

Review

Physiological Demands and Training Recommendations for Formula Racing Drivers: A Brief Review Drawing from Broader Motorsport Evidence

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Abstract

Background: Motorsport competition imposes significant psychophysiological demands on athletes, characterized by prolonged cardiovascular strain, high cognitive workloads, and extreme thermal environments. However, scientific literature focusing specifically on the category of single-seater race cars remains lacking. Therefore, the objective of this review was to identify possible physiological demands in Formula drivers to suggest training recommendations and to examine gaps in the literature for future studies. **Methods:** A narrative literature search was conducted including the following search engines: PubMed/MEDLINE, ScienceDirect, and Google Scholar. All studies until October 2025 were included. **Results:** A total of eight studies were selected. The limited physiological demands of Formula drivers suggest that professional drivers exhibit specialized physical adaptations. These findings describe high aerobic capacity, elevated sustained heart rates during competition, and targeted musculoskeletal development, particularly regarding neck and upper body strength required to withstand gravitational loads. **Conclusions:** Although the currently available data provide valuable preliminary insights into the physiological impact of auto racing, the extremely limited and heterogeneous nature of the existing samples prevents definitive conclusions from being drawn. There is an urgent need for future longitudinal research using high-fidelity, category-specific monitoring to establish robust and standardized psychophysiological profiles and provide training recommendations applicable throughout an entire single-seater racing career.



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1. Introduction

Motorsport competitions encompass a diverse array of formats, ranging from sprint to endurance events, and utilize both open-cockpit single-seaters and closed-cockpit vehicles [1]. The regulations of each racing series can significantly affect the physiological stress experienced by motorsport athletes, influencing the physiological responses of drivers [2]. Auto racing series represent a part of motorsports events characterized by an open cockpit,

such as Formula 1 and IndyCar, or a closed cockpit, such as International Motor Sports Association sports car racing (IMSA GTD) and National Association for Stock Car Automobile Racing (NASCAR) [3,4]. In the open-cockpit competitions, the IndyCar series drivers race on road/street courses, such as the Long Beach Grand Prix, and oval tracks, such as the famed Indianapolis 500 [5,6]. The other specific part of open-cockpit motorsports competition is the Formula Racing Championships, which imposes a unique environment. Formula races typically last about 90 to 120 min, covering at least 305 km. To fully understand the physical and physiological demands of Formula racing, it is essential to be aware of the structured and highly competitive path of single-seater racing. This path is organized according to a pyramid-shaped structure regulated by the Fédération Internationale de l'Automobile (FIA). Formula 4 (F4) is the first step into single-seater cars, introducing drivers to aerodynamic downforce and basic telemetry analysis. Formula 3 (F3) is a highly competitive international tier featuring significantly higher speeds, moderate lateral g-forces, and increased physical demands on the neck and upper body. Formula 2 (F2) is the direct feeder series to Formula 1, where cars possess near-performance levels, demanding exceptional cardiovascular fitness and complex tire management strategies. Formula 1 (F1) is the absolute pinnacle of motorsport car races. F1 represents the ultimate convergence of extreme engineering and human athletic limits, exposing drivers to sustained lateral and braking forces, extreme cockpit temperatures, and unparalleled cognitive loads. In addition, circuit design varies between themselves: some are characterized by high-speed straights, while others feature technical turns. Drivers must comply with specific rules that influence performance, such as mandatory pit stops to change tires, limitations on fuel load, and adherence to circuit-specific track limits and safety protocols [7]. The environment inside a Formula racing car is particularly demanding. It differs from that of the IndyCar, with a temperature range of 50–100 °C in the cockpit due to limited ventilation, tightly sealed driver compartments, and the heat load of the car's components, exposing pilots to a decline in overall health and well-being over time [8–10]. Driving in the Formula Championship also involves unavoidable exposure to high levels of carbon monoxide and noise [10–12]. In particular, Gwin et al. reported high carbon monoxide levels during a car race, ranging from 202 to 835 parts per million (ppm), that are greater than the maximum limit recommended by NIOSH [10,13]. These elevated levels of carbon monoxide seem to be influenced by factors such as the number of vehicles on the track, the proximity of cars to one another, the duration of the race, and extended periods of engine idling or testing [10,11]. The Formula drivers are also subjected to prolonged high g-forces of 4 to 6 g during cornering, braking, and acceleration, which are found to be greater than those recorded in IndyCar races [10]. Mechanical demands result from heavy steering systems, vibrations from high-speed driving, and the ergonomic strain imposed by the confined driving position. Moreover, considering the high gravitational forces, the driver's neck muscles must resist these forces to maintain head control and achieve optimal driving performance [14]. Their inability to maintain head control, especially during the apex of turns, can impair proper trajectory visibility and may cause accidents during competitions [14]. Therefore, many athletes perform neck training protocols, especially for strength and endurance during flexion and extension movements. For these reasons, drivers must also wear multi-layered fireproof suits, gloves, helmets, and head-and-neck support devices (HANS), which provide safety but can exacerbate heat stress and physical fatigue [15,16]. Drivers in most racing disciplines remain at 65–85% of their maximum heart rate (HR) during competition, a physiological demand comparable to athletes in traditional endurance sports like running or swimming [17,18]. This prolonged cardiovascular strain requires high cardiorespiratory fitness (VO_{2peak}) and a high blood volume to optimize stroke volume, oxygen delivery to contracting muscles, and systemic blood

circulation [19,20]. Cardiovascular strain is significantly exacerbated by extreme heat stress, with high temperatures inside the vehicle. Under these conditions, high cardiorespiratory capacity and high blood volume facilitate blood flow to the skin, promoting heat dissipation through profuse sweating and preventing dangerous spikes in core body temperature [10]. Heat stress and dehydration are commonly occurring phenomena in Formula drivers. These conditions could cause greater perceptions of exertion and discomfort, a decline in performance, cognitive disorders, cardiovascular drift, and loss of consciousness [10,21]. To mitigate the inevitable rise in body temperature during competitions, many athletes use pre-cooling strategies before the start of the race. These strategies include the use of cooling vests, immersion in cold water, or the intake of ice slurry to maintain cognitive function and motor precision during the competition [21,22]. The cardiovascular demands on professional race car athletes are very high due to physiological and psychological stress [17,23]. Moreover, the physiological stresses vary considerably between track configurations and dimensions. It is also influenced by physiological fatigue and other stressors: the ability to maneuver the vehicle with precision may decrease as fatigue increases [17]. Furthermore, interest in this sport is growing significantly, as evidenced by the 186,000 spectators who attended the three consecutive days of competition [24]. While several comprehensive reviews have previously addressed motorsport physiology and driver science, no specific review was conducted focusing strictly on Formula racing drivers. So, this brief review aimed to assess the physiological demands and physiological profiles of athletes in the Formula Racing Championship, through a narrative form [25]. More specifically, this study aimed to provide a comprehensive overview of what is currently known in the literature regarding the physiological demands and training recommendations relevant to athletes in the Formula Championship. Finally, a critical discussion of potential research gaps that could lead to future research is presented. To summarize the results of this review, the results were narratively grouped into subsections. The first section showed the possible physiological demands of Formula drivers; the second suggested the possible training that may be useful for them; and the last section established the possible research gap present in the literature.

2. Materials and Methods

This brief review of the literature was conducted to map the limited evidence available in the literature on this topic and to provide insights into training recommendations and future studies.

2.1. Data Sources and Search Strategy

To find eligible articles, a manual search was conducted on the following databases: PubMed/MEDLINE (bibliographic database using specific field tags to target titles and abstracts), ScienceDirect (literature platform using title, abstract, and author-specified keywords), and Google Scholar as an additional scholarly search engine. The literature search was conducted in October 2025, and all studies published up until that time were evaluated. To identify articles, the following terms were used: ('Formula One racing', OR 'Formula racing', OR 'open-wheel racing', OR 'motorsport'), AND ('cardiovascular regulation', OR 'physical performance', OR 'physical conditioning', OR 'heat stress').

2.2. Eligibility Criteria

Professional, elite, or junior competitive race car drivers of both sexes were assessed. Studies focusing exclusively on recreational drivers or minors (<18 years old) without competitive licenses were not considered. The primary focus was placed on single-seater, open-wheel categories regulated by the FIA hierarchy (Formula 1, Formula 2, Formula 3,

and Formula 4) and closely related open-wheel championships (e.g., IndyCar, Formula Ford, Formula Renault, Formula Nissan). Studies evaluating broader motorsport cohorts (e.g., NASCAR, IMSA GTD, sports cars, rally racing) were included only if they provided comparative data directly contrasting those cohorts against open-wheel or Formula drivers. Peer-reviewed original research articles (observational, experimental, cross-sectional, and case studies) as well as existing literature reviews were eligible for inclusion to ensure a comprehensive narrative mapping of the sparse evidence base. Nevertheless, original research was considered primary studies; literature reviews were considered secondary studies for the interpretation of the results. Only studies published in English were considered; all studies in the literature published in other languages were excluded. The studies included in this review were chosen based on their relevance to physiological aspects or training recommendations for Formula drivers. The search was extended using the bibliography within the recruited full texts. Studies were excluded if they investigated two-wheeled competitions (motorcycles), off-road formats exclusively (e.g., motocross), or focused solely on vehicular engineering parameters, simulator technology validation without human physiological tracking.

2.3. Study Selection Process and Data Extraction

Given the narrative nature of this brief review, a manual screening and selection process was adopted. Initial record identification was performed by two independent investigators, who screened titles and abstracts retrieved from the databases. Duplicates across databases were identified and removed manually during the initial screening phase. Potentially relevant full-text articles were then thoroughly evaluated against the pre-established eligibility criteria. Any discrepancies or ambiguities regarding study inclusion were discussed between the two primary screeners until a consensus was achieved, with a third senior investigator available to arbitrate if required. A manual data extraction was used to capture relevant parameters from the included studies. The specific data elements extracted consisted of (a) publication details; (b) study design and methodology; (c) participant sample characteristics; (d) specific racing categories evaluated; (e) physiological outcomes useful for hypothesizing training recommendations and research gaps. Given the narrative scope of this brief review and the recognized scarcity of driver science literature, a formal risk-of-bias assessment was not executed. Instead, a critical appraisal of the evidence base was performed to contextualize the reliability of the synthesized findings.

3. Results

A total of eight studies were included: six original studies and two literature reviews. The findings of the included studies are detailed in Table 1, which explores the type of studies (including participants), the type of physiological outcome/variable, and the main results.

3.1. Study Characteristics

This brief review analyzed data from 93 participants across six original studies [18,20,26–29] and two literature reviews [10,19]. The studies included various types of drivers; only one focused exclusively on Formula 1 drivers, and it was a case study with just two participants [18]. Three studies evaluated anthropometric measurements [19,27,29]; five studies recorded oxygen consumption and HR during races or laboratory testing [10,18,20,26,29] and two studies reported upper and lower limb muscle strength [27,28]. The primary outcomes came from the original studies; the secondary outcomes came from literature reviews.

Table 1. The list of studies included.

Date and First Author	Type of Study	Participants	Type of Outcomes/Variables Studied	Main Results
1987, Schwabegger [26]	Original Research/Primary study	Twenty motor car race drivers among Formula Ford and Renault 5 Cup	- Heart rate during car racing and during a laboratory incremental bike test - Adrenaline and noradrenaline excretion - Metabolic blood parameters: lactate, glucose, FFA (free fatty acids), plasma protein, insulin, HGH (human growth hormone)	Heart rate during car racing represented approximately 90% of the maximal heart rate achieved during the bike test. All outcomes are increased significantly after car races.
2002, Jacobs [20]	Original research/Primary study	Seven male professional open-wheel racing drivers	- Oxygen consumption and heart rate during paced driving sessions on two different tracks and one maximal treadmill running test	Driving on a road course at peak sustained speed resulted in significantly higher oxygen consumption compared to a speedway course. Similarly, mean heart rate was approximately 10 beats per minute higher on the road course.
2005, Backman [27]	Original research/Primary study	Twenty-eight subjects divided into: experienced international-level open-wheel drivers (n = 9), experienced international-level rally drivers (n = 9), and a physically active nondriving male control group (n = 10)	- Speed - Muscle strength - Endurance tests - Anthropometric characteristics	Open-wheel drivers had higher values of neck forces, hand grip, shoulder flexion, and leg extension compared to the control group. The open-wheel drivers tended to be lighter and had the lowest body fat percentage compared to the other groups. The open-wheel drivers showed stronger neck lateral flexions and extension forces compared to rally drivers.
2013, Raschner [28]	Original research/Primary study	Eighteen open-wheel car drivers divided into experienced (n = 9) and junior (n = 9)	- Multiple reactions and multiple anticipation - Postural stability - Isometric upper body strength, isometric leg extension strength, and isometric grip strength - Cyclic foot speed - Jump height	Significant differences between the experienced and junior drivers were found only for the jump height parameter. The experienced drivers tended to perform better in leg strength, cyclic foot speed, and grip strength (18–25%). None of the other variables differed between the groups.
2019, Reid [10]	Review/Secondary study	/	- Heart rate, cardiac output and oxygen consumption - Metabolic rate, cardiovascular regulation and mental stress	The metabolic rate, expressed in MET, is equal to the metabolic costs of traditional sports like soccer, boxing, and basketball. The heart rate of a driver can average 90% of maximal heart rate during a maximal cycle ergometry.

Table 1. Cont.

Date and First Author	Type of Study	Participants	Type of Outcomes/Variables Studied	Main Results
2019, McKnight [29]	Original research/Primary study	Eighteen elite car drivers recruited from Formula 1 (n = 5), IndyCar (n = 5), IMSA GTD (n = 4), and NASCAR (n = 4)	- Oxygen consumption - Percentage of body fat and percentage of lean mass - Isometric neck strength	Formula 1 drivers weighed 12.3% less than drivers competing in the other series, had a body fat percentage that was 53.4% lower than that of IndyCar and NASCAR drivers, and 67.4% less than that of IMSA GTD drivers. Both Formula 1 and IndyCar drivers exhibited a higher aerobic capacity compared to IMSA GTD drivers. About the maximal isometric force exerted by the neck: during extension, side flexion to the left, and anterior flexion, Formula 1 drivers exerted greater force when compared with IMSA GTD drivers; during side flexion to the right, Formula 1 drivers exerted the highest amount of force compared with IMSA GTD and NASCAR drivers; and during anterior flexion, Formula 1 drivers exerted greater force when compared with IMSA GTD drivers.
2021, Saijo [18]	Original research/Primary study	Two professional Formula drivers	Heart rate during a racing Formula competition	Heart rate increased progressively as driving time increased. The stages of the race (pre-attack and attack) had different effects, both in the official free practice and qualifying sessions for both athletes. However, differences in the phase sessions were recorded from the pre-attack phase to the end of the attack lap. In the attack phase, there was a significant correlation between g-force and Heart rate in one driver, and a positive trend in the other driver.
2024, Beaumont [19]	Review/Secondary study	/	- Anthropometric values - Percentage of body fat - Oxygen consumption and heart rate	Formula racing drivers were shorter and lighter than IndyCar and Go-kart racing drivers. Concerning the cardiorespiratory profile, the Formula athletes reported the greatest oxygen consumption. Greater cardiac output, stroke volume, and blood volume are shown to be related to individuals repeatedly exposed to high-G accelerations.

3.2. Primary Outcomes

The primary evidence comprises six original research articles [18,20,26–29], which display high heterogeneity regarding their testing contexts, sample sizes, and driver cohorts.

3.2.1. Anthropometrics and Body Composition

Direct evidence evaluating specific Formula cohorts remains extremely scarce. McKnight et al. provided direct cross-category comparisons, demonstrating that Formula 1 drivers weighed 12.3% less and exhibited a body fat percentage 53.4% lower than that of IndyCar and NASCAR drivers, and 67.4% lower than that of IMSA GTD drivers [29]. Broadening the scope to open-wheel categories, Backman et al. observed that elite open-wheel drivers tended to be lighter and possess the lowest body fat percentages compared to both elite rally drivers and active non-driving controls [27]. In contrast, Raschner et al. focused on open-wheel racing series compared to junior categories, but found no significant anthropometric differences between experienced drivers and those in the junior categories [28].

3.2.2. Cardiovascular Strain and Aerobic Capacity

In the study conducted by Schwaberg, competitive driving in Formula Ford and Renault 5 Cup elicited a sustained HR equivalent to approximately 90% of the maximal HR achieved during incremental laboratory cycle ergometry [26]. This high cardiovascular demand was further qualified by Jacobs et al. in a sample of seven professional open-wheel drivers; they demonstrated that racing on a technical road course induced significantly higher oxygen consumption and a mean HR approximately 10 bpm higher compared to an oval speedway course [20]. Direct fitness benchmarking by McKnight et al. confirmed that elite Formula 1 and IndyCar drivers possess a significantly higher aerobic capacity than closed-cockpit IMSA GTD drivers, pointing toward category-specific cardiorespiratory adaptations [29]. Moreover, Saijo et al., in an exclusive two-driver F1 case study, observed that HR rose progressively with driving duration and identified a significant correlation between lateral g-forces and HR [18].

3.2.3. Musculoskeletal Adaptation and Neuromuscular Strength

For musculoskeletal and neuromuscular strength, Backman et al. established that open-wheel drivers generate significantly higher neck forces, hand grip, shoulder flexion, and leg extension strength than active controls, alongside superior lateral neck flexion and extension forces compared to rally drivers [27]. Moreover, McKnight et al. corroborated these results by confirming that F1 drivers exerted the highest maximal isometric force when directly contrasted with NASCAR and IMSA GTD cohorts [29]. Regarding the junior-to-elite progression, Raschner et al. noted that experienced open-wheel drivers trended toward higher upper-body, unilateral leg, and grip strength (18–25% higher) than junior counterparts [28].

3.3. Secondary Outcomes

The secondary evidence base consists of two review papers [10,19]. Reid and Lightfoot conducted a broad physiological synthesis of auto racing, noting that the metabolic rate of competitive driving (expressed in METs) scales equivalently to traditional high-demand sports like soccer or basketball [10]. More recently, the scoping review by Beaumont et al. attempted to map driver profiles across multiple disciplines [19]. Their analysis confirmed the primary outcome that within the limited pool of strictly Formula-specific literature (three studies, 23 total drivers), Formula athletes were consistently shorter and lighter than IndyCar or Go-kart cohorts [19]. Moreover, authors explicitly underscored that out of the

entire tracked Formula sample, only a single driver had direct cardiorespiratory fitness quantified, emphasizing that secondary review conclusions regarding single-seater profiles are built upon heavily restricted primary data [19].

4. Discussion

This brief review contextualizes the potential physiological demands of Formula racing drivers. However, given the extreme scarcity and high heterogeneity of the included literature, these findings must be interpreted as preliminary rather than a definitive profile. To augment the primary data and avoid double-counting synthesized outcomes, review-level evidence was isolated and utilized to contextually map broader motorsport trends. Crucially, direct evidence strictly focusing on modern Formula series (F1–F4) remains limited, requiring careful distinction from broader open-wheel racing or mixed motorsport samples. Nevertheless, from the results obtained, it is possible to provide recommendations on training for this type of driver. Based on these results, it is also possible to provide insights and reflections for future studies by analyzing the research gaps that the included studies reported.

4.1. Anthropometric Characteristics

In the scoping review of Beaumont et al., just three studies met the inclusion criteria in the Formula series [19]. In 23 pilots evaluated, Formula racing drivers were found to be shorter and lighter than IndyCar and Go-kart racing drivers and to have a lower percentage of body fat than IndyCar drivers, in agreement with the study of McKnight et al. [19,29]. The explanation could be due to the different vehicle design regulations of the two categories [19]. The minimum dimensions of the cockpit for Formula One in 2023 were length ≥ 1830 mm and width ≤ 550 mm, and the mass of the driver plus ballast could not be less than 80 kg at any time during the race. Instead, the IndyCar regulations require that the seat be designed for the individual driver and that the driver plus ballast cannot weigh less than 83.9 kg. As a result, Formula One may cause teams to look for drivers who best fit the vehicle [19]. In agreement with these studies, the original study conducted in 2005 by Backman et al. reported that the open-wheel drivers (mainly Formula 1 drivers) tended to be lighter and had the lowest body fat percentage [27].

4.2. Gravitational Forces and Muscle Strength

The gravitational forces (g-forces) in the Formula Racing Championship are among the highest, exposing athletes to muscular injuries, particularly of the cervical spine [30]. In this regard, the study conducted by Backman et al. aimed to investigate the differences in strength, speed, and endurance between elite open-wheel drivers, elite rally drivers, and a control group of physically active nondriving males [27]. Furthermore, they demonstrated greater strength in neck lateral flexions and extension forces when compared with rally drivers [27]. The substantial neck strength observed in open-wheel drivers could be a functional requirement to counteract lateral g-forces. Mechanistically, maintaining head control is not merely a matter of injury prevention, but it directly underpins visual stability and steering precision. Insufficient neck endurance leads to head tilt during cornering apexes, impairing the driver's visual trajectory, spatial orientation, and late-race reaction times, thereby compounding safety risks. Moreover, the trunk flexion and extension forces of racing drivers are comparable to those of top Swedish wrestlers and are 30–40% higher than those of elite Swedish tennis players and Finnish basketball players [27]. This may be attributed to the necessity of strong trunk muscles in race driving, as the abdominal muscles must contract during braking and cornering [27]. In addition, the leg extension force was 10% higher in open-wheel drivers than in basketball players, measured using the

same method. This may be explained by the reclined driving position in open-wheel cars, which engages the quadriceps muscles and is reflected in the leg strength results [27].

4.3. Cardiopulmonary Fitness

Already in 1987, Schwabergers study revealed the high level of fitness required to compete in motor racing, including Formula racing [26]. The intensity required during a motor race in HR reached approximately 90% of that in a previously conducted cardiopulmonary test in the laboratory [26]. Instead, the study conducted by Jacobs et al. aimed to analyze the physiological responses of experienced drivers to high-speed open-wheel racing across various types of racecourses and dimensions [20]. The outcomes examined included oxygen consumption and HR during preseason equipment testing on two courses: a road course at Sebring International Raceway in Sebring, and an oval speedway course at Homestead–Miami Speedway in Homestead [20]. This research indicated that driving on a road course at peak sustained speed resulted in significantly higher oxygen consumption compared to a speedway course [20]. Similarly, the mean HR was approximately 10 beats per minute higher on the road course [20]. These results may assist Formula drivers who will face different racetrack types. Conversely, a study conducted by McKnight et al. aimed to quantify various physical fitness variables, including $\text{VO}_{2\text{peak}}$, among different motorsport racing drivers, including Formula drivers [29]. No statistically significant difference was found in $\text{VO}_{2\text{peak}}$ value between IndyCar and Formula drivers; however, both groups were found to have higher values than IMSA GTD drivers [29]. While in the studies previously analyzed, the drivers were from different disciplines, in the case study conducted by Saijo et al., only two Formula drivers were evaluated during a racing competition [18]. This study outlined different physiological responses, expressed through HR in different phases of the race, differentiated into pre-attack and attack. The latter phase was also examined in relation to the type of competition (free practice or qualifying), demonstrating significant differences [18]. However, while competitive driving elicits a sustained heart rate near 90% of laboratory maxima, this elevated cardiovascular response must not be viewed solely as an indicator of pure cardiopulmonary or mechanical workload. In professional racing, heart rate reflects a complex, multi-factorial integration of physical strain alongside autonomic and environmental stressors. Factors such as extreme cockpit heat stress (50–100 °C), psychological stress, high cognitive load, noise exposure, vibration, dehydration, and competitive arousal significantly drive sympathetic activation.

4.4. Training Recommendations

To optimize physical preparation for Formula racing, conditioning programs should not be applied as generic protocols but must be structured according to the directness and strength of the available evidence base. Concerning cardiovascular fitness, Formula 1 drivers had a higher aerobic capacity and $\text{VO}_{2\text{peak}}$, which could lead us to say that they adapted their cardiovascular system in response to a high cardiovascular demand during the races [29]. Additionally, in the study by Watkins, a correlation was found between aerobic fitness and lower average HR across various lap speeds, as well as reduced instantaneous HR at specific locations on the track [31]. Motorsport evidence supports aerobic conditioning, while evidence from endurance physiology indicates that aerobic training (such as running and cycling) can increase stroke volume and blood volume [19]. In addition, high-intensity interval training protocols are thoroughly proven to maximize VO_2 max with programs consisting of training sessions that include supramaximal efforts, although their direct efficacy within the Formula cohorts has not been specifically evaluated for that category [19,32]. Regarding the neck and shoulder muscles, the results showed that the isometric neck strength was the highest in Formula 1 and IndyCar drivers as compared

with IMSA GTD and NASCAR drivers [29], and open-wheel drivers were stronger in neck lateral flexions and extension forces compared with the rally drivers [27]. This could be due to the g-forces being the highest in open-wheel racing, and even more so in Formula racing [10]. Thus, to tolerate sustained gravitational forces, drivers should focus on improving neck strength and endurance, particularly for lateral flexion and extension. In agreement, Backman et al. suggest that competitive long-term car racing and specialized training improve neuromuscular performance, and they recommend that open-wheel drivers prioritize neck muscle training while also training all other muscle groups evenly [27]. Moreover, Raschner et al. showed that fitness training for drivers should include general and race car-specific strength, sensorimotor skills, coordination, speed, and endurance, and that young drivers should be taught proper techniques early on, with coaches focusing on this to optimize neural adaptations, especially intramuscular coordination [28]. In this regard, Horvath et al. evaluated the effects of a 6-week reactive agility training protocol, using light stimulation, on the physiological and cognitive abilities of racing car drivers [33]. Results showed beneficial effects on some physiological performance measures, such as HR, suggesting how this type of training could be useful for race car drivers [33]. However, further research is needed to investigate the best training program for drivers and specifically discover which one is the most similar training for the neck that simulates the g-forces on the racetrack.

4.5. Research Gaps

The physiological demands in Motorsport are not a highly researched and studied field, and even more so in the Formula Racing Championship. In the scoping review conducted by Beaumont et al., just three studies met the inclusion criteria in the Formula series, with a population of 23 subjects, of which just one recorded a measure of cardiopulmonary fitness [19]. Instead, Reid et al. identified 46 original studies on auto racing athletes published between 1966 and 2019, with most involving fewer than 15 subjects and lacking control groups [10]. Our review aimed to identify the physiological demands placed on athletes in the Formula Championship, but research in this area is limited. The results primarily offer general insights applicable to open-wheel drivers, rather than specifically addressing Formula drivers, and fail to differentiate among the Formula 1, Formula 2, and Formula 3 Championships. The first gap to highlight is, in our opinion, the few primary research studies; the need for a higher number of original research studies is important. In addition, data and research are needed in the Formula Racing Championship and all the other championships. This would help to identify the different physiological demands in the different championships, dividing them by race type and duration. Moreover, despite the clear distinction between the various Formula categories, there is a distinct lack of longitudinal research analyzing how a driver's psychophysiological profile adapts as he moves up through the ranks, from F4 to F1. Therefore, future studies should focus on the individual Formula categories and provide training recommendations tailored to each category. The second gap to highlight, analyzed by McKnight et al., is the lack of standardized tests that do not permit comparison of the data and provide more analysis [29]. Standardization of tests, so that results and data can be compared across studies, could lead to the production of more studies. Furthermore, although simulators are effective for procedural training, they completely lack the broader socio-environmental, psychosocial, and physical stressors that elite pilots face in the real world. Recent research has identified a physiological and psycho-emotional discrepancy observed in simulator results, which further underscores the need to integrate comprehensive mental health monitoring and psychiatric risk assessment into the broader framework of flight science, as virtual environments do not appear capable of replicating these high-risk psychiatric pressures [34]. So,

future studies should focus on the psychophysiological profiles of athletes, particularly on the development of strategies centered on the actions of drivers during competitions [35]. In addition according to the results of this study, further research should focus on determining if the differences seen in the drivers of different categories are due to the conditioning of racing or physical fitness training [19,27]; identifying the differences between the diverse levels of athletes, between women and men, and in various ages [10,28]; and investigating the effectiveness of potential training modalities for drivers and study training protocols that simulate the g forces on the racetrack and their effectiveness [29].

5. Conclusions

In conclusion, while the available literature provides valuable preliminary insights into the physical demands of motorsport, the current evidence base is highly constrained by limited sample sizes and significant methodological heterogeneity. The poor findings suggest that open-wheel and Formula racing environments place unique psychophysiological requirements on athletes, specifically regarding anthropometric constraints, multi-directional cervical strength, and high cardiovascular demands driven by mixed physical, autonomic, and environmental stressors. However, due to the inclusion of mixed motorsport cohorts and broader open-wheel samples rather than strictly Formula-specific populations, these physiological profiles cannot yet be considered definitive or universally generalizable across the entire Formula category. The main take-home message underscores that physiological adaptations and training requirements are profoundly influenced by category-specific regulations, race type, and event duration. Consequently, sports scientists and motorsport coaches must exercise caution when extrapolating general sport science conditioning protocols to these unique athletes. To transform driver science into a highly rigorous and predictive discipline, future research must move away from descriptive case studies and focus on the deployment of standardized testing methodologies, high-fidelity ecological race monitoring during live competitions, and robust longitudinal training-intervention studies across junior development pathways.

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