Training Methods in the Sport of Surfing: A Scoping Review

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ABSTRACT

Surfing has grown significantly in the past decade as highlighted by its inclusion in the 2020 Olympic Games. This growth substantiates a need for training methods that improve surfing performance. The purpose of this review is to (a) identify training methods available to competitive and recreational surfers in peer-reviewed literature, (b) evaluate the effectiveness of these methods, and (c) highlight any limitations and potential areas for future research. Five electronic databases were searched, and 8 papers were identified that met the eligibility criteria. Five of these studies used a quasiexperimental design, and 1 used a case study. The remaining 2 studies used field-based outcome measures specific to paddling; however, no study demonstrated improvement in wave-riding performance. The main training methods identified were (a) resistance training, (b) unstable surface training, and (c) cardiovascular training. Maximal strength training of the upper-body and high-intensity and sprint-interval paddling demonstrated effectiveness for improving paddling performance; however, unstable surface training was ineffective. Although all interventions improved laboratory-based outcomes, there were no objective measures of wave-riding performance. The findings of this scoping review demonstrate a paucity and low level of evidence in peer-reviewed literature relating training methods to surfing performance.

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INTRODUCTION

In the last decade, there has been significant growth in both recreational and competitive surfing. In fact, in 2012, the International Surfing Association reported a worldwide surfing population of 35 million people with a growth expected to exceed 50 million people by 2020 (2). This growth can be further highlighted by the sport's inclusion into the 2020 Tokyo Olympic Games; a process requiring the sport to be practiced by men in at least 75 countries and 4 continents and women in at least 40 countries and 3 continents (4).

In its essence, surfing is a sport that is centered around standing on a board while riding an unbroken wave (43). To ride a wave, a surfer must first be able to position themself appropriately in the water and paddle both efficiently and expeditiously before explosively "popping up" onto their board to catch a wave. Based on time motion analysis of competitive surfers, roughly 50% of surfing is spent paddling, whereas approximately 3% is spent riding a wave (44,54). This time breakdown is mirrored in recreational surfing (7,35). Once a wave is successfully caught, surfing performance can be subjectively based on 5 key elements established by the World Surfing League (WSL). These include (a) commitment and degree of difficulty, (b) innovative and progressive maneuvers, (c) combination of major maneuvers, (d) variety of maneuvers, and (e) speed, power, and flow (3). Although each of these elements is used to judge competitive surfers, recreational surfers may also aspire to improve their performance in each of these aspects to increase enjoyment and physical benefits through an enhanced ability to catch waves and perform maneuvers. Regardless of the level of ability of the surfer, improving performance requires practice

KEY WORDS:
surfing; surfing performance; strength and conditioning; surf training; surfboarding performance

and training to develop the skills and fitness components necessary to excel. At the elite level, athletes spend a significant amount of time training for their respective sports. For example, Olympic athletes have been shown to spend up to 21 hours per week engaging in strength, conditioning, and mobility training leading up to competition (17,29). In contrast to this, competitive adolescent surfers have been shown to spend less than 5 hours per week developing these same aspects (22).

The effects of training on sport-specific outcomes have been well documented by research in various sports. For example, a 12-week strength and sprint protocol improved sprint time in masters road cyclists (16). In addition, an 8-week and 15-week strength and power protocol was found to improve tackling ability in semiprofessional rugby players (58,59). However, although sports such as cycling and rugby have outcomes such as sprint time and tackling ability that directly correlate to sport performance, the same cannot be said about surfing, which is subjectively scored. Although this is true, in particular, the WSL judging criteria of speed and power may be developed through land-based training. This has been demonstrated in an article by Secomb et al. (52) which found that surfers with more lower-body strength and power scored higher in competition compared with their weaker counterparts. Although this observational study presents a correlation between lower-body strength and power and higher scores, the direct causation cannot be concluded and further experimental designs are needed to explore this relationship. With such a difference in the land-based training volume of competitive surfers compared with other Olympic athletes, there is an opportunity to explore the potential effects of training on surfing performance.

In regard to surfing, one study found that more than half of a 20–30 minute competition is spent in brief paddling efforts lasting between 1 and 20 seconds, with minimal rest time between exertions (20). It should be noted that these times may be affected by environmental conditions in the ocean. As such, surfers require a strong anaerobic system built on a highly developed aerobic foundation to meet these energy demands. On an individual level, there are a plethora of studies outlining the physiological and physical characteristics of surfers. Competitive surfers have been shown to have greater anaerobic power (19,27), maximal oxygen consumption (1,37,43), faster paddling velocities in aerobic and anaerobic events (14,21,47,52,56,57,60), and greater upper-body and lower-body strength (14,24,28,47,48,52,56) compared with recreational surfers. In addition, a positive relationship between competition scores in elite surfers and lower-body strength and power has been reported in the literature (52). Competitive surfers have also been shown to have increased postural control and balance (26,30,31,46), ankle dorsiflexion (25,28), lumbar extension, and hip and shoulder internal rotation (28). This last point is poignant given that the act of paddling requires a high degree of rotation around the shoulder for an efficient stroke (42). All these characteristics offer insight into areas in which surf performance can be improved through training.

However, to the best of the authors' knowledge, there have been no studies that have examined the effects of a training intervention on any objective measures of wave-riding ability such as speed, acceleration, and force output. Although outcome measures such as force plates, global positioning system (GPS), and accelerometers are a valid and reliable way to measure these variables on land (34,45,63), the aquatic environment challenges these concepts. This is likely a result of the fact that these measures are influenced by uncontrollable environmental factors such as swell period (the time between waves), wave height, wave shape, and current. However, recent advancements in wave pool technology may offer an ideal experimental paradigm, which allows for outcome variables associated with training interventions to be measured in a controllable wave-riding environment.

The purpose of this review is to thoroughly collate the peer-reviewed literature surrounding training methods in the sport of surfing, determine its quality and relevance, and highlight areas for future research. To the best of the authors' knowledge, there is currently a paucity of published data on this topic. Therefore, a scoping review was determined to be the optimal study design to address these questions because it allows for both the examination and summarization of novel heterogeneous literature that has not previously been comprehensively reviewed (49).

OBJECTIVES

The objective of this scoping review was to (a) identify training methods available to surfers in the peer-reviewed literature, (b) synthesize the findings, and (c) highlight any limitations and potential areas for future research.

METHODS

PROTOCOL AND REGISTRATION

An a priori protocol was developed using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) Extension for Scoping Reviews: Checklist and Explanation (50). This final protocol was registered prospectively with the Open Science Framework osf.io/zyq4f.

ELIGIBILITY CRITERIA

The eligibility criteria were informed by the Population-Concept-Context framework recommended by the Joanna Briggs Institute (JBI) Reviewer's Manual (32).

Population. Given the paucity of available research on this topic, no restrictions were imposed on surfing populations for this review. Competitive and recreational level surfers were included. For the purpose of this review, a recreational surfer was defined as someone who participates in surfing recreationally only, whereas a competitive surfer was defined as someone who competes in the sport of surfing (41). Moreover, all genders of any age were suitable for inclusion.

Concept. The concept of this review was to identify and examine the different training methods for surfers available in the peer-reviewed literature. For the purpose of this review training, methods were defined as any physiological training regime that was substantiated by a background in exercise science and had explicit or implicit effects on surfing performance.

Context. All periods, duration of intervention, follow-up, training locations (land and water), age groups, and level of surfing ