

Determinants of surfing performance: A systematic review of the multifactorial factors involved

FRANCISCO CAMOLESI IDE¹, MÔNICA CRISTINA FLACH², IRAMAR BAPTISTELLA DO NASCIMENTO³.

^{1,2} Programa de Pós-Graduação de Ciência do Movimento Humano da Universidade do Estado de Santa Catarina. Centro de Ciências da Saúde e do Esporte - CEFID / UDESC - Florianópolis, SC, BRASIL.

³ Departamento de Ciências da Saúde da Universidade do Estado de Santa Catarina. Centro de Ciências da Saúde e do Esporte - CEFID / UDESC - Florianópolis, SC, BRASIL.

Published online: February 28, 2026

Accepted for publication: February 15, 2026

DOI:10.7752/jpes.2026.02031

Abstract

This systematic review aimed to investigate the physical, technical, physiological, and psychological factors that influence performance in surfing. Methods: Literature searches were performed in the PubMed, Embase, SPORTDiscus, SciELO, LILACS, and Web of Science databases between July 5 and 11, 2025. The search followed the guidelines of the Cochrane Collaboration and PRISMA-2020. The methodological quality and risk of bias of the included studies were assessed using tools from the National Heart, Lung, and Blood Institute (NHLBI). Results: Physical factors, including upper limb strength, core strength, lumbar flexibility, and hamstring flexibility, were associated with performance in executing the pop-up technique. Success in aerial maneuvers was linked to hip and knee mobility, which also contributes to injury reduction. Within the physiological domain, pre-warming strategies were shown to be effective in enhancing performance. During sprint paddling, the latissimus dorsi and deltoid muscles exhibit greater activation; furthermore, sodium bicarbonate supplementation may enhance paddling performance by increasing anaerobic capacity. Heart rate can approach maximum levels, increasing the risk of premature falls, as can low energy availability, which may also impact overall yield. Technical studies revealed that aerial maneuvers vary in height, efficiency, and execution according to the type of movement and the surfer's gender, with high technical fidelity in simulations and significant joint differences between styles. Conclusion: An integrated approach to the relationship between strength, mobility, and pop-up execution techniques is recommended, as is the importance of developing flexibility and balance for performing aerial maneuvers. Emphasis is placed on enhancing aerobic and anaerobic capacities, as they are determinants of both wave-riding duration and recovery efficiency between efforts. It is also suggested that sodium bicarbonate supplementation be investigated as a potential strategy to optimize paddling performance. Finally, special attention is recommended to psychological factors and, above all, to the prevention of low energy availability due to its potential negative impact on performance. The results confirm that surfing performance is inherently multifaceted. However, significant gaps remain in the understanding of biomechanical technical patterns, in the consideration of psychological factors, and in studies involving female athletes. Future research should address these gaps to optimize training strategies and maximize performance potential in the sport.

Key words: Biomechanics, Athletic Performance, Physical Fitness, Motor Skills, Sports Physiology.

Introduction

Surfing, an ancient practice with deep roots in Polynesian cultures, has transcended its recreational origins to become a global professional sport with significant economic and cultural impact. Its evolution, marked by the establishment of professional leagues such as the World Surf League (WSL), attracting millions of viewers and generating substantial business (estimated at approximately \$3.1 billion in 2020), with projections to grow to \$5.2 billion by 2027, driven by tourism, equipment, and events (Global Industry Analysts, 2025), underscores its importance. A landmark for the sport was its inclusion in the Tokyo 2020 Olympic Games (held in 2021) and its retention for Paris 2024, catalyzing an increase in visibility and scientific interest in the multiple factors that contribute to athletic performance in this modality. Furthermore, surfing can be considered an exemplary model of multidisciplinary in sports science, integrating unpredictable environmental challenges, intense athletic demands, and complex psychological components (Moreira et al., 2014).

The growing professionalization and Olympic recognition of surfing have driven academic interest, which resulted in a modest but steady increase in publications on training and high performance. Among the factors that comprise high performance, the physical, technical, physiological, and psychological factors (PTPP) are fundamental in sports sciences (Sharma et al., 2021; Mujika et al., 2018; Weinberg et al., 2023). Although

literature contains research related to these factors, gaps persist in the understanding of the specific needs of this modality and the most effective training strategies (Nessler et al., 2019).

The intermittent nature of surfing renders physical conditioning important due to the aerobic and anaerobic demands intrinsic to the modality (Mujika et al., 2018). This fitness has emerged as a key element, directly influencing paddling efficiency, maneuver execution, and stability on the board (Bravo et al., 2016). After surfing a wave, the surfer may return to the starting point with a light and rhythmic paddle; as soon as a new wave is sighted, they quickly turn around and initiate a strong and intense paddle to catch the wave and surf again. Between one and two seconds later, they perform the pop-up (a transitional movement that shifts them from the prone position on the board to the standing position), followed by high-power actions to execute maneuvers, primarily involving the lower limbs, over a period that can last up to 20 seconds (Secomb et al., 2015; Minghelli et al., 2017). The inherent characteristics of waves, demand not only physical skills but also technical ones, owing to the speed at which surfers must react and execute maneuvers of high difficulty and risk. Research consistently demonstrates that higher performance levels are associated with superior technical execution and advanced tactical skills, such as decision-making and anticipation, which often serve as differentiators among elite athletes (Cook et al., 2024a). Although the existing literature presents advances, there are still considerable gaps concerning technical factors. Specifically, technical movement patterns, supported by consistent biomechanical foundations, remain underexplored despite their relevance to performance and injury prevention (Seroyer et al., 2010). Physiological factors are intrinsic to the intermittent nature of surfing, which requires both aerobic and anaerobic fitness. These capacities, added to muscular strength and thermoregulation directly influence athletic efficiency. They are crucial in surfing due to the intermittent demands of intense paddling and explosive maneuvers, wherein anaerobic conditioning sustains short bursts of effort and aerobic conditioning supports prolonged sessions, thereby impacting wave riding duration and recovery (Mendez-Villanueva et al., 2005). Time-motion analyses indicate that surfing involves periods of intense paddling interspersed with moments of waiting, which requires a well-balanced physiological profile (Secomb et al., 2015). Studies have also emphasized the importance of anaerobic fitness for intense paddling and explosive maneuvers, which are essential for competitive success (Secomb et al., 2015).

Finally, psychological factors are as crucial as the others, given the subjective nature of competitive evaluation and the need for quick decisions under pressure (Araújo et al., 2019). The ability to manage anxiety and stress, maintain focus, have the self-confidence to select the right wave, and even risk critical maneuvers to achieve the necessary score and win a heat are key factors in psychological preparation that culminate in better performance (Sharma et al., 2021). Research indicates that previous performance errors can negatively impact subsequent performance, highlighting the need for psychological resilience in surfers (Klingner et al., 2023).

It is important to note that the ecological analysis of surfing is complex due to the particularities of the environment. As a preparatory strategy, researchers resort to simulated situations, such as the use of artificial wave pools, paddling ergometers, or laboratory analyses, to attempt to replicate the surfing context. These simulations can be useful for studying performance, as they allow greater control over variables and test repetition. However, the absence of real elements promotes greater postural rigidity and compensatory adjustments, making metrics of balance and motor control significantly different between simulated and oceanic scenarios (Lee et al., 2025; Delavari et al., 2025). Although specialized research addresses the factors mentioned, a holistic understanding of the sport is essential for optimizing training and seeking best practices (Turner et al., 2019). The holistic approach to high-performance sports refers to an integrative perspective that considers the athlete not as an isolated entity, but as a complex interconnected system. This translates into programs that combine physical training with psychological, nutritional, and recovery support, recognizing that factors such as emotional stress can directly impact physical performance. Studies indicate that athletes who adopt this approach have 20-30% lower injury rates and longer careers (Sarkar & Fletcher, 2014). Contemporary literature shows very few studies addressing more than one performance factor, concluding that there is a significant gap in research regarding a comprehensive analysis that synthesizes these findings. As PTPP factors are indispensable foundations for understanding high-performance in sports, a more integrated in-depth research is needed. Based on this evidence, this study aimed to conduct a comprehensive systematic review of the existing literature on the PTPP factors that influence surfing performance. By analyzing and integrating these diverse elements, this work seeks to offer a holistic perspective that can guide training methodologies and contribute to the advancement of surfing as a competitive sport.

Materials and Method

This review followed the guidelines established by the Cochrane Collaboration (Higgins et al., 2019) and PRISMA-2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (Page et al., 2021) (supplementary material S1). The protocol is pre-registered in the International Prospective Register of Systematic Reviews (PROSPERO) with the registration number: CRD420251158777.

Throughout the study, some methodological criteria were reviewed. Subsequently to the registration in PROSPERO, an update was performed in the methodology, including the PECOS strategy for observational studies.

Eligibility Criteria

Inclusion criteria: experimental studies: Controlled Clinical Trial (CCT), Randomized Controlled Clinical Trial (RCCT), Controlled Experimental Crossover Study (CECS). Similarly, observational studies: Cohort Studies (CS), Cross-Sectional Studies (CSS), and Case-Control Studies (CCS), considering articles available in Portuguese, English, and Spanish languages.

Exclusion criteria: studies that do not provide robust evidence, such as case reports, case series, reviews, or expert opinions without systematic criteria; dissertations/theses; short articles; articles published in congresses; studies that evaluated individuals with some type of disability; and studies that did not present a relationship between one or more PTPP factors and performance in surfing.

In the initial phases, a pre-protocol was developed with criteria that prioritized studies published in English, Portuguese, and Spanish languages, from the period of January 2019 to June 2025. As support, the search was conducted using the PICOS strategy (Santos et al., 2007), for experimental studies, according to the following inclusion criteria: (P) Surfing practitioners aged 12 to 60 years, amateur or elite surfers of all male and female categories, and recreational surfers; (I) Experimental studies containing the applicability of interventions related to PTPP factors and performance in surfing; (C) Studies that included a control group; (O) Qualitative or quantitative data clearly relating any PTPP aspect to performance in surfing; (S) Controlled clinical trials, randomized controlled clinical trials, and randomized crossover experimental studies with an intervention group (IG) and a control group (CG). The exclusion criteria were: (P) Surfing practitioners with some type of disability, any other type of board sport modality, and other water sports; (I) Studies that did not investigate the direct relationship between any PTPP aspect and performance in surfing, studies that did not describe the intervention protocols used and the results in a clear and objective manner; (C) Studies without a CG; (O) Any uncertainty regarding the relationship between the investigated aspect and performance; (S) Observational studies, review studies, case reports, case series, reviews, or expert opinions without systematic criteria; dissertations/theses; short articles; articles published in congresses; studies that evaluated individuals with some type of disability; and studies that did not present a relationship between one or more PTPP factors and performance in surfing.

The PECOS strategy was applied following Morgan et al. (2018), for observational studies. The inclusion criteria were: (P) Surfing practitioners aged 12 to 60 years, amateur or elite surfers of all male and female categories, recreational surfers; (E) Studies that examined levels of skill, interventions, or environmental conditions that could influence performance, including comparisons between exposed and non-exposed groups; (C) Observation on skill levels, interventions or environmental conditions that influence performance, including comparisons between exposed versus non-exposed groups; (O) Qualitative or quantitative data clearly relating any PTPP aspect to performance in surfing; (S) Observational studies (cross-sectional, cohort, case-control). Exclusion criteria: (P) Surfing practitioners with some type of disability, any other type of board sport modality and other water sports; (E) Studies that did not investigate the direct relationship between any PTPP aspect and performance in surfing, studies that did not describe the intervention protocols used and the results in a clear and objective manner; (C) Studies that compared performance to other factors different than PTPP; (O) Qualitative or quantitative data clearly relating any PTPP aspect to performance in surfing; (S) Randomized controlled trials (RCT), quasi-experimental studies, narrative or systematic reviews, case reports, letters to the editor, opinions lacking methodological rigor, and other publications without appropriate scientific structure.

Data Bases

For the search and identification of articles, the following electronic databases were accessed: PubMed, Embase, SPORTDiscus, SciELO, Latin American and Caribbean Health Sciences Literature (LILACS), and Web of Science. Furthermore, gray literature was included to minimize publication bias.

Search Strategy

The literature search was conducted from July 5 to 11, 2025. The following descriptors from the Medical Subject Headings (MeSH) were used: Water Sports, Athletic Performance, Surfing, Physical Fitness, Motor Skills, Physiology, Sports Physiology, Psychology, Sports Psychology, combined with the Boolean operators “AND” and “OR”. The distribution by database can be found in Supplementary Material S1.

The search was guided by the following question: What are the PTPP factors that can influence performance in surfing practice?

Selection Process

A protocol was developed with pre-established criteria in terms of publication year, types of studies (experimental and observational), studies from 2019. Preferences were assigned to studies with higher levels of scientific evidence and internal validity. The information was supported by the guidelines of the Centre for Evidence-Based Medicine, Oxford, United Kingdom, which are aligned with the pyramid of the hierarchy of evidence (Murad et al., 2016).

Data collection and registration process

The screening of titles and abstracts was followed by a full-text review of the eligible studies. Two independent reviewers (F.C.I.; M.C.F.) conducted the search, discussing and resolving any discrepancies through consensus. In cases where consensus could not be reached, a third reviewer (I.B.N.) made the final decision. The

online platform Rayyan Web was used for study storage, duplicate checking, and independent selection. The lead reviewer supervised the entire search strategy, along with the study coordinator, to ensure adherence to the protocol. Studies excluded after the eligibility analysis steps had their reasons recorded (Supplementary Material S2). The data collection pattern followed the defined protocol as follows: Author/Year/Country: aimed at identifying where the highest concentration of research is located; Sample Size/Sex/Age: provides a spectrum of primary characteristics of the participants; Objective/Study Type: indicates the specific objective of each study and the design used, also for guiding future research; Specific Situation in Surfing: this field seeks to identify what kind of specific situation or maneuver the studies were focusing; Performance Aspect: indicates which PTPP factors are the subjects of the study; Inclusion and Exclusion Criteria: identifies secondary characteristics of the participants; Results and Conclusion: presents the relationship between the analyzed factors and surfing performance. Two independent reviewers (F.C.I.; M.C.F.) performed the data extraction to minimize bias and ensure accuracy. Discrepancies between the reviewers were discussed and resolved by consensus. In cases where consensus could not be reached, a third reviewer made the final decision (I.B.N.).

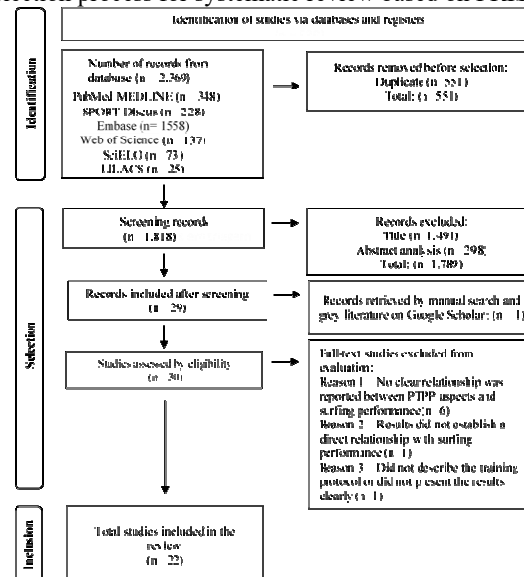
Qualitative assessment of risk of bias

Methodological quality was assessed using tools developed by the National Heart, Lung, and Blood Institute (NHLBI, n.d.), part of the National Institutes of Health (NIH). These criteria guide the analysis of risk of bias, internal validity, and applicability of findings, enabling a systematic evaluation of evidence reliability, following specific criteria for different research designs. Previous studies attest to the efficacy of the tools (Sarkies et al., 2017). For this review, two assessment tools were employed: one for observational cohort and cross-sectional studies, and one for controlled intervention studies. The questions follow a response pattern of “yes,” “no,” “cannot be determined,” “not applicable,” or “not reported.” For the scoring scale, a value of 1 was assigned to “yes” responses, and 0 to “no,” “cannot be determined,” and “not reported” responses. When the response was “not applicable,” the question was excluded from the total sum. Studies were classified as having “high,” “moderate,” or “low” risk of bias based on the percentage score achieved. It was arbitrarily established that studies scoring up to 49% would be classified as “high,” those from 50% to 74% as “moderate,” and those above 74% as “low.” Assessments were conducted independently by two reviewers (F.C.I.; M.C.F.), with discrepancies resolved through consensus. For quality standardization purposes, a threshold of at most 5% of studies with a “high” classification was set for inclusion in the final selection. To quantify inter-rater reliability, the agreement between reviewers was calculated using Cohen's Kappa index for two raters, implemented in the statistical software R version 4.0.2 with the “irr” package (Gamer et al., 2019), yielding a substantial level of agreement for k (0.61–0.80).

Results

The database search yielded a total of 2,369 records. In the initial screening phase, a comprehensive review of titles and abstracts was conducted, guided by the PICOS and PECOS frameworks. After exclusion, 1,491 records were evaluated by title and 298 by abstract. Following the title and abstract review, 1,789 did not meet the eligibility criteria. Subsequently, one additional study was retrieved through a manual search of the gray literature (Google Scholar), resulting in 30 studies going through full analysis. Studies excluded after the full-text eligibility assessment are listed in Supplementary Material S2. In the final inclusion phase, 22 scientific studies remained, as shown in Figure 1.

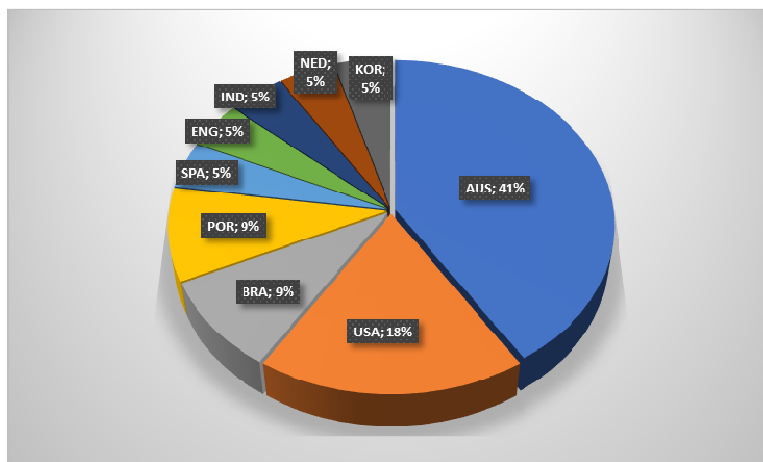
Figure 1. Flowchart of the selection process for systematic review based on PRISMA



Source: Checklist de Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. PRISMA 2020 Statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:71. doi: 10.1136/bmj. n71. <http://www.prisma-statement.org/>.

The initial qualitative analysis aimed to identify the concentration of research across countries (Figure 2). The results indicate a concentration of studies in Australia (41%), followed by the United States (18%). Brazil and Portugal each account for 9% of the studies, while other countries represent 5%.

Figure 2 – Research concentration across countries

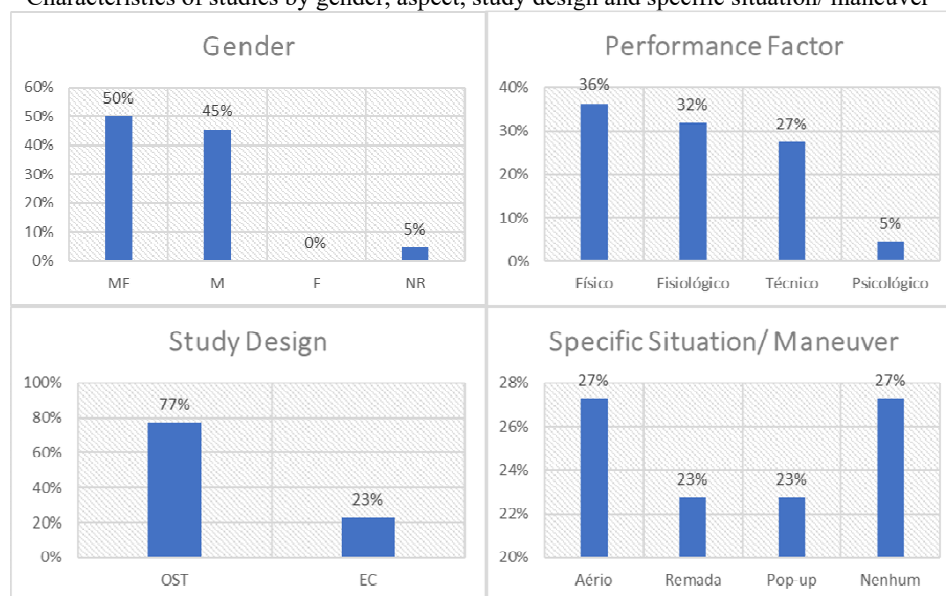


Source: Authors, 2025. Abbreviations: AUS – Australia; USA – United States of America; BRA – Brazil; POR – Portugal; SPA – Spain; ENG – England; IND – Indonesia; NED – Nederland; KOR – Korea.

Regarding gender, 50% of the studies investigated mixed groups, while 45% focused solely on male participants. Only one study did not mention gender, and no study focused exclusively on female participants. Concerning the analysis of the studied PTPP factors, the majority evaluated physical factors (PA) (36%), whereas the psychological factors (PSA) were the least studied (5%). Notably, only 23% of studies design were clinical trials, with cross-sectional observational studies comprising the majority (77%).

Aerial maneuvers were the biggest subject of analysis (27%), followed by paddling and pop-up (23%). Figure 3 presents the descriptive statistical analysis concerning the four mentioned dimensions.

Figure 3 – Characteristics of studies by gender, aspect, study design and specific situation/ maneuver



Source: Authors, 2025. Abbreviations: CS – Cross Section; F – Feminine; M – Masculine; MF – Masculine and Feminine; NR – Not reported; RCT – Randomized clinical trial.

Table 1 presents the summarized data of the selected studies, according to the established protocol.

Author/ Year/ Country	Ss/ Gender / Average age or range	Objective/ Study type	Specific surf situation	Performance Factor	Inclusion/ Exclusion criteria	Outcomes and Conclusion
Parsonage et al., 2020/ Australia	n=18/ MF/ 18	To analyze the reliability of the isometric push-up, dynamic push-up, and pop-up as measures of upper-body isometric and dynamic strength/ CS.	Pop-up	Physical	IC: surf for a minimum of 10 years, and surfed more than three times a week/ EC: any upper body injuries or medical conditions that were contraindications to participation.	Significant and moderate correlation between relative peak strength (isometric pull test and plyometric squat) and pop-up time. The authors conclude that upper body strength and power measures are important predictors of pop-up performance.
Utama et al., 2023/ Indonesia	n= 80/ M/ 20-40	To investigate the relationship between core muscles, leg arches, hamstring, and lumbar flexibility on pop-up ability/ CS.	Pop-up	Physical	IC: men aged 20-40 years who had been surfing for at least one year/ EC: musculoskeletal injury or is under treatment and has bone and muscle disorders.	Significant correlation between core muscles, leg arches, hamstring and lumbar flexibility and pop-up ability. Lumbar flexibility was the most dominant factor.
Borgonovo-Santos et al., 2021/ Portugal	n=20/ M/ 28	To describe the kinematics and GRF parameters of a simulated pop-up and to measure anthropometric properties to determine correlation with the performance of simulated pop-up/ CS.	Pop-up	Physical/ Technical	IC: have surfed regularly for at least two years, practicing at least once a week/ EC: have suffered any serious musculoskeletal injury in the last six months.	The pop-up had an average duration of 1.20 ± 0.19 s (60% push-up phase, 40% reaching/landing phase). During the push-up, the non-dominant hand exerted greater peak force (52% vs. 48%), but the impulses were symmetrical. On landing, the front foot applied 72% of the force against 28% from the rear foot. Inverse relationship between muscle mass and total pop-up time.
Fernandez-Gamboa et al., 2020/Spain	n=83/ MF/ 18	To compare the pop-up and counter movement jump and to analyze the relationships among the variables between genders and different ages/ CS.	Pop-up	Physical	IC: competitive surfers at nation level/ EC: not reported	Significant differences in strength between genders and ages. Men O16 exhibited greater strength in the vertical jump and flexion phase than women. Women U16 and O16 had a higher eccentric unloading rate. The correlation between vertical jump and pop-up was moderate, indicating that pop-up can be influenced by coordination and upper limb strength. Upper body and coordination training is recommended.

Perejmibida et al., 2023/ Australia	n=19/ M/ 14	To identify the physical performance capabilities of adolescents and to explore the association of these capabilities with the age and stage of maturation/ CS.	None	Physical	IC: teenage male surfers at state level, aged between 11 and 16 and undergoing training (one or two in-water training sessions led by coaches)/ EC: High Performance Program athletes.	Flexibility, lower limb power and strength, upper limb pulling strength and total Athletic Ability Assessment improved with age and maturity. Relative strength, dynamic balance and some components of the Athletic Ability Assessment showed no improvement. It is important to emphasize a more robust training approach aimed at optimising athletic performance. Well-structured off-water training is needed.
Monaco et al., 2023/ USA	n= 22/ MF/ 35	To investigate the effects of a sport-specific, land-based-home exercise programme on performance/ RCT.	Pop-up	Physical	IC: active recreational surfers with at least 1 year experience of surfing year-round and were between the ages of 18–60 years old/ EC: competing higher than local club level, providing surf coach instruction for a surf school, cognitively impaired, previous hand/wrist, elbow, shoulder, spine, hip, knee, ankle or foot surgery within 1 year, and injuries to the aforementioned areas within 3 months.	Results showed a significant improvement in SPQ for EG. EG also showed an improvement in pop-up time vs CG. SPQ and pop-up are effectively improved by this LB-HEP, demonstrating land-water transferability.
MacDonald et al., 2024/ Australia	n=28/MF/21-61	To explore and understand the importance of paddling to overall surfing performance/ CS.	Paddling	Physical	IC: athletes had to be currently or have had experience competing on the WSL - CT and/or Challenger Series (CS); Coaches and practitioners had to have experience working with athletes at this competition level. EC: not reported.	Paddling improves physical capacity and gives competitive edge. Strengthening the paddle expands opportunities for action, accelerates the development of skills and increases the surfer's confidence.
Author/ Year/ Country	Ss/ Gender / Average age or range	Objective/ Study type	Specific surf situation	Performance Factor	Inclusion/ Exclusion criteria	Outcomes and Conclusion
Dowse et al., 2020/ Australia	n=36/ M/ 22	To determine whether ankle proprioception differs by competitive level and is related to years of surf-specific experience. To compare the physical capacities and abilities that may differentiate between the competitive levels/	None	Physical	IC: senior-elite (WQS level) and over 16; junior-elite (state level or higher) and 12–18 years of age, recreational surfers (minimum of two years surfing experience; surfing at least once a week and over 18)/ EC: lower-body injury or medical condition.	Senior-elite showed significantly better proprioception and ankle ROM than junior and recreational surfers. Senior-elite had lower relative peak force. No significant relationship between years of surf-specific experience and proprioception. Authors conclude that proprioception,

		CS.				ROM and the ability to attenuate energy are distinctive characteristics of high-level surfers.
Nessler et al., 2019/ USA	n=12/ MF/ 29	To examine activity in 5 muscles that contribute to paddling at different velocities/ RCT.	Paddling	Physiological	"IC: minimum of 5 years of surfing experience,	Muscle activation increased with water speed, with the latissimus dorsi showing the greatest increase between endurance paddling and sprinting. Medial deltoid activated earlier in the sprint and a linear increase in oxygen consumption, paddling cadence and board movement with increasing water speed. Study suggests focusing on pectoralis major, latissimus dorsi, triceps brachii and deltoid to improve sprint performance.
Hanada et al., 2023/ Brazil	n=18/ M/ 16-20	To investigate the metabolic response (blood lactate) of high-performance surfers through the administration of sodium bicarbonate/ RCT.	Paddling	Physiological	IC: aged between 16 and 20/ EC: not reported.	Sodium bicarbonate improved paddling time and increased post-exercise blood lactate. The study concluded that sodium bicarbonate positively affected the performance of surfers, prolonging the lactate release delay time and optimizing paddling time.
Greever et al., 2019/ USA	n=11/ M/ 22	To verify associations between fitness markers and post-paddling breath-hold capacity/ CS.	Paddling	Physiological	IC: compete on the "A" level team, showing the ability to perform multiple turns, carves, and air maneuvers on a single wave/ EC: no pre-existing cardiovascular, respiratory, metabolic, or orthopedic conditions that would limit their participation in moderate-to-vigorous physical activity.	VO2peak was the only marker significantly associated with greater apnea capacity. A 30-second paddle reduced apnea by almost 80%. The conclusion is that improving VO2peak can enhance surfer safety but it's not directly related to the performance.
Saulino et al., 2019/ USA	n=13/ MF/ 14	To characterize the heart rate response of surfers performing frontside and backside maneuvers in an artificial wave	Paddling	Physiological	IC: professional athletes sponsored by Hurley International/ EC: Not reported.	Average heart rates and peak heart rates had no significant differences between frontside and backside directions. Artificial waves can reach near-

	pool/ CS.						maximum HR, which can impact performance. Specific training programs for competitive formats in artificial waves is recommended.
Cook et al., 2024a/ Australia	n=34/ MF/ 30	To measure thermal profiles with and without warm-up and passive heat retention, and secondarily to assess potential influence on free surfing/ RCT.	None	Physiological	IC: being advanced surfers down to intermediate-level recreational surfers/ EC: not reported.		Warm-up and passive heat retention increased core body temperature, testosterone, cortisol and there was an improvement in wave performance. T the strategy optimizes the thermal profile and surfing performance.
Cook et al., 2024b/ Australia	n=19/ MF/ 24	To explore the effectiveness of a warm-up in terms of readiness to perform/ RCT.	None	Physiological	IC: advanced surf level/ EC: not reported.		Active warm-up and passive heat retention increased core body temperature. Wave two entry score was better with warm-up. Overall performance tended to be better. Tthe strategy benefits heat attainment and retention, with potential improvement in performance and injury risk reduction.

Author/ Year/ Country	Ss/ Gender / Average age or range	Objective/ Study type	Specific surf situation	Performance Factor	Inclusion/ criteria	Exclusion	Outcomes and Conclusion
Baker et al., 2023/ United Kingdom	n=21/ MF/ 30	To investigate the prevalence of the risk of LEA and to identify whether competitive status and/or surfing ability correlated with the risk of LEA/ CS.	None	Physiological	IC: age 18 or over; without medical conditions that could affect dietary intake; surfing at least twice a week; being a surfer for at least two years; self-identification as an intermediate or advanced surfer/ EC: use of medication that may affect energy balance homeostasis or dietary intake; surf at a level considered to be >8/10 of best ability.		57% of surfers were at risk of Low Energy Availability (50% male, 80% female). No significant relationship between competitive status, however, the study suggests the need for intervention to mitigate these risks related to energy availability, which can negatively impact athletic performance
Seixas et al., 2023/ Portugal	n=5/ M/ x	To analyse parameters of high-level surfing aerial manoeuvres, supporting specific training and injury prevention/ CS.	Aerial manoeuvres	Technical	IC: top-5 male surfers from the 2018 and 2019 WSL competitive seasons/ EC: not reported.		The average of the parameters measured were: air maneuver height: 169.60±52.85cm; BoS: 79.17±13.72cm; front knee flexion: 113.78±19.90°; front ankle dorsiflexion: 32.74±14.51°. BAR360 was 30cm higher. FA/BA are the basis for FAR360/BAR360. Descriptive analysis help optimize performance and prevent injuries.

Tietzman et al., 2020/ Brazil	n=49/ M/ 29	To check whether the frequency and scores of the aerial maneuvers were related to final ranking in the events and in the season, and to check the influence of the type of aerial, the surfer's position (front or backside) and the act of grabbing the board or not on the scores/ CS.	Aerial maneuvers	Technical	IC: surfers who participated in at least one event in the main division of the 2016 WSL men's season/ EC: not reported.	Aerials were effective in single and final matches, but not the main determinant of the final ranking of the season. The "reverse 360 air" scored significantly higher (average 8.3) than the "reverse air" (average 7.1). Position or gripping the board did not influence the scores.
Forsyth et al., 2021a/ Austrália	n=14/ M/ 20	Which technical and physical attributes could predict superior and/or safe landing performance when surfers performed variations of a simulated aerial task/ CS.	Aerial maneuvers	Physical/ Technical	IC: participants reported 11.8 ± 6.7 years of surfing experience and were engaged in surfing practice (recreational or structured) approximately 9.9 ± 4.1 hours per week at the time of testing. They had competed in an average of 45 heats (range: 2–199) in surfing competitions at a national level or above/ EC: any lower limb injury.	Technical ability in the FAR was influenced by hip and knee mobility. The risk of injury in FA and FAR can be mitigated by greater ankle dorsiflexion and hip extensor mobility. Simple mobility measures can predict success and safety.
Forsyth et al., 2021b/ Austrália	n=15/ M/ 20	To determine whether there were any differences in how surfers used their lead and trail limbs when landing two variations of a simulated aerial manoeuvre, and whether technique affected the forces generated at landing/ CS.	Aerial maneuvers	Technical	IC: previously competed in national level surfing competitions or above; reported surfing experience of 11.8 ± 6.7 years and practice times of 1.9 ± 0.8 hours/day, 6.1 ± 1.1 days/week/ EC: any lower limb injury.	Surfers generated significantly higher relative load rates on landing to the trail limb and on FA vs FAR. There was no difference in kinematics or muscle activity comparing aerial variation and limbs. Training should take into account these high loads on the trail limb when performing FA.
Chun et al., 2025/ Korea	n=6 / MF/ 28	To explore variables influencing FAR among professional female surfers and verify gender-based differences/ CS.	Aerial maneuvers	Technical	IC: high performance surfers that were ranked between 1st and 10th in the 2021 World Pro Surfing Federation/ EC: not reported.	Female success in the FAR: approach phase, board angle <45° and upper extremity rotation; gripping the board in the airborne; knees <90° and board nose in the center of the wave in the landing.
Author/ Year/ Country	Ss/ Gender/ Average age or range	Objective/ Study type	Specific surf situation	Performance Factor	Inclusion/ Exclusion criteria	Outcomes and Conclusion
Forsyth et al., 2020/ Australia	n=14/ NR/ 20	To compared the technique features displayed by surfers when landing simulated aerial maneuvers on land to critical features previously established as necessary to successfully land aerials/ CS.	Aerial maneuvers	Technical	IC: highly skilled competitive surfers, currently or had recently competed in at least national surfing competitions/ EC: any lower limb injury.	Simulated air landings replicated most of the critical characteristics. Athletes landed with 1.0-3.7° of dorsiflexion. The FAR showed significantly less ROM of the ankle, knee and hip than the FA. These tasks are useful for training, but the FAR may require complementary exercises due to incomplete replication and loading risks.
Klingner et al., 2023/ Netherlan ds	n=80/ MF/ 25	How psychological pressure influences performance/ CS.	None	Psychological	IC: elite surfers from World Surf League/ EC: not reported.	Prior errors caused a significant decrease in surfing performance on the next wave. Situational pressure had no significant effect on wave scores. There were no inter-individual differences in how prior-errors or situational pressure affected performance.

Abbreviations: BA - Backside Air; BAR - Backside Air Reverse; BoS - Base of Support; CG - Control Group; CS - Cross-section Study; IC - Inclusion Criteria; EC - Exclusion Criteria; EG - Experimental Group; F; Female; FA - Frontside Air; FAR - Frontside Air Reverse; GRF - Ground Reaction Force; LEA - Low Energy Availability; LB-HEP - Land Based-Home Exercise Programme; LLMP - Lower Limb Muscle Power; M - Male; MAD - Maximum Ankle Dorsiflexion; MF - Male and Female; O16 - Over 16 years of age; QES - Quasi-Experimental Study; RCT - Randomized Clinical Trial; ROM - Range of Motion; SPQ - Surfer's Performance Questionnaire; Ss - Sample size; STP - Sensorimotor Training Programme; U16 - Under 16 years of age; WQS - World Qualifying Series; WSL - World Surf League; YBT-LQ - Y-Balance Test Lower Quarte.

The scores from the qualitative assessment of observational studies, conducted using the NHLBI tool, identified two studies (n = 2) exhibiting low risk of bias, with scores exceeding 74%, while fifteen studies (n = 15) were classified as having moderate risk of bias. The average inter-rater agreement index (Kappa) was 89.43% for the criteria of observational studies contained in the NHLBI (Table 2).

Table 2 - Qualitative assessment of observational cross-sectional studies according to NHLBI tools.

Author/ Question															MS	s	Bias risk
Parsonage <i>et al.</i> , 2020/ Australia																	
Utama <i>et al.</i> , 2023/ Indonesia																	:rate
Borgonovo-Santos <i>et al.</i> , 2021/ Portugal																	:rate
Fernandez-Gamboa <i>et al.</i> , 2020/Spain																	:rate
Perejmibida <i>et al.</i> , 2023/ Australia																	:rate
MacDonald <i>et al.</i> , 2024/ Australia																	:rate
Dowse <i>et al.</i> , 2020/ Australia																	:rate
Greever <i>et al.</i> , 2019/ USA																	:rate
Saulino <i>et al.</i> , 2019/ USA																	:rate
Baker <i>et al.</i> , 2023/ United Kingdom																	:rate
Seixas <i>et al.</i> , 2023/ Portugal																	:rate
Tietzmann <i>et al.</i> , 2020/ Brazil																	:rate
Forsyth <i>et al.</i> , 2021a/Australia																	:rate
Forsyth <i>et al.</i> , 2021b/Australia																	:rate
Chun <i>et al.</i> , 2025/ Korea																	:rate
Forsyth <i>et al.</i> , 2020/ Australia																	:rate
Klingner <i>et al.</i> , 2023/ Netherlands																	
Agreement % (Kappa)																	
Classification Kappa	AP	S	AP	AP	S	AP	AP	AP	AP	AP	AP	AP	S	AP			

Abbreviations: AP – Almost perfect; MS – Maximum score; NA – Not Applicable; Q1 - Was the research question or objective in this paper clearly stated?; Q2 - Was the study population clearly specified and defined?; Q3 - Was the participation rate of eligible persons at least 50%?; Q4 - Were all the subjects selected or recruited from the same or similar populations (including the same time period)? Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants?; Q5 - Was a sample size justification, power description, or variance and effect estimates provided?; Q6 - For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?; Q7 - Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?; Q8 - For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g., categories of exposure, or exposure measured as continuous variable)?; Q9 - Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?; Q10 - Was the exposure(s) assessed more than once over time?; Q11 - Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?; Q12 - Were the outcome assessors blinded to the exposure status of participants?; Q13 - Was loss to follow-up after baseline 20% or less?; Q14 - Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?; S – Strong; SO – Score obtained.

Regarding the scores from the qualitative assessment of experimental studies using the NHLBI tool, it was identified that one (n = 1) indicated a “low” risk of bias, while four (n = 4) studies were classified as “moderate”. The average inter-rater agreement index (Kappa) was 87.14% (Table 3).

Table 3 – Qualitative assessment of intervention studies according to NHLBI tools.

Author Question	/	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	SO/ MS	Points	Bias risk
Monaco et al., 2023/ USA		1	0	0	0	1	1	1	0	1	0	1	1	1	0	8/14	57%	Moderate
Nessler et al., 2019/ USA		0	NA	NA	NA	0	NA	1	NA	1	1	1	1	1	NA	6/8	75%	Low
Hanada et al., 2023/ Brazil		1	0	0	0	0	1	1	NA	1	1	1	0	1	1	8/13	62%	Moderate
Cook et al., 2024a/ Australia		1	0	0	0	1	1	1	NA	1	1	1	0	1	1	9/13	69%	Moderate
Cook et al., 2024b/ Australia		0	NA	NA	0	1	1	1	NA	1	1	1	0	1	NA	7/10	70%	Moderate
Agreement % (Kappa)		80	80	100	100	80	100	100	80	100	80	100	60	80	80		87,14	
Classification Kappa		S	S	AP	AP	S	AP	AP	S	AP	S	AP	M	S	S			

Abbreviations: AP – Almost perfect; M – Moderate; MS – Maximum score; NA – Not applicable; Q1 - Was the study described as randomized, a randomized trial, a randomized clinical trial, or an RCT?; Q2 - Was the method of randomization adequate (i.e., use of randomly generated assignment)?; Q3 - Was the treatment allocation concealed (so that assignments could not be predicted)?; Q4 - Were study participants and providers blinded to treatment group assignment?; Q5 - Were the people assessing the outcomes blinded to the participants' group assignments?; Q6 - Were the groups similar at baseline on important characteristics that could affect outcomes (e.g., demographics, risk factors, co-morbid conditions)?; Q7 - Was the overall drop-out rate from the study at endpoint 20% or lower of the number allocated to treatment?; Q8 - Was the differential drop-out rate (between treatment groups) at endpoint 15 percentage points or lower?; Q9 - Was there high adherence to the intervention protocols for each treatment group?; Q10 - Were other interventions avoided or similar in the groups (e.g., similar background treatments)?; Q11 - Were outcomes assessed using valid and reliable measures, implemented consistently across all study participants?; Q12 - Did the authors report that the sample size was sufficiently large to be able to detect a difference in the main outcome between groups with at least 80% power?; Q13 - Were outcomes reported or subgroups analyzed prespecified (i.e., identified before analyses were conducted)?; Q14 - Were all randomized participants analyzed in the group to which they were originally assigned, i.e., did they use an intention-to-treat analysis?; S – Strong; SO – Score obtained.

Discussion

The sport of surfing, characterized by a dynamic and unpredictable environment, demands a complex set of PTPP capabilities for high performance. The aim of this study was to conduct a comprehensive systematic review of the existing literature over the past 5 years, on the PTPP factors that influence surfing performance, offering a comprehensive integrated understanding of the determinants of success in this sport and indicating directions for future research and training interventions.

The results of the qualitative analysis revealed a concentration of research in Australia (41%), which can be attributed to its status as the third country worldwide with the highest number of practitioners, approximately two million (Australian Sports Commission, 2022). The absence of studies focusing solely on female participants may be associated with the proportion of practitioners. In the United States, the country with the largest number of surfers globally, 35% of practitioners are female (SIMA, 2024). The predominance of cross-sectional observational studies (77%) may be related to ecological considerations. Replicating identical conditions across multiple sessions is virtually impossible in the ocean, leading to confounding bias and low reproducibility due to the number of independent variables beyond control. Furthermore, ethical issues hinder the approval of clinical trials, given the high degree of risk exposure in the ocean. Consequently, research utilizing simulation environments creates an ecological validity bias, representing one of the main limitations for generalizing results (Merchán-Hamann et al., 2021; Furness et al., 2015; Bickley et al., 2021).

Physical Factors

Physical factors (PFs) are determinants in various situations, from paddling to the execution of complex maneuvers. The results showed that PFs (36%) were the most investigated when seeking a relationship with performance. This fact may be attributed to the relative ease of measuring physical parameters, such as strength and mobility, and comparing them to performance monitoring indicators.

The pop-up, a rapid and coordinated movement to stand on the board, is an essential surfing technique, as it marks the initial moment when the surfer begins to perform on the wave. Therefore, the execution speed of this technique is crucial for optimal wave performance. PFs such as isometric push and pull strength, core musculature, lumbar and hamstring flexibility, foot arches, and muscle mass are associated with pop-up time. Stronger surfers exhibit a faster average pop-up time (1.05 ± 0.16 seconds) compared to weaker ones (1.30 ± 0.20 seconds; $p = 0.017$, $d = 1.29$). They demonstrate a relative maximum isometric pull-up strength of 1.75 ± 0.27 times body weight (BW), compared to 1.29 ± 0.15 BW in weaker surfers ($p < 0.001$, $d = 2.10$), and a relative maximum isometric push-up strength of 1.83 ± 0.23 BW versus 1.53 ± 0.19 BW ($p = 0.007$, $d = 1.40$). Strong correlations are observed between relative maximum isometric pull-up and push-up strength and pop-up time ($r = -0.86$, $p < 0.001$ and $r = -0.77$, $p < 0.001$, respectively), indicating that higher strength levels explain up to 74% of performance variance (Parsonage et al., 2020). However, the study noted that individual technical skill can, in some cases, surpass pure strength metrics, as some weaker surfers achieved faster pop-ups, suggesting that movement efficiency is not solely dependent on brute strength. Another study revealed that core muscles ($r = 0.57$, $p < 0.001$) and lumbar flexibility ($r = 0.496$, $p < 0.001$) demonstrated very strong correlations with pop-up capability, with lumbar flexibility being the most dominant factor (Odds Ratio = 12.896). Foot arches ($p = 0.001$) and hamstring flexibility ($p = 0.002$) also showed strong correlations (Utama et al., 2023). Additionally, researchers found an inverse relationship between the percentage of skeletal muscle mass and pop-up duration ($r = -0.50$, $p = 0.01$), suggesting that greater muscle mass may optimize the speed of this technique (Borgonovo-Santos et al., 2021).

Another study compared PFs among competitive surfers of different genders and ages. Male surfers over 16 years old (O16) demonstrated greater push strength in the pop-up (POPPUSH, $p < 0.05$, $ES = 0.76$, difference of 33.66%) compared to their female counterparts. Moderate correlations were found between lower body strength capacity, measured by the countermovement jump (CMJ), and pop-up (CMJFMAX and POPPUSH, $r = 0.32$), suggesting that the pop-up is influenced by other factors such as coordination and upper body strength, in addition to general strength (Fernandez-Gamboa et al., 2020). The authors also conclude that, despite not presenting comparative outcomes in pop-up performance between genders, the result may indicate that men (O16) would have an advantage in wave positioning due to their ability to perform the push phase more quickly, establishing that greater strength can result in better performance. Additionally, another study showed that flexibility (sit and reach: age $r = 0.54$, maturation $r = 0.66$) and lower limb power (standing long jump: age $r = 0.79$, maturation $r = 0.86$) improved with age and maturation. However, relative lower limb strength (Isometric mid-thigh pull: age $r = 0.09$, maturation $r = -0.07$) and dynamic balance did not show significant improvements, revealing inefficiencies in current physical preparation (Perejmibida et al., 2023).

The pop-up can also be improved by an eight-week land-based home exercise program (LB-HEP). This was demonstrated on an experiment among recreational surfers. The program comprised strength exercises for both upper and lower limbs, concluding that targeted training programs can be effective even in unsupervised environments (Monaco et al., 2023). However, it is noteworthy that the primary subjective measure of improvement, the Surfer's Performance Questionnaire (SPQ), although internally validated, is susceptible to the individual perception of the surfer. Also, despite the pop-up being one of the outcomes for which the LB-HEP showed improvement, the effect did not reach statistical significance ($p = 0.065$), although it was accompanied by a large effect size ($\eta^2 = 0.160$).

Paddling is a critical factor in surfing and is directly associated with performance. In competitive situations, athletes encounter paddling courses where they may alternate between high, medium, and low intensities during heats lasting between 20 to 30 minutes. Therefore, PFs are essential to sustain prolonged and continuous paddling efforts, especially in challenging conditions such as strong currents or long waves. A predominantly qualitative study, based on semi-structured interviews, reveals a remarkable consensus among 28 elite athletes, coaches, and Australian support professionals, with 27 out of 28 participants (approximately 96.4%) emphasizing paddling as integral. They highlight that paddling ability directly impacts greater possibilities for maneuvers on the wave, accelerates skill development, increases confidence, and generates a significant competitive advantage (MacDonald et al., 2024).

Still within the PFs, ankle-related characteristics such as proprioception, range of motion (ROM), and landing capacity are correlated with enhanced performance. Elite senior surfers exhibited significantly better proprioception (Front Foot scores of 0.73 ± 0.06 and Back Foot of 0.72 ± 0.06 vs. 0.67 for juniors and recreational surfers, $p \leq 0.04$) and greater ankle dorsiflexion ROM (Front Foot of 14 ± 2 cm and Back Foot of 14 ± 3 cm vs. 10 cm, $p \leq 0.02$) compared to lower-level groups. They also demonstrated superior landing performance (lower relative peak force, 3.22 ± 0.86 vs. 4.68 ± 1.38 for juniors, $p = 0.04$). However, no significant correlation was found between proprioception and years of experience ($r_s \leq 0.31$, $p \geq 0.07$), suggesting that experience alone may not be the best indicator of training quality (Dowse et al., 2021).

Physiological Factors

As in other Olympic sports, physiological factors (PHFs), which accounted for 32% of the studies included in this review, are fundamental to athletic performance in surfing. Studies evaluating the physiology of paddling reported that, when comparing endurance paddling with sprint paddling, the medial deltoid activated

earlier ($p = 0.005$) during sprint paddling, as did the latissimus dorsi, which exhibited the greatest increase ($p < 0.001$). It was also observed that oxygen consumption (VO_2) increased linearly ($R^2 = 0.97$), as speed increased, reaching an average peak of $31.38 \pm 6.03 \text{ ml/kg/min}$ (Nessler et al., 2019). Sodium bicarbonate supplementation demonstrated a positive impact on paddling performance, evidencing greater anaerobic work capacity, with significantly higher post-exercise blood lactate levels (mean $16.43 \pm 3.1 \text{ mg/dL}$ vs. $14.83 \pm 2.7 \text{ mg/dL}$ in the placebo group, $p = 0.04$) and shorter paddling time (mean 10.68 ± 0.8 seconds vs. 10.88 ± 0.6 seconds, $p = 0.05$) (Hanada et al., 2023). Additionally, it was found that peak VO_2 ($\beta = 0.975$, $p = 0.034$) is associated with longer post-paddling apnea duration in high-performance surfers. However, ventilatory thresholds showed no correlation, indicating that apnea capacity does not directly influence surfing performance (Greeve et al., 2019). The authors emphasize that the methodology employed does not replicate ocean environmental conditions, which may significantly influence physiological demands and apnea capacity.

