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Circus Performers as Highly Skilled Athletes: An Analysis of Physical Loads and Health Risks

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Abstract

The article conceptualizes circus performance practice as a form of high-performance athletic activity in which a trick action constitutes a complex biomechanical event requiring the integration of strength and power capacities, flexibility, neuromuscular coordination, sensorimotor stabilization, and high tolerance to fatigue. The aim of the study is to substantiate an applied analytical framework for examining physical loads and injury prevention in highly skilled athletes within circus disciplines. Methodologically, the study is conducted as a narrative synthesis of contemporary scientific articles and doctoral-level research in the fields of circus medicine, biomechanics, and professional training pedagogy, with priority given to epidemiological and prospective study designs and to exposure-based metrics. Particular emphasis is placed on the significance of traumatic brain events: a decade-long epidemiology of concussion demonstrates a measurable incidence per artist-performance exposure, the presence of recurrent concussions, and average timelines for return to full performance, which necessitates the formalization of «removal-assessment-return» protocols specifically adapted to the stage-performance context. Genre-specific analysis identifies critical zones of overload: in aerial disciplines, the scapulohumeral complex is at heightened risk of tendinopathies and impingement conditions due to cumulative stabilizer fatigue and disruption of the scapulothoracic rhythm; in floor-based acrobatics, the lower extremities and lumbar spine are predominantly affected as a result of peak ground reaction forces and repetitive landings. The conclusions substantiate the importance of shifting from assessments based on «training intensity» toward exposure management and the implementation of a multilevel medical-pedagogical monitoring system aligned with contemporary recommendations in circus biomechanics and physiology, as well as with Ukrainian approaches to organizing circus training in higher education institutions of an artistic profile.

Keywords: *Epidemiological Surveillance; Organizational Determinants of Injury; Psychoprophylaxis in Performing Professions; Return-to-Stage Protocols; Sensorimotor Integration; Touring Cycle.*

INTRODUCTION

Contemporary professional circus increasingly functions as a domain of high-performance athleticism, in which artistic expressiveness is realized through movements of heightened biomechanical complexity and inherent potential risk. In circus disciplines, a trick action is not an «aestheticized exercise» in a narrow sense; rather, it constitutes a multicomponent motor event that requires the synchronous mobilization of strength and power capacities, flexibility, precision of sensorimotor control, neuromuscular coordination, fatigue resistance, and rapid adaptation to variable stage conditions. At the same time, circus activity exhibits a fundamentally different load configuration compared to classical sports: it combines high-risk elements with a high frequency of repetitions within the training contour and an additional «performance» contour of exposure, in which the physiological cost of movement increases due to temporal, emotional, and contractual-organizational factors.

The scientific premises of the study are associated with the accumulation of epidemiological data that have enabled a transition from isolated descriptions of injuries to the systematic measurement of risks in professional troupes and in pre-professional training. The problem gains additional significance due to the evidence-based characterization of the risk of traumatic brain injury, which documents measurable incidence rates, a proportion of recurrent concussions, and average timelines for return to full performance, thereby indicating the necessity of protocolizing clinical and pedagogical decision-making specifically within the context of stage activity [9]. In parallel, prospective cohort observations in student circus programs demonstrate the methodological relevance of monitoring not only acute

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injuries but also «substantial» conditions that limit work capacity and tend to become chronic [13].

Within this context, a number of applied-level tasks remain unresolved. First, there is a need to refine the operational model for describing load in circus practice, where «training volume» does not fully capture actual risk exposure, and where metrics such as the number of repetitions, suspensions, landings, and the duration of holds within the rehearsal-performance cycle become decisive. Second, there is a methodological necessity to «translate» epidemiological and biomechanical findings into the language of training management-specifically, to determine what should be monitored, how exposure should be dosed, and which early indicators of overload should be embedded in pedagogical management. Third, it is essential to align international evidence-based approaches with national trajectories of institutionalizing circus education and performer training, as described in Ukrainian doctoral research, which point to the need to strengthen the medical-biomechanical component within the structure of professional preparation.

The aim of the article is to provide a scientifically grounded interpretation of the circus performer as a highly skilled athlete through a practice-oriented analysis of the structure of physical loads and health risks, with a focus on genre-specific «load profiles» and controllable factors of injury prevention. To achieve this aim, the study conceptualizes the dual-contour nature of exposure (rehearsal-training and performance-related), specifies the most vulnerable anatomical and functional zones in key disciplines (in particular, the scapulohumeral complex in aerial acrobatics and the lower extremities in jumping and floor-based genres), and substantiates the framework «discipline → type of exposure → tissue-specific risk → organizational-behavioral modification» as a methodological tool for developing monitoring, screening, and preventive protocols in professional troupes and pre-professional training systems.

MATERIALS AND METHODS

The study was conducted within an interdisciplinary approach integrating principles of physical load theory, movement biomechanics, performing arts medicine, and the pedagogy of professional circus training. The methodological foundation of the research is the concept of the circus performer as a highly skilled athlete with a genre-specific structure of load exposure, within which health risks emerge at the intersection of biomechanical, organizational, and psychophysiological factors.

The research materials comprised contemporary scientific articles and doctoral-level studies by Ukrainian and international authors addressing injury epidemiology in circus arts, the biomechanics of aerial and floor-based acrobatics, the physiology of loads in performing professions, and issues related to the organization of professional circus training. The analysis included publications based on data from professional circus troupes and student cohorts, particularly studies employing exposure-based metrics as well as prospective and retrospective epidemiological designs.

The research methodology involved a combination of several complementary methods. The primary method was a narrative and comparative-analytical review of scientific sources, which enabled the systematization of existing data on the structure of physical loads and injury profiles across different circus disciplines. To refine the applied dimension of the analysis, a functional-biomechanical method was used, within which loads were interpreted through dominant modes of muscular activity, peak ground reaction forces, the characteristics of kinematic chains, and the repetitiveness of motor actions. In addition, a structural-logical modeling method was applied to construct the analytical framework «discipline → type of exposure → tissue-specific risk → organizational-behavioral modification», which served as the basis for further systematization of the results.

The research protocol consisted of several sequential stages. At the first stage, sources were selected according to criteria of relevance, scientific representativeness, and correspondence to the topic of physical loads and health risks in circus performers. At the second stage, materials were classified according to circus discipline genres and types of load, which made it possible to identify typical «load profiles» for aerial acrobatics, floor-based and jumping genres, equilibrism, paired strength acts, and scenic eccentric performance. At the third stage, data were synthesized regarding dominant zones of vulnerability, the frequency and nature of injuries, and organizational and psychological risk factors. The final stage focused on integrating the obtained results into a practice-oriented methodological model of load management and injury prevention within professional and pre-professional circus training systems.

The applied methodology ensures the reproducibility of the results and allows the findings to be used as a scientifically substantiated foundation for further empirical research, as well as for the development of regulatory and methodological documents aimed at the safe organization of circus activities.

RESULTS AND DISCUSSION

Contemporary professional circus increasingly demonstrates the athletic nature of performance: a trick action is not an «aestheticized exercise» but a complex biomechanical event that requires high levels of strength, power, flexibility, neuromuscular coordination, sensorimotor stability, and resistance to fatigue. In this respect, circus performers belong to the group of highly skilled executants whose characteristics are comparable to those of elite athletes, yet whose load structure is fundamentally different. This structure is defined by the combination of maximally risky elements with a high frequency of repetitions in the training process and by a performance-competitive «dual-contour» mode of activity,

in which technical precision, artistic expression, and hazard control must be maintained simultaneously.

Epidemiological data from large companies such as Cirque du Soleil indicate that, overall, the majority of injuries sustained by professional performers are minor, and that the incidence of severe injuries may be lower than in many forms of student sport; however, the risk profile is determined by the discipline, the specificity of tricks, and the context of exposure [11]. In student cohorts, where technique has not yet been fully stabilized and adaptive reserves are uneven, the frequency of acute injuries and the contribution of organizational factors are often higher, as evidenced by analyses of accidents among circus students [16].

Circus genres generate distinct «load profiles». Aerial acrobatics and equilibrism (rings, silks, trapeze, straps, corde-de-parille, and apparatus balancing) produce substantial traction and compressive loads on the shoulder girdle and the cervicothoracic junction, a high proportion of isometric holds, repeated suspensions, and cyclic «grip-hang» phases dominated by the activity of finger flexors, scapular stabilizers, the rotator cuff, and core muscles. Consequently, the shoulder consistently emerges as one of the principal «nodes of vulnerability» among student performers: in a study of injuries within a circus student population, the shoulder joint accounted for the largest proportion of upper-limb injuries [5]. This interpretation is further supported by recent studies analyzing shoulder mechanics and recovery trajectories in aerial acrobatics, which emphasize the relationship between loading patterns, cumulative fatigue, and the risk of impingement and tendinopathic conditions [6].

Floor-based acrobatics, jumping disciplines, parterre eccentric performance, hand-to-hand acts, and rapid series of rolls and landings form a different vector of exposure characterized by high peak ground reaction forces, repetitive landings, eccentric braking, and an elevated risk of overload affecting the ankle-foot complex, the knee, and the lumbar spine. In student samples, the lower extremity often dominates the injury structure; in particular, the lower limbs may constitute the largest share of all injuries, with a concentration at the ankle and the knee [5].

The **sport-art continuum** in circus performance is further complicated by the fact that the structure of a performance program imposes rigid constraints of tempo, musical timing, and dramaturgical sequencing; as a result, the actual biomechanics of movement may diverge from «optimal» sport technique. This circumstance reinforces the need for specialized training methodologies in which safety techniques and functional readiness are integrated with artistic objectives [8].

The most productive analytical framework for circus performance is the model «discipline → type of exposure → tissue-specific risk → behavioral and organizational modification». First, circus disciplines exhibit distinct injury profiles, as confirmed by contemporary population-based studies comparing risks by age, sex assigned at birth, professional status, and genre [4]. Second, it is essential to account for the phenomenon of «injury concealment» or delayed help-seeking behavior, which has been documented in adolescent and school-based circus programs and has direct consequences for the chronification of conditions and the accumulation of cumulative damage [7]. Psychological predictors of injury among circus performers have also been investigated, revealing associations between psychological factors and injury risk and underscoring the necessity of psychoprophylaxis as an integral component of the medical-pedagogical system [10].

A separate line of inquiry concerns injury patterns among students and amateurs, where the intensity of adaptive processes coincides with a deficit of established «safety routines» and variability in coaching approaches. Prospective observations of subgroups of circus performers across training cycles provide data on injury incidence and structure in relation to genre specialization [12].

In aerial acrobatics, the shoulder emerges as a central biomechanical link due to the combination of extreme joint positions (abduction and external rotation), repetitive traction loads, a high proportion of closed kinematic chains under fixed grip conditions, and the requirement for precise scapular control. When fatigue of the scapular stabilizers and the rotator cuff is superimposed, a characteristic cascade develops: altered centering of the humeral head, increased subacromial conflict, reactive tendinopathies, pain, compensatory technique, and, consequently, an elevated risk of a «fatal error» during technically complex elements [5].

One of the fundamental methodological errors in circus training lies in the uncritical transfer of the sport logic «training = load» without recognizing that, in circus practice, performance constitutes a distinct loading domain with its own psychophysiological cost. Exposure in circus contexts is more appropriately described through integral units such as the «artist-performance», which have been employed in studies of professional troupes and enable the correlation of injury frequency with the actual volume of performance activity [11]. It is also essential to distinguish between external load (number of lifts, drops, landings, minutes of suspension, height, apparatus type, and stage surface) and internal load (subjective strain, heart rate, recovery markers, pain signals). This dual-contour structure is methodologically adequate for circus practice and should be incorporated into the pedagogical management of the rehearsal process.

The circus environment combines high performance demands, the interpersonal density of touring life, perfectionism, and continuous evaluation. Studies of the mental health of circus performers indicate that, on several indicators of mental well-being, they may demonstrate lower levels than normative population values while simultaneously exhibiting high levels

of resilience; the predictive role of age, gender, and «circus-specific» factors has also been identified [15]. Given the established associations between psychological factors and injury risk in circus performers, injury prevention strategies must incorporate a psychological module as an element of the overall safety system [10].

A separate dimension concerns eating behavior and the risks of energy deficiency, particularly in genres characterized by an «aesthetic» body norm. Although the specific features of Relative Energy Deficiency in Sport (RED-S) have been studied primarily in sport and dance, circus-related literature also documents problems of maladaptive eating behavior patterns and associated symptoms, which necessitates the transfer of medical-pedagogical screening protocols to circus training programs [14].

Professional circus activity represents a specific form of high-performance athleticism in which physical load cannot be reduced to «training» in the conventional sporting sense but instead consists of two parallel contours of exposure: a rehearsal-training contour (high repetition of elements, accumulation of microdamage, and progressive fatigue of stabilizing musculature) and a performance contour (peak loads under emotional and temporal pressure, increased demands for error-free execution, and often different conditions of surface, lighting, and rigging). This approach is well aligned with epidemiological data from professional troupes, where risk is expressed in terms of the number of exposures and where a substantial proportion of recurrent concussions and average timelines for return to performance have been demonstrated [13].

Table 1. Genre-specific «load profiles» and dominant health risks in circus performers

Genre / Technical Block	Dominant Type of Load	Key Zones of Vulnerability	Typical Health Risks	Early Indicators of Overload
Aerial acrobatics	Isometric holds, traction loads, repeated suspensions, extreme shoulder ranges	Scapulohumeral complex, elbow-wrist chain, cervicothoracic region	Shoulder tendinopathies and impingement, elbow and forearm overload, grip-related problems	Pain during suspension, movement asymmetry, reduced scapular control, decreased grip endurance
Floor-based and jumping acrobatics	Peak ground reaction forces, repetitive landings, eccentric braking	Ankle-foot complex, knee, lumbar spine, Achilles tendon	Ankle sprains, knee overload, low back pain, achillodynia	«Hard» landings, knee instability, post-series pain, delayed fatigue
Hand-to-hand, paired balances	High force peaks, prolonged holds, synchronization load	Shoulders, wrists, lumbar spine, cervical region	Shoulder and wrist overload, muscle strains, low back pain	Increased localized pain, timing disruptions, more frequent «near-failures»
Equilibrism	Static postures, sensorimotor stabilization, cognitive balance control	Ankle-foot complex, knee, pelvis / lumbar spine, shoulders, vestibular system	Chronic foot overload, lumbar and cervical pain, disorientation	Tremor, reduced precision of micro-corrections, early loss of concentration
Juggling and object manipulation	Repetitive upper-limb movements, fine motor activity	Forearm, wrist / hand, cervicothoracic segment	Forearm tendinopathies, cervicalgia, myofascial pain	Hand «burning» sensation, forearm pain, altered throwing trajectory
Scenic eccentric performance, clowning	Contact loads, falls, variability of stage conditions	Knees, elbows, pelvis, ribs, head	Contusions, sprains, concussion risk, chronic joint pain	Frequent falls, accumulation of microtrauma, headaches, slowed reaction time

The practical value of the genre-specific «load profile» (Table 1) lies in its ability to translate an abstract understanding of the complexity of a circus act into manageable parameters: what exactly is repeated, which tissues are subjected to cumulative exposure, and which early signs of overload a methodologist can identify before an injury occurs that would result in missed performances. In aerial disciplines, the shoulder risk contour is predominant, a finding supported both by injury epidemiology in circus environments and by specialized studies on shoulder mechanics and recovery pathways in aerial acrobatics. For circus students, prospective cohort data demonstrating a substantial incidence of injuries per 1,000 hours of exposure are particularly important, as they render «hours» and «repetitions» more meaningful planning units than formal «classes».

For professional troupes, in addition to musculoskeletal issues, concussion represents a distinct line of concern as a manageable but non-zero risk, characterized by a notable proportion of recurrent cases and measurable timelines for return to performance, which necessitates protocolization at the level of rehearsals and shows [9]. Within the Ukrainian educational and organizational context, such a load profile is methodologically compatible with scientific approaches to

the institutionalization and organization of circus training, as it allows medical-pedagogical monitoring to be embedded within the structure of the educational process without undermining artistic logic [3].

Table 2. Practical matrix for managing injury risk

Key Risk Contour	Typical Triggers in the Rehearsal-Performance Cycle	Core Methodological Interventions	Practical Effectiveness Markers
Cumulative musculoskeletal overload (shoulder, knee, ankle)	Excessive suspensions and landings, compressed schedules, work in extreme ranges under fatigue	Exposure quota management (suspensions / landings), rotation of movement regimes, genre-adapted warm-up, early volume modification in response to pain	Reduced pain frequency, technical stability at the end of sessions, fewer «near-failure» events
Acute traumatic events and TBI	Falls, collisions, timing or rigging errors, repeated impacts	Immediate exposure cessation protocol, controlled return-to-performance clearance, training in early concussion signs	Lower recurrence of concussions, controlled return timelines, fewer incidents in high-risk scenes
Organizationally driven injuries	Inconsistent warm-up quality, abrupt load increases, mismatch between task difficulty and readiness	Standardized session structure, graded progression of complexity, systematic recording of pain signals	Fewer injuries during peak periods, reduced absences due to pain, stable well-being indicators
Psychologically mediated risks	Touring stress, perfectionism, a «culture of silence» regarding pain	Safe reporting channels for injury, psychoeducation, regular state monitoring before peak blocks	Earlier pain reporting, fewer chronic injuries, stable recovery indicators
Systemic fatigue and energy deficiency	Restrictive diets, chronic fatigue, insufficient recovery	Screening for recovery and energy deficit signs, alignment of nutrition with load, temporary plan adjustments	Reduced chronic fatigue, stabilized performance quality, improved load tolerance

The presented matrix (Table 2) demonstrates that prevention in circus practice is primarily a matter of managing exposure and behavioral / organizational risk modifiers. For the shoulder risk contour in aerial disciplines, the most effective approach is the logic of «suspension quota management» combined with early load modification upon the emergence of pain, which is methodologically consistent with contemporary syntheses on shoulder mechanics in aerial acrobatics and with data on injury prevalence in circus populations [6]. With regard to concussion, protocolization is crucial, as the measurable incidence of concussions per unit of exposure, the substantial proportion of recurrent cases, and the average timelines for return to performance translate directly into a practical rule: «suspected concussion = immediate cessation of exposure and a controlled return pathway».

For organizational factors in student and early-career professional groups, the evidentiary basis is provided by studies of circus students that analyzed injury causes and the preventive potential of warm-up quality and structured optimization programs [5]. Regarding psychologically mediated risks, contemporary literature indicates that mental factors and the culture of injury reporting are not merely ancillary but constitute elements of the causal model of injury and therefore must be incorporated into the pedagogical management of a troupe or educational program.

In the national context, it is important that Ukrainian scholarly works on the development and organization of circus education create an institutional foundation for implementing such matrices as standards of safe training, as they can be integrated into the educational process as elements of quality assurance and accountability within the educational and production system [2]. The Ukrainian scientific tradition in circus studies has largely developed within the domains of art studies, professional education pedagogy, and methodologies for the formation of performance mastery. Doctoral research devoted to the training of contemporary circus performers in higher education systems describes the multilevel nature of professional formation and the competency profile of the future artist [3]. Publications in Ukrainian professional journals also articulate the challenges of contemporary circus training and outline institutional trajectories of professionalization [1]. At the same time, the «medical-biomechanical» component in domestic circus pedagogy often remains fragmented; consequently, it is methodologically advisable for practitioners to integrate international data on injury epidemiology and the psychophysiology of risk into curricula, rehearsal protocols, and safety quality control systems.

In practical terms, this implies a reorientation of preparedness assessment from an abstract notion of «technical readiness» toward profiled functional readiness. For aerial genres, this entails monitoring scapulohumeral rhythm, stabilizer endurance, grip symmetry, and tolerance to suspension; for floor-based and jumping genres, it involves the quality of

landings, eccentric strength [4], and the stability of the knee and ankle-foot complex; for equilibrism, it encompasses sensorimotor integration, vestibular stability, and strategies for center-of-mass control. Such a framework is consistent with international approaches to genre-specific injury analysis.

CONCLUSIONS

The conducted analysis allows for a well-founded assertion that the contemporary circus performer is a highly skilled athlete with a fundamentally specific structure of physical loads that cannot be adequately described solely within the framework of the traditional sports paradigm. The results confirm that circus activity is characterized by a dual-contour model of exposure, in which rehearsal-training loads with a high frequency of repetitions are combined with a performance contour that generates additional psychophysiological pressure associated with time constraints, stage responsibility, and the requirement for error-free execution of tricks under variable environmental conditions.

The systematization of scientific data demonstrates that the health risk profile of circus performers is genre-specific and is shaped at the intersection of biomechanical characteristics of movement, exposure regimes, and organizational factors of training. In aerial disciplines, the scapulohumeral complex represents a critical zone of vulnerability, where cumulative stabilizer fatigue, disruption of the scapulothoracic rhythm, and repetitive isometric holds contribute to an increased risk of tendinopathies and functional impairments. In floor-based, jumping, and parterre genres, dominant loads affect the lower extremities and the lumbar spine, driven by peak ground reaction forces, eccentric braking, and repetitive landings. In paired and strength acts, synchronization demands and shared performer responsibility assume additional importance, whereas in genres of scenic eccentric performance, the role of contact microtrauma and the risk of traumatic brain injury become more pronounced.

An important outcome of the study is the confirmation of the methodological appropriateness of shifting from the evaluation of load as an abstract «training intensity» toward the analysis of exposure through quantitative and qualitative parameters of motor activity, including the number of suspensions, landings, holds, and the duration of stage work. This approach enables a more precise alignment between the physical demands of circus practice and health risks and provides a foundation for the early identification of overload before the onset of clinically manifest injury.

The relevance of the present study for the field of circus arts lies in its applied potential. The proposed analytical framework «discipline → type of exposure → tissue-specific risk → organizational-behavioral modification» establishes a scientifically grounded basis for integrating medical-biomechanical monitoring into professional training and higher arts education systems without disrupting the artistic logic of performance. The findings may be used in the development of methodological guidelines, curricula, internal safety protocols, and load monitoring systems within circus troupes.

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