business continuity, operational resilience, and organizational resilience (Galaitsi et al., 2023). Similarly, while agility emphasizes the ability to change direction rapidly, resilience aims to make this speed sustainable through organizational learning; otherwise, it is possible for similar weaknesses to recur in the face of the same shocks (Evenseth et al., 2022; Kegelaers, 2023).

In this sense, resilience brings the immediate response of crisis management, the preventive logic of risk management, business continuity planning, and the speed of agility. Yet it is more than the sum of these: it is a dynamic meta-capability that makes "bouncing forward" possible by learning from disruptions (Duchek, 2020; Kara, 2025).

Table 1 systematically summarizes the relationship of organizational resilience with neighboring concepts and the dimensions in which it differs from them. This mapping makes it possible to position resilience in sport organizations not only as “recovery” (bouncing back), but also as a capacity to become stronger through learning and adaptation (bouncing forward).

This conceptual mapping shows that resilience does not exclude approaches such as crisis management, risk management, and business continuity; rather, it integrates them within a broader strategic time horizon. However, the practical emergence of this integrative capacity depends on two fundamental mechanisms: (i) governance design, which enables decision-making and coordination during a crisis, and (ii) structured learning cycles, which transform post-crisis learning into organizational change.

Table 1. Conceptual Distinctions and Conceptual Mapping

Concept	Focus / Aim	Time Horizon	Key Question	Typical Tools	Success Measure	Relationship with Resilience
Organizational resilience	Anticipating, managing, and learning from shocks to adapt; bouncing forward when necessary	Before, during, and after the crisis	How can we function sustainably and become stronger under uncertainty?	4R; anticipation–coping–adaptation cycle; AAR; governance design	Continuity, finance, and trust/ legitimacy	Umbrella concept; integrates the tools of risk, crisis, business continuity, and agility
Crisis management	Limiting damage and coordinating during an acute event	During the crisis (short term)	What should we do now?	Crisis team; communication plan; rapid decision-making; task allocation	Reduced disruption/ damage; rapid recovery	Strengthens the coping phase; not sufficient on its own
Risk management	Identifying and reducing threats (probability–impact)	Before the crisis (medium–long term)	What can go wrong, and how can we reduce it?	Risk register; risk map; control plans; audit	Reduced exposure; compliance	Strengthens the anticipation/ preparedness component; limited in surprise risks
Business continuity	Maintaining critical processes under disruption and restoring service	During and immediately after the crisis	How can we maintain the critical service?	Backup systems; manual workflows; recovery plans	Time to recovery (TTR); reduced downtime	Strengthens the operational dimension; transformation dimension is narrower
Agility	Rapid direction change and flexible response	Continuous (dynamic)	How can we change direction rapidly?	Flexible teams; rapid iteration; empowerment	Speed of adaptation; shortened cycle time	Contributes to resilience; vulnerability may persist if learning is not institutionalized
Organizational learning / AAR	Learning from experience; reducing recurring errors	After the crisis and routinely	What have we learned, and what will we change?	Debrief; action list; SOP update	Action closure; reduction in recurring problems	Engine of adaptation/ renewal

Resilience Approaches: Bouncing Back and Bouncing Forward

Two main emphases stand out in the resilience literature. The first is the bouncing back approach, which refers to the system’s ability to return to its "previous equilibrium" as quickly as possible after a shock. The second is a more transformative approach that aims not only to overcome the crisis, but also to develop a structure and functioning more suitable for new conditions by learning from the crisis; in other words, to become stronger by bouncing forward (Duchek, 2020; Kegelaers, 2023).

From the perspective of sport organizations, treating resilience merely as "repairing the old" is often insufficient, because crises produce simultaneous pressures in areas such as performance goals, stakeholder expectations, revenue flow, and reputation management (Duchek, 2020; Vogus & Sutcliffe, 2007). Therefore, in this review, resilience is not considered merely as a "speed of recovery," but as a strategic capacity that can sustain decision-making under uncertainty, reconfigure its resources, and, when necessary, update its organizational functioning by redefining its purposes. In other words, for sport organizations, resilience is less about "returning to the same place" than about "evolving toward a more suitable place."

Organizational Resilience Models and Mechanisms

Different sets of models and mechanisms are used together in the literature to explain how organizational resilience "works." Process-based approaches consider resilience not only as an outcome (remaining standing after a crisis), but also through the institution's pre-crisis capacity for preparation and sensing, its ability to coordinate and make decisions during a crisis, and its competence in learning and restructuring after a crisis (Duchek, 2020).

Within this framework, one of the prominent lines of explanation associates resilience with the set of dynamic capabilities that enables the institution to adapt to changing conditions. The dynamic capabilities approach explains how sustainable performance can be produced under uncertainty by focusing on micro-mechanisms such as reconfiguring resources, updating functioning, and managing strategic changes in direction (Eisenhardt & Martin, 2000; Teece, 2007). At the organizational level, these mechanisms become visible in practices such as monitoring environmental signals, making rapid decisions, activating alternative resources, redesigning processes, and reconfiguring stakeholder communication.

A second line of explanation addresses resilience through a capacity approach built through human resources, leadership, communication, and learning mechanisms. This view positions resilience not as a "crisis plan," but as a set of organizational competencies produced within routines and activated during a crisis (Lengnick-Hall et al., 2011). In addition, some studies discuss measurable dimensions such as the organization's level of preparedness, scenario-based planning, and coordination capacity in assessing organizational resilience (Somers, 2009).

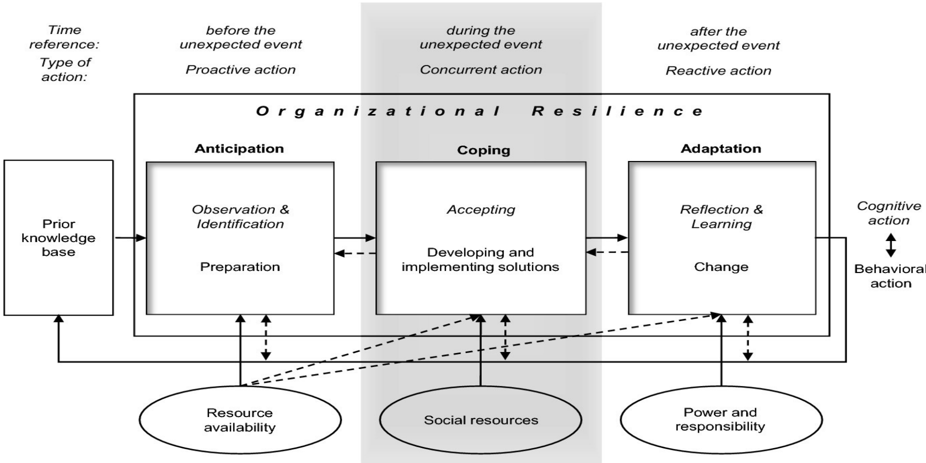

Figure 1. Duchek's (2020) Process-Based Framework of Organizational Resilience

Five-Capital Model and Dynamic Capabilities

One of the most recent approaches that strengthens the theoretical foundation of resilience in sport organizations is the five-capital structure proposed by Marques et al. (2025). This model argues that sport organizations use economic, social, technological, human, and political forms of capital as sources of resilience during periods of crisis. According to this approach, which is integrated with the dynamic capabilities perspective, resilience is built not only by possessing these resources, but also through the rapid acquisition, reconfiguration, and integration of these forms of capital during a crisis. For example, in a crisis where financial (economic) capital shrinks, the organization's strong bond with its stakeholders (social capital) or the expertise of its employees (human capital), when combined with technological infrastructure, serves as a key driver that enables the organization to "bounce forward" (Marques et al., 2025).

Process-Based Approach: Anticipation–Coping–Adaptation

Duchek's (2020) process-based framework treats resilience not as a "momentary" reaction, but as a cyclical set of mutually reinforcing competencies. In the context of sport organizations, this cycle is embodied in the steps of (i) detecting possible disruptions early by monitoring weak signals (anticipation), (ii) rapidly managing coordination and resource allocation during a crisis (coping), and (iii) redesigning routines by learning from the crisis (adaptation) (Duchek, 2020). This perspective suggests that sport organizations should emerge from crises not only by "recovering" (bouncing back), but also by "reconfiguring" their structural and social capital according to the new realities presented by the crisis.

When Figure 1 is read from the perspective of sport organizations, the "anticipation" stage corresponds to early warning practices such as monitoring weak signals related to fixtures, facilities, weather conditions, safety, and cyber risks, as well as scenario planning. The "coping" stage refers to the rapid coordination of matchday operations, stakeholder communication, and resource allocation (staff, volunteers, budget, alternative supply), while "adaptation" refers to post-crisis evaluation (after-action review), the updating of routines, and the formalization of organizational learning. Thus, resilience becomes concrete not as a one-time crisis plan, but as a recurring cycle of learning and reconfiguration.

4R Framework: Robustness, Redundancy, Resourcefulness, Rapidity

The 4R framework (robustness, redundancy, resourcefulness, rapidity) conceptualizes organizational resilience not by reducing it to a single "recovery" outcome, but through complementary capacity dimensions that enable organizations to withstand shocks (Wicker et al., 2013). From this perspective, robustness refers to the preservation of core functions as much as possible during disruption; redundancy refers to reducing dependence on single points of failure in critical resources and processes; resourcefulness refers to producing creative solutions under constraints and creating value by recombining available resources (bricolage); and rapidity refers to accelerating the decision-making and implementation cycle. Thus, the 4R provides an analytical framework that explains resilience around the question of "which capacities did we have when entering the crisis, and how did these capacities work together?" before asking "what did we do during the crisis?"

From the perspective of sport organizations, the 4R framework offers a functional lens, especially because match/event day operations are conducted under time pressure and high visibility. For example, robustness becomes visible through the standardization of critical processes such as safety, facilities, and digital infrastructure; redundancy through the prior design of options such as alternative suppliers/facilities/communication channels; resourcefulness through the rapid reorganization of resources via volunteer labor, stakeholder collaborations, and creative "temporary solutions"; and rapidity through role–authority clarity and coordination mechanisms. Therefore, 4R forms a useful conceptual bridge for addressing resilience in sport organizations together with fragile outcomes such as operational continuity and stakeholder trust/reputation.

Strategic Response Paths: Capitalizing–Realigning–Repurposing

During crises, organizational resilience is not only a technical protection mechanism that ensures operational continuity, but also a critical strategic orientation choice that determines the institution's future position and market identity (Sadeqi-Arani & Ghahfarokhi, 2022; Shepherd & Williams, 2022).

Accordingly, depending on the severity of the external shock, the market's response, and their own resource base, organizations may follow three main trajectories. Capitalizing refers to proactively capturing the growth opportunities unexpectedly offered by the crisis through "simple rules" and scaling rapidly, whereas realigning involves the measured repositioning of existing resources in light of institutional values in response to changes in market demand (Shepherd & Williams, 2022). On the other hand, the path of repurposing, which comes into play in existential crisis scenarios where demand suddenly collapses, requires abandoning all dysfunctional routines of the past, making a radical "strategic pivot," and structuring the limited available resources according to an entirely new market need through "hustling" (creative effort) (Sadeqi-Arani & Ghahfarokhi, 2022; Shepherd & Williams, 2022).

For sport organizations, these strategic response paths become vital adaptation mechanisms according to the structural characteristics of the institution and the institutional principles it adopts (De Bock et al., 2022; Poo et al., 2025). While elite clubs and major leagues absorb financial shocks during crisis periods such as the pandemic by achieving realignment through digital content and e-sports integration, local clubs dependent on matchday revenue may have to adopt a repurposing strategy through community-supported financing and social capital in the face of an existential threat (Poo et al., 2025; Sadeqi-Arani & Ghahfarokhi, 2022). In this process, keeping "Minimum Viable Organization" (MVO) plans ready, in which the core processes indispensable for operational continuity are mapped, has an indispensable strategic importance for all three response paths in enabling the institution to emerge from the crisis not only by recovering, but also by learning and becoming stronger (bouncing forward). The data of Poo et al. (2025) indicate that elite clubs absorb financial shocks through broadcasting rights and digital content production, whereas local clubs dependent on matchday revenue need community support and state aid much more in existential crises. This situation shows that resilience in the sport ecosystem has an asymmetric structure in terms of "financial vulnerability" and "strategic depth."

Organizational Learning and the High Reliability Approach

Making resilience capacity sustainable depends on transferring crisis experiences to organizational memory and embedding them into everyday functioning. Therefore, organizational learning should not be considered merely as a post-crisis "lesson-drawing" activity, but as a governance mechanism that captures weak signals beforehand, produces in-process feedback, and updates routines (Evenseth et al., 2022).

The high reliability organizing approach is a system of thought that, in environments where uncertainty and risk are high, focuses not on eliminating error entirely, but on creating organizational awareness and flexibility in a way that enables early detection of errors and limits their impact (Weick & Sutcliffe, 2007). At the center of this view are principles such as accepting that errors are inevitable, detecting "small" deviations early, monitoring operations in real time, and, when a problem emerges, making decisions based on expertise rather than hierarchy. Thus, resilience operates, on the one hand, through preventive micro-practices that limit the impact of disruptions, and on the other hand, through a cycle that institutionalizes learning through post-crisis evaluation and routine updating.

From the perspective of sport organizations, the high reliability perspective is particularly functional, because event-day operations consist of processes carried out with low tolerance, under high time pressure, and in front of stakeholders. In this context, collecting micro-data such as accident reports and incident records; avoiding the simplification of attributing failures to a "single cause" through root cause analysis; keeping situational awareness constantly up to date through short briefing–debriefing cycles in field operations; and granting decision authority to areas of expertise such as IT/security/health at critical moments support detecting errors before they grow and limiting their impact. As a result, when these practices are combined with AAR (after-action review), they enable sport organizations not only to "recover," but also to develop a capacity set that is more prepared for the next shock.

Institutional Theory, Legitimacy, and Stakeholder Pressures

Resilience in sport organizations is a relational process that cannot be reduced solely to technical capacity or economic resources, and is fundamentally built on the organization's ability to protect its institutional legitimacy and maintain the trust of its stakeholders (Kara, 2025; Robertson et al., 2022). The perspective of institutional theory argues that the decisions sport organizations make during crises are shaped not only by the search for the "most efficient technical solution," but also by regulatory expectations, professional norms, and the dominant practices of the field (isomorphism) (Robertson et al., 2022). According to this perspective, even if a sport organization remains operationally standing, if it loses the moral and pragmatic foundations of legitimacy such as fairness, transparency, and accountability in the eyes of its stakeholders, it faces an existential threat (Kara, 2025; Suchman, 1995). Therefore, while resilience strategies aim for operational continuity, they must simultaneously build the organization's reputation and the social trust that stakeholders have in the institution as a "social backbone" (Kara, 2025; Robertson et al., 2022).

In the multi-layered stakeholder structure of sport, actors such as fans, athletes, sponsors, media, and federations each read crises through their own priorities and risk perceptions (Kara, 2025). For example, in the university sports ecosystem, legitimacy depends on fairness in resource allocation, consistent communication, and student-centered decision-making processes, whereas in professional clubs, financial transparency and expectations of success may come to the fore (Kara, 2025; Poo et al., 2025). In this complex environment of pressure, resilience requires, on the one hand, realigning resources according to new realities, and on the other hand, it must be supported by mechanisms such as ethical consistency and stakeholder participation that will ensure the social acceptance of decisions (Kara, 2025; Shepherd & Williams, 2022). For national federations, which manage the dual mission tension between "winning medals" and "sport for all," resilience requires managing the conflicting institutional logics between the elite sport logic focused on "medal success" and the mass sport logic focused on "participation and health." In this context, legitimacy becomes a dynamic governance capacity that includes difficult strategic choices about which principles will be prioritized during crises and how these choices will be made sense of by stakeholders (sensemaking) (De Bock et al., 2022; Robertson et al., 2022).

Governance and Learning Mechanisms for Building Resilience

Governance Design: Decision-Making, Coordination, and Accountability in Crisis

Organizational resilience is determined not only by the amount of resources, but also by how quickly and consistently these resources can be mobilized during a crisis. At the center of this mobilization lies governance design: defining role clarity, decision authority, escalation lines, information flow, and stakeholder communication in advance reduces the cost of coordination under uncertainty. In sport organizations, because of high visibility and multiple stakeholder pressures, minor operational disruptions can rapidly move into the domains of reputation and legitimacy; therefore, governance design provides a framework that protects both the operational and relational dimensions of resilience.

Three basic elements stand out for an effective governance design. The first is decision architecture: who makes decisions in which types of events, at what threshold the crisis team becomes involved, and for which decisions senior management approval is required. The second is the role and responsibility matrix: when the roles of execution, approval, consultation, and information are clarified, delays and role conflicts during a crisis decrease. The third is communication governance: when the principle of single-voice communication, the timing of the first official statement, the order of informing stakeholders, and the post-crisis transparency routine are defined in advance, the risk of loss of trust decreases.

AAR as a Learning Mechanism: The Engine of Bouncing Forward in Resilience

The "bouncing forward" dimension of organizational resilience becomes visible through what the organization learns after a crisis and to what extent it transforms this learning into permanent change. Therefore, AAR (After-Action Review) can be considered a fundamental mechanism that institutionalizes adaptation by moving beyond approaches that reduce resilience merely to the speed of recovery. AAR is not a fault-finding or blame-oriented meeting; rather, it is a structured learning practice that strengthens preparedness for the next shock by analyzing the course of the event, the quality of decisions, coordination performance, and communication effectiveness.

From the perspective of sport organizations, the critical value of AAR lies in the fact that crises often simultaneously produce operational disruption, financial pressure, and reputational/legitimacy erosion. AAR treats this multiple impact not merely as an event that has occurred, but as an input for organizational learning. However, the effectiveness of AAR depends less on producing a report and more on whether the actions emerging from it are (i) assigned to a responsible person, (ii) tied to a timeline, and (iii) reflected in SOPs/workflows. When this cycle is operated, AAR activates the "adaptation" phase of resilience processes and reduces the recurrence of the same weaknesses in the face of similar shocks.

Implementation Strategies: How Is Resilience Built?

Organizational resilience in sport organizations should be regarded not as a one-time crisis plan, but as an organizational meta-capability that can sustain decision-making under uncertainty, rapidly reorganize its resources, and evolve into a more suitable functioning by learning from crises (Duchek, 2020). In the context of sport management, this approach includes not only "overcoming the shock," but also the logic of rebuilding and strengthening post-shock functioning (Bostock & Breese, 2023).

At this point, the two mechanisms explained in the previous section play a critical role: (i) governance design, which enables decision-making and coordination during a crisis, and (ii) AAR (after-action review), which transforms post-crisis learning into permanent change. The steps presented in this section focus on systematically building resilience by embedding these two mechanisms into organizational routines.

The first step in building resilience is to identify and prioritize the organization's vulnerabilities in a focused manner. In practice, for this purpose, (i) critical processes (e.g., event/competition calendar, licensing/visa, budget flow, registration–ticketing, communication), (ii) high-probability–high-impact risks (e.g., cyber disruption, extreme weather event, financial shock, reputation crisis), and (iii) the most sensitive stakeholder groups are evaluated together, and the first three priorities are determined. This step reduces the pressure of "trying to keep up with everything" and enables the highest impact to be produced with limited resources. Findings on how resilience emerges in shocks such as natural disasters in the context of sport clubs show that components such as robustness–redundancy–resourcefulness–rapidity come into play in different ways in practice (Wicker et al., 2013).

The second step is to institutionalize the mechanisms that produce resilience. At the center of this stage lies the governance design detailed in the previous section: role–authority clarity, the escalation line, and the principle of single-voice communication. In addition, resilience is strengthened by resource flexibility: it is important to set a basic financial buffer target, plan alternative processes/suppliers for critical services, and take diversification steps that will reduce revenue dependency (Duchek, 2020). Human resource continuity is also a critical determinant; backup for critical roles, cross-training, and short SOPs reduce vulnerability to shocks by protecting organizational memory (Bostock & Breese, 2023). At the operational level, "Minimum Viable Organization" (MVO) plans, which enable the organization to focus its resources on vital "core" processes such as athlete health, safety, and basic communication during a crisis, play a critical role. In the post-crisis process, After-Action Review (AAR) should be operated not merely as reporting, but as a systematic learning cycle that includes data collection, root cause analysis, and the updating of standard operating procedures (SOPs).

The third step is to test and improve this capacity system. At least twice a year, tabletop scenario exercises (e.g., system collapse on matchday, cancellation of an organization due to bad weather, reputation crisis on social media) should be conducted, and the "first 2-hour plan," the first statement draft, and coordination steps should be reviewed. Following the tests, collecting learning through short, structured "after-action review/debrief" sessions meaningfully supports performance and development; meta-analytic findings show that debrief practices are generally effective (Keiser & Arthur, 2021). Turning these learning outputs into an action list and assigning each action to a responsible person with a deadline secures the "learning" dimension of resilience.