When measuring heart rate (HR), researchers observed no differences when comparing paddling in frontside versus backside surfed waves. Their outcomes indicate that paddling requires moderate to high cardiovascular effort, approaching the maximum capacity of young athletes. Participants achieved an average peak HR of $184.9 \pm 13.0 \text{ bpm}$, corresponding to $90.0 \pm 0.1\%$ of the age-predicted maximum HR, over an average paddling duration of 28.1 ± 7.1 seconds. Notably, the conclusion of paddling occurred, on average, approximately 5 seconds after surfers reached peak HR. This suggests that near-maximal effort may influence the duration a surfer can remain on the wave, potentially leading to premature falls due to fatigue-induced performance deficits (Saulino et al., 2019).

Warm-up is essential for any intense physical activity. By improving neuromuscular coordination and tissue viscoelasticity, it enhances performance and reduces the risk of acute injuries. A study evaluating land-based warm-up combined with passive heat retention observed that core body temperature was significantly higher ($p \leq 0.03$) until the end of the session, along with a 20% improvement in wave scores ($p \leq 0.01$) and elevations in testosterone ($p = 0.01$) and cortisol ($p \leq 0.001$), indicating greater competitive readiness (Cook et al., 2024a). The authors themselves emphasize that the differences in hormone levels were of small magnitude. Although statistically significant, the practical relevance of these small variations for actual performance or the psychological state of surfers may be limited. A subsequent study identified a significantly greater increase in core body temperature for the experimental condition (warm-up and passive heat retention) compared to the control group (no warm-up) ($p = 0.006$), and in the duration it remained elevated ($p < 0.001$). Regarding performance, although the data were predominantly categorical, the entry score on wave 2 was significantly better in the warm-up condition ($Z = 2.30$, $p = 0.02$, $r = 0.53$) than without warm-up, out of a total of 9 waves evaluated (Cook et al., 2024b). The fact that the researchers did not consider fatigue raises questions about the comparison of scores, given the number of waves surfed and the interval between them. It is important to highlight that the thermometric pills ingested to measure temperature, in both studies, were not used in the most appropriate manner, which may have affected the accuracy of the readings.

Finally, energy availability can also be considered another critical factor within the PHFs. Researchers revealed a 57% prevalence of risk for low energy availability (LEA) among surfers, with 77% exhibiting inadequate carbohydrate intake, which directly impacts energy supply for high-intensity efforts (Baker et al., 2023). It is noteworthy that this study has a strong bias toward male and recreational participants, and that the use of the Eating Disorder Examination Questionnaire (EDE-Q) in men to assess the risk of LEA is a tool not validated for this purpose in male samples.

Technical Factors

Technical factors (TFs) are crucial for high performance in any sport. The analyzed studies (27%) reveal findings on the biomechanics of complex maneuvers, the influence of cognitive-technical factors, and the replication of movements in simulated environments, aiming to understand the TFs that enhance performance in surfing. In the field of aerial maneuvers, Seixas et al. (2023) provided a detailed technical-quantitative overview. They identified common characteristics such as head/trunk rotation, triple flexion of the lower limbs, and flexion of the head, trunk, and arms from takeoff to the peak of the flight, culminating in the anterosuperior displacement of the center of mass (CoM). Quantitatively, the study revealed that the Backside Air Reverse 360 (BAR360) was approximately 30 cm higher (mean of 190.59 cm vs. 160.69 cm) than the Frontside Air Reverse 360 (FAR360), despite the latter presenting a base of support (BoS) approximately 7.2 cm wider. Additionally, another study found that the Air Reverse 360 received significantly higher scores (mean of 8.3) in the World Surf League (WSL) compared to the Air Reverse 180 (mean of 7.1, $p = 0.017$). However, the surfer's position (frontside/backside to the wave) and the act of grabbing the board did not influence the scores ($p = 0.447$ and $p = 0.410$, respectively) (Tietzmann et al., 2020).

The complexity of landing in aerial maneuvers is a crucial factor, with implications for performance and injury risk. Evidence indicates significantly higher relative loading rates on the leg positioned at the tail of the board compared to the front leg, which lands in the middle of the board ($+28.8 \text{ BW/s}$; $F(1,303) = 20.660$, $p < 0.0001$). Additionally, loading rates were higher in the Frontside Air (FA) maneuver compared to the Frontside Air Reverse (FAR) ($+23.6 \text{ BW/s}$; $F(1,303) = 31.655$, $p < 0.0001$), with no significant interactions in kinematics or muscle activity between limb and aerial variation (Forsyth et al., 2021a). Another study suggested that greater

passive hip flexion of the lead limb may increase total peak force during FA landing (adj $R^2 = 0.40$), while passive hip flexion of the trail limb and the range of dorsiflexion of the lead ankle ($-8.3 \text{ BW} \cdot \text{s}^{-1}$ for an increase of 8.1° in loading rate, $p < 0.005$, adj $R^2 = 0.48$) may mitigate injury risk. The technical performance of FAR was influenced by hip flexion and elevation of the extended leg of the lead limb (adj $R^2 = 0.70$) (Forsyth et al., 2021b). When comparing the FAR maneuver between genders, it was found that female surfers predominantly fail during the aerial phase, whereas males fail during landing. Technically, female success in FAR was associated, during the approach phase, with a board angle less than 45° relative to the vertical and the use of upper limb rotation, as well as grabbing the board during the aerial phase, a notable difference compared to men. This finding suggests distinct technical strategies for success across genders (Chun et al., 2025). However, the analysis was limited to a single case of female success, in addition to the use of a descriptive rather than statistical method.

The kinetics and kinematics of the pop-up have also been studied in laboratory settings, where researchers quantified the average duration at $1.20 \pm 0.19 \text{ s}$ and observed an asymmetry in force application: the non-dominant hand exerted significantly more peak force ($52 \pm 4\%$ vs. $48 \pm 4\%$, $p = 0.03$) during the push-up phase, while the front foot applied more force ($72 \pm 8\%$ vs. $28 \pm 8\%$, $p < 0.01$) during the reaching phase (Borgonovo-Santos et al., 2021). Despite the laboratory environment presenting an ecological validity bias, Forsyth et al. (2020) consider simulated tasks as valid training tools, where their studies revealed that participants replicated 100% of the critical characteristics for the simulated FA and 60% for the FAR. Simulated landing analysis showed $1.0\text{--}3.7^\circ$ of ankle dorsiflexion, it also demonstrated significantly less range of motion (ROM) in the front limb's ankle ($p < 0.01$) and lower ROM in the knee and hip ($p = 0.002$; 0.048 , respectively) compared to the FA. Conversely, it is important to remember that the fidelity of simulating technical movements in the laboratory is subject to the participant's level of awareness of the movement; that is, they may simulate differently from how they perform the movement intuitively and automatically in a real context (Lee et al., 2025; Delavari et al., 2025). Therefore, the importance of a more in-depth study regarding biomechanical movement patterns is emphasized, so that technical improvement training outside the water can be more effective.

Psychological Factors

The influence of psychological factors (PSFs) on high performance is extensively studied in sports science, as the brain modulates physiological responses, such as hormone release and neural activation, which affect motor coordination. In surfing, PSFs have been scarcely explored, with only one study investigating performance-related psychological issues. Klingner et al. (2023) evaluated the influence of psychological pressure and previous performance errors in 80 elite surfers. Their results revealed that prior errors caused a significant decrease in the scores of subsequent waves. Surprisingly, no significant effect of situational pressure (defined by time and score) on performance was found. Although higher-ranked surfers scored an average of 0.584 points more, there were no interindividual differences. However, the study did not directly measure the athletes' subjective perception of pressure, relying solely on situational indicators.

Conclusion

This review, grounded in contemporary literature, aimed to conduct a comprehensive systematic review of the existing literature on the PTPP factors that influence surfing performance and offer a holistic perspective contribute to the advancement of surfing. PFs, such as upper limb strength, core stability, and flexibility, are crucial for pop-up speed and board stability, while proprioception and ankle mobility are fundamental for maneuver execution and injury prevention. In terms of TFs, rotational and flexion movements, as well as base distance and weight distribution during landing, serve as key differentiators for performing high-performance maneuvers. On the PHFs, aerobic and anaerobic capacities underpin paddling, which can be positively impacted by sodium bicarbonate intake, with effort peaks directly influencing wave riding time and recovery. Low energy availability, for instance, has been shown to negatively affect performance. Finally, although underexplored, PSFs, such as frustration from performance errors, interfere with the scoring of subsequent waves, reinforcing the importance of psychological preparation in training programs for competitive surfers.

Furthermore, a predominance of cross-sectional observational studies was observed. This methodological inclination may be justified by the inherent difficulty in replicating oceanic conditions and ethical considerations in clinical trials, often resulting in ecological validity biases in simulated scenarios. Nonetheless, the analysis reveals a concentration of research on physical factors and the male population. Future investigations should delve deeper into surfing-specific biomechanical patterns and expand the body of knowledge on psychological nuances and gender differences in performance. Such directions are essential for refining training strategies and maximizing athletic potential in this Olympic discipline.

Conflict of interest The authors declare no conflicts of interest.

Limitations The primary limitations identified include the predominance of cross-sectional observational studies, which hinders reproducibility due to the ocean's unpredictability. There is an ecological validity bias in simulation environments, as well as a scarcity of research focused on female athletes and psychological factors. Some methodologies also presented subjective measures or unvalidated tools. The aim of limiting the research to contemporary studies from the last five years also limits the amount of information.

References

- Global Industry Analysts (accessed on July 7th, 2025). GJOB20127778. Sports & Recreation Market Research, Published date: June, 2025. Available at: <https://www.marketresearch.com/Global-Industry-Analysts-v1039/Surfing-41395543/>.
- Moreira, M., & Peixoto, C. (2014). Qualitative task analysis to enhance sports characterization: a surfing case study. *Journal of human kinetics*, 42, 245. <https://doi.org/10.2478/hukin-2014-0078>.
- Sharma, A. P., & Mujika, I. (2021). 8 Quantification of training and competition loads in endurance sports. *Recovery and Well-being in Sport and Exercise*, 111. DOI:10.4324/9781003258117-10
- Mujika, I., Halson, S., Burke, L. M., Balagué, G., & Farrow, D. (2018). An integrated, multifactorial approach to periodization for optimal performance in individual and team sports. *International journal of sports physiology and performance*, 13(5), 538-561. <https://doi.org/10.1123/ijsp.2018-0093>.
- Bravo, M. M., Cummins, K. M., Nessler, J. A., & Newcomer, S. C. (2016). Heart rate responses of high school students participating in surfing physical education. *The Journal of Strength & Conditioning Research*, 30(6), 1721-1726.
- Secomb, J. L., Sheppard, J. M., & Dascombe, B. J. (2015). Time-motion analysis of a 2-hour surfing training session. *International journal of sports physiology and performance*, 10(1), 17-22. <https://doi.org/10.1123/ijsp.2014-0002>.
- Minghelli, B., Graça, S., Paulino, S., & Sousa, I. (2017). Time-motion analysis of young competitive surfers: southern Portugal. *J Sports Med Dopng Stud*, 7(194), 2161-0673. DOI: 10.4172/2161-0673.1000194.
- Cook, C. J., Serpell, B. G., & Hanna, L. J. (2024a). The effects of a land-based warm-up and accompanying passive heat retention on core body temperature, hormones, and subsequent performance in elite surfers. *Frontiers in Sports and Active Living*, 6, 1458268. <https://doi.org/10.3389/fspor.2024.1458268>.
- Seroyer, S. T., Nho, S. J., Bach, B. R., Bush-Joseph, C. A., Nicholson, G. P., & Romeo, A. A. (2010). The kinetic chain in overhand pitching: its potential role for performance enhancement and injury prevention. *Sports health*, 2(2), 135-146. <https://doi.org/10.1177/1941738110362656>.
- Mendez-Villanueva, A., Bishop, D. (2005). Physiological aspects of surfboard riding performance. *Sports Medicine*, 35(1), 55-70. DOI: 10.2165/00007256-200535010-00005.
- Araújo, D., Hristovski, R., Seifert, L., Carvalho, J., & Davids, K. (2019). Ecological cognition: expert decision-making behaviour in sport. *International Review of Sport and Exercise Psychology*, 12(1), 1-25.
- Klingner, F. C., Huijgen, B. C., & Kempe, M. (2023). The heat is on: Investigating the effect of psychological pressure on competitive performance in elite surfing. *Journal of Sports Sciences*, 41(6), 596-604. <https://doi.org/10.1080/02640414.2023.2230032>.
- Lee, T. D., & Schmidt, R. A. (2025). *Motor learning and performance: From principles to application*. Human Kinetics.
- Delavari, F., Hashemi Golpayegani, S. M. R., & Ahmadi-Pajouh, M. A. (2025). Motor Imagery Task Alters Dynamics of Human Body Posture. *Physiotherapy Research International*, 30(4), e70095. <https://doi.org/10.1002/pri.70095>.
- Turner, A. N., Bishop, C., Cree, J., Carr, P., McCann, A., Bartholomew, B., & Halsted, L. (2019). Building a high-performance model for sport: A human development-centered approach. *Strength & Conditioning Journal*, 41(2), 100-107. DOI: 10.1519/SSC.0000000000000447.
- Sarkar, M., & Fletcher, D. (2014). Psychological resilience in sport performers: a review of stressors and protective factors. *Journal of sports sciences*, 32(15), 1419-1434. <https://doi.org/10.1080/02640414.2014.901551>.
- Higgins, J. P. T., Thomas, J., Chandler, J., Cumpston, M., Li, T., Page, M. J., & Welch, V. A. (Eds.). (2019). *Cochrane handbook for systematic reviews of in-terventions* (2nd ed.). John Wiley & Sons. DOI:10.1002/9781119536604.
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., ... Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *International Journal of Surgery*, 88, 105906. <https://doi.org/10.1016/j.ijssu.2021.105906>.
- Santos, C. M. D. C., Pimenta CAM, Nobre MR. The PICO strategy for the re-search question construction and evidence search. *Latin American Journal of Nursing*. 2007; 15, 508–511. <https://doi.org/10.1590/s0104-11692007000300023>.
- Mujika, I. (2017). Quantification of training and competition loads in endurance sports: methods and applications. *International journal of sports physiology and performance*, 12(s2), S2-9.
- Santos, C. M. D. C., Pimenta, C. A. M., Nobre, M. R. The PICO strategy for the research question construction and evidence search. *Latin American Journal of Nursing*. 2007; 15, 508–511. <https://doi.org/10.1590/s0104-11692007000300023>.
- Murad MH, Asi N, Alsawas M, Alahdab F. New evidence pyramid. *Evid. Based Med*. 2016; 21, 125–127. <https://doi.org/10.1136/ebmed-2016-110401>.

- Morgan, R.L.; Whaley, P.; Thayer, K.A.; Schünemann, H.J. Identifying the PECO: A Framework for Formulating Good Questions to Explore the Association of Environmental and Other Exposures with Health Outcomes. *Environ. Int.* 2018, 121, 1027–1031.
- Study Quality Assessment Tools. (Aug. 15th, 2025). *Health Topics*. <https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools>.
- Sarkies, M. N., Bowles, K. A., Skinner, E. H., Haas, R., Lane, H., & Haines, T. P. (2017). The effectiveness of research implementation strategies for promoting evidence-informed policy and management decisions in healthcare: a systematic review. *Implementation Science*, 12(1), 132. DOI 10.1186/s13012-017-0662-0.
- Gamer, M., & Lemon, Jim, I. F. P. S. (2019). irr: *Various Coefficients of Interrater Reliability and Agreement*. <https://cran.r-project.org/package=irr>.
- Australian Sports Commission. (2022). AusPlay focus: Participation in water sports. Clearinghouse for Sport. <https://www.ausport.gov.au/clearinghouse>.
- Surf Industry Members Association. (2024). Diversity in Surfing Report. <https://surfindustry.org/pages/diversity-in-surfing-report>.
- Merchán-Hamann, E., & Tauil, P. L. (2021). Proposed classification of different types of descriptive epidemiological studies. *Epidemiologia e Serviços de Saúde*, 30, e2018126. <https://doi.org/10.1590/s1679-49742021000100026>.
- Furness, J., Hing, W., Walsh, J., Abbott, A., Sheppard, J. M., & Climstein, M. (2015). Acute injuries in recreational and competitive surfers: incidence, severity, location, type, and mechanism. *The American Journal of Sports Medicine*, 43(5), 1246-1254. <https://doi.org/10.1177/0363546514567062>.
- Bickley, R. J., Belyea, C. M., Harpstrite, J. K., & Min, K. S. (2021). Surfing injuries: a review for the orthopaedic surgeon. *JBJS reviews*, 9(4), e20. DOI: 10.2106/JBJS.RVW.20.00152.
- Parsonage, J., Secomb, J. L., Sheppard, J. M., Ferrier, B. K., Dowse, R. A., & Nimphius, S. (2020). Upper-body strength measures and pop-up performance of stronger and weaker surfers. *The Journal of Strength & Conditioning Research*, 34(10), 2982-2989. DOI: 10.1519/JSC.0000000000002377.
- Borgonovo-Santos, M., Telles, T., Nessler, J., de Castro, M. P., Fernandes, R. J., & Vilas-Boas, J. P. (2021). Are the kinetics and kinematics of the surf pop-up related to the anthropometric characteristics of the surfer?. *Sensors*, 21(5), 1783. <https://doi.org/10.3390/s21051783>.
- Utama, A. A. G. E. S., Kamayoga, I. D. G. A., Widnyana, M., & Putra, I. P. Y. P. (2023). Relationship between core muscles, leg arch, hamstring and lumbar flexibility on pop-up ability among surfers. *Physical Therapy Journal of Indonesia*, 4(1), 25-30. <https://doi.org/10.51559/ptji.v4i1.65>.
- Fernandez-Gamboa, I., Yanci, J., Granados, C., Freemyer, B., & Camara, J. (2020). Sex differences in competitive surfers' generic and specific strength capacity. *Biology of sport*, 37(1), 49-57. <https://doi.org/10.5114/biolSport.2020.91498>.
- Perejmibida, A., Conlon, J. A., Lyons, M., & Cripps, A. (2023). The impact of age and maturation on physical performance capacities in emerging adolescent surfing athletes: An argument for off-water training. *International Journal of Sports Science & Coaching*, 18(2), 437-445. <https://doi.org/10.1177/17479541221083481>.
- Monaco, J. T., Boergers, R., Cappaert, T., Miller, M., Nelson, J., & Schoenberger, M. (2023). The effects of a land-based home exercise program on surfing performance in recreational surfers. *Journal of Sports Sciences*, 41(4), 358-371. <https://doi.org/10.1080/02640414.2023.2213034>.
- MacDonald, L. A., Chalkley, D., Parsonage, J., Gosney, S., Webster, H., & Minahan, C. L. (2024). The importance of paddling to surfing performance: Insights from elite athletes, coaches, and performance support practitioners. *International Journal of Sports Science & Coaching*, 19(6), 2334-2344. <https://doi.org/10.1177/17479541241268674>.
- Dowse, R. A., Secomb, J. L., Bruton, M., & Nimphius, S. (2021). Ankle proprioception, range of motion and drop landing ability differentiates competitive and non-competitive surfers. *Journal of Science and Medicine in Sport*, 24(6), 609-613. <https://doi.org/10.1016/j.jsams.2020.12.011>.
- Hanada, T. Z., Knack, R., Mayr, K., Knack, R. S., Guedes, D., Scorcine, C., ... & Hanada, T. Z. (2023). Analysis of the use of Sodium Bicarbonate for the performance of surfing athletes. *Qeios*, CC-BY 4.0. <https://doi.org/10.32388/5WBMHS>.
- Greever, C. J., Groseclose, K. K., Denny, A. L., & Jones, D. C. (2019). Aerobic fitness markers associated with post-paddling breath-hold capacity in competitive surfers. *International Journal of Exercise Science*, 12(6), 366. <https://doi.org/10.70252/AXXD5381>.
- Saulino, M., Skillern, N., Warner, M. E., Martinez, A., Moore, B., Nessler, J. A., & Newcomer, S. C. (2019). Characterization of heart rate response during frontside and backside wave riding in an artificial wave pool. *Am J Sports Sci*, 7(4), 136-140. DOI: 10.11648/j.ajss.20190704.11.
- Cook, C. J., Serpell, B. G., Hanna, L. J., Fox, A., & Fourie, P. J. (2024a). Heat attainment and retention in surfers with and without a land-based warm-up and accompanying passive heat retention. *Sports*, 12(9), 241. <https://doi.org/10.3390/sports12090241>.

- Cook, C. J., Serpell, B. G., & Hanna, L. J. (2024b). The effects of a land-based warm-up and accompanying passive heat retention on core body temperature, hormones, and subsequent performance in elite surfers. *Frontiers in Sports and Active Living*, 6, 1458268. <https://doi.org/10.3389/fspor.2024.1458268>.
- Baker, M., Magee, P., & Williamson, J. (2025). Surfboard riders are at risk of low energy availability—A pilot study. *Nutrition and health*, 31(2), 605-614. <https://doi.org/10.1177/02601060231204927>.
- Seixas, P., Oliveira, R., Carita, A. I., & Moreira, M. (2023). Setting qualitative performance parameters of elite surfing aerial manoeuvres with 360° rotation. *Cuadernos de psicología del deporte*, 23(2), 169-193. ISSNediciónweb(<http://revistas.um.es/cpd>):1989-5879.
- Tietzmann, L. E., Pacheco, E. A., Roesler, H., & Pereira, S. M. (2020). Aerials and their influence on World Surfing League surfer performance (WSL flights). *Revista Brasileira de Cineantropometria & Desempenho Humano*, 22, e67473. <https://doi.org/10.1590/1980-0037.2020v22e67473>.
- Forsyth, J. R., Richards, C. J., Tsai, M. C., Whitting, J. W., Riddiford-Harland, D. L., Sheppard, J. M., & Steele, J. R. (2021a). Rate of loading, but not lower limb kinematics or muscle activity, is moderated by limb and aerial variation when surfers land aerials. *Journal of Sports Sciences*, 39(15), 1780-1788. <https://doi.org/10.1080/02640414.2021.1898167>.
- Forsyth, J. R., Tsai, M. C., Sheppard, J. M., Whitting, J. W., Riddiford-Harland, D. L., & Steele, J. R. (2021b). Can we predict the landing performance of simulated aerials in surfing?. *Journal of Sports Sciences*, 39(22), 2567-2576. <https://doi.org/10.1080/02640414.2021.1945204>.
- Chun, S., Park, J., Ryu, J., & Choi, H. (2025). Exploring the Influencing Variables for Frontside Air Reverse in Professional Female Surfers: A Case Study. *Exercise Science*, 34(1), 60-70. <https://doi.org/10.15857/ksep.2024.00647>.
- Forsyth, J. R., Riddiford-Harland, D. L., Whitting, J. W., Sheppard, J. M., & Steele, J. R. (2020). Training for success: Do simulated aerial landings replicate successful aerial landings performed in the ocean?. *Scandinavian journal of medicine & science in sports*, 30(5), 878-884. <https://doi.org/10.1111/sms.13639>.

Declaration of generative AI and AI-Assisted Technologies in the writing process

The authors acknowledge the use of ChatGPT (OpenAI, 2025) as a tool to assist in the linguistic review and formatting of sections of the manuscript, without interfering with the analysis, interpretation of results, or conclusions of the study.

After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Supplementary material S1.

Pubmed:	((("Water Sports"[Mesh] OR "Surfing"[tiab]) AND ("Athletic Performance"[Mesh] OR "Physical Fitness"[Mesh] OR "Motor Skills"[Mesh] OR "Physiology"[Mesh] OR "Sports Physiological Phenomena"[Mesh] OR "Psychology"[Mesh] OR "Psychology, Sports"[Mesh])) AND (surfing OR surf) AND (performance OR fitness OR skills OR physiology OR psychology))
Web of Science:	TS=("Water Sports" OR "Surfing") AND TS=("Athletic Performance" OR "Physical Fitness") AND TS=("Motor Skills") AND TS=("Physiology" OR "Sports Physiology") AND TS=("Psychology" OR "Sports Psychology")
Embase:	('water sport'/exp OR 'surfing'/exp) AND ('athletic performance'/exp OR 'physical fitness'/exp OR 'motor performance'/exp) AND ('physiology'/exp OR 'sports physiology'/exp) AND ('psychology'/exp OR 'sports psychology'/exp)
SPORTDiscus:	(DE "SURFING" OR DE "WATER SPORTS" OR DE "SURFBOARDING" OR TI "surfing" OR AB "surfing") AND (DE "ATHLETIC PERFORMANCE" OR DE "PHYSICAL FITNESS" OR DE "MOTOR ABILITY" OR DE "PHYSICAL ENDURANCE" OR DE "MOTOR SKILLS" OR TI "athletic performance" OR AB "athletic performance") AND (DE "SPORTS PHYSIOLOGY" OR DE "EXERCISE PHYSIOLOGY" OR DE "HUMAN PHYSIOLOGY" OR AB "physiology") AND (DE "SPORTS PSYCHOLOGY" OR DE "ATHLETIC PSYCHOLOGY" OR DE "PSYCHOLOGY" OR TI "sports psychology" OR AB "sports psychology")
SciELO:	("water sports" OR surfing OR "esportes aquáticos" OR surf) AND ("athletic performance" OR "physical fitness" OR "motor skills" OR physiology OR "sports physiology" OR psychology OR "sports psychology" OR "desempenho atlético" OR "aptidão física" OR "habilidades motoras" OR fisiologia OR "fisiologia do esporte" OR psicologia OR "psicologia do esporte")
LILACS:	("esportes aquáticos" OR "water sports" OR surfing OR surf OR "deportes acuáticos") AND ("desempenho atlético" OR "athletic performance" OR "aptidão física" OR "physical fitness" OR "habilidades motoras" OR "motor skills" OR fisiologia OR physiology OR "fisiologia do esporte" OR "sports physiology" OR psicologia OR psychology OR "psicologia do esporte" OR "sports psychology" OR "rendimiento atlético" OR "acondicionamiento físico" OR "destreza motora" OR "fisiologia del deporte" OR "psicología del deporte")
Grey Literature:	("water sports" OR surfing) AND ("athletic performance" OR "physical fitness" OR "motor skills" OR physiology OR "sports physiology" OR psychology OR "sports psychology").

Supplementary material S2

Studies excluded after eligibility assessment with full-text review of scientific articles (Supplementary Material S2).

Studies excluded based on eligibility	Reasons for exclusion
Minghelli, B., Paulino, S., Graça, S., Sousa, I., & Minghelli, P. (2019). Time-motion analysis of competitive surfers: Portuguese championship. <i>Revista da Associação Médica Brasileira</i> , 65, 810-817. https://doi.org/10.1590/1806-9282.65.6.810 .	No relationship was reported between PTPP factors and surfing performance.
Pina, G. (2019). Task scheduling and performance: Evidence from professional surf tournaments. <i>Journal of Economic Psychology</i> , 75, 102097. https://doi.org/10.1016/j.joep.2018.08.006	No relationship was reported between PTPP factors and surfing performance.
Silva, B., Cruz, G., Rocha-Rodrigues, S., & Clemente, F. M. (2020). Monitoring physical performance and training load in young surf athletes. https://doi.org/10.14198/jhse.2021.162.03	No relationship was reported between PTPP factors and surfing performance.
Morales-Vargas, R., Valdes-Badilla, P., & Guzmán-Muñoz, E. (2021). Relationship between the anthropometric profile and physical fitness of surfers and their dynamic postural balance. <i>Camp d</i> , 107. DOI: 10.18176/archmeddeporte.00033	No relationship was reported between PTPP factors and surfing performance.
Silva, B., Cruz, G., & Zamith, J. (2025). Profiling Shoulder Strength in Youth Surfers: Implications for Injury Prevention and Performance Enhancement. <i>Retos: nuevas tendencias en educación física, deporte y recreación</i> , (62), 580-586. ISSN-e 1988-2041, ISSN 1579-1726	No relationship was reported between PTPP factors and surfing performance.
Weiss, A., Lluch, E., Masmoudi, I., Doellinger, M., Heinrich, D., & Koelewijn, A. D. (2025). Simulating surfing with optimal control: sensor fusion for biomechanical analysis. <i>Multibody System Dynamics</i> , 1-21. https://doi.org/10.1007/s11044-025-10071-3	No relationship was reported between PTPP factors and surfing performance.
Guo, Z., & Wang, H. (2022). Influence of core training on the ability of control and balance in surfers. <i>Revista Brasileira de Medicina do Esporte</i> , 28, 723-725. https://doi.org/10.1590/1517-8692202228062022_0042	The result did not establish a direct relationship with surfing performance.
Parsonage, J., MacDonald, L., Shephard, M., Gosney, S., Deny, A., & Minahan, C. (2025). Paddle-to-Podium: a four-phased applied research model, translating research into practice for female surfers. <i>Frontiers in Sports and Active Living</i> , 7, 1619283. https://doi.org/10.3389/fspor.2025.1619283	Did not describe the exercise protocol or did not present the results clearly.