The final step is to transform learning into permanent change as required by the "bouncing forward" approach. Post-crisis strategic orientations may differ: some organizations may grow by capitalizing on opportunities, some may adapt by realigning their resources, and others may sustain their existence by repurposing their business model (Shepherd & Williams, 2022). Therefore, resilience should be designed and monitored in sport organizations not as a temporary reflex reacting to crises, but as a governance capacity that produces sustainable performance and legitimacy under uncertainty (Hillmann & Guenther, 2021). At this point, the outputs of AAR should not remain merely as a "report"; they should be connected to organizational memory through SOP updates and actions assigned with responsible persons and dates. Table 2 summarizes how the resilience cycle is translated into implementation strategies through mechanisms, implementation steps, and concrete outputs.

Table 2. Mini Mapping from the Resilience Cycle to Implementation Strategies

Stage (Cycle)	Mechanism / Focus	Implementation Step	Concrete Output (Example)
1) Anticipation & Preparedness	Vulnerability/risk screening; weak signal monitoring; identification of critical processes	Diagnosis and prioritization	List of critical processes; top 3 vulnerabilities; scenario set
2) Coping	Governance design: decision architecture, escalation line, role matrix (RACI), single-voice communication	Design and institutionalization	Escalation line; RACI; communication protocol; short SOP set
3) Recovery & Continuity	Business continuity approach; restoration of critical service; alternative process/channel plan	Testing and improvement	Stress tests; tabletop scenarios; critical process recovery plan
4) Adaptation & Renewal	AAR (after-action review) and learning cycle; strategic realignment/repurposing	Institutionalization of learning and adaptation	Action closure; SOP update; permanent improvement outputs

Conclusion

In the modern management paradigm, organizational resilience in sport organizations is no longer merely a strategy for "surviving a crisis," but a strategic meta-capability that transforms uncertainty into an opportunity for organizational growth and learning. The theoretical models discussed throughout this study show that resilience is based not on static resistance, but on the dynamic reconfiguration of economic, social, technological, human, and political forms of capital. This five-capital structure, emphasized particularly by Marques et al. (2025), explains how sport organizations transform the resources they possess during crises into tools of adaptation; for example, digital infrastructure and data capacity (technological capital), community support and collaboration networks (social capital), and the backup of critical roles and cross-training (human capital) are concrete mechanisms through which this transformation takes place.

Due to their high visibility and intensive stakeholder interactions, sport organizations operate in a sensitive ecosystem where even the smallest operational disruption can quickly spread into the domains of revenue flow, trust, reputation, and legitimacy. Therefore, resilience is not only about "saving" an event/match or recovering in the short term; it is about being able to sustain operations, reorganize resources intelligently, and maintain institutional direction by protecting stakeholder trust at the same time. The main contribution of this chapter is that it offers an applicable framework that integrates the fragmented approach to resilience in the sport management literature and jointly addresses organizations' capacity to prepare for crises, manage the crisis moment, and renew themselves by learning from crises.

As a result, the fundamental lesson that the period of polycrisis brings to the sport world is that resilience should be understood as a continuous organizational learning and renewal process rather than a fixed endpoint. This process must become an integral part of organizational culture. The practical equivalent of this journey is the identification of critical processes (MVO), the clarification of the role–authority–communication order (governance design), the protection of organizational memory through short SOPs, and the linking of learning to action closure through AAR after each event. When these mechanisms are not established effectively, organizations emerge from crises only by returning to their former states (bouncing back) and face the risk of repeating the same vulnerabilities in similar shocks; when they are established, resilience makes "bouncing forward" possible through learning and adaptation.

Future research should make organizational resilience measurable in ways specific to sport organizations and test which mechanisms determine resilience outcomes across different types of organizations. In particular, the digitalization–cyber vulnerability dilemma, stakeholder trust/legitimacy dynamics, and capacity building under resource constraints should be examined in greater depth due to the distinctive conditions of the sport ecosystem. In this direction, longitudinal studies and mixed-method multiple case designs will make the "process" nature of resilience visible and provide a strong contribution to the literature.

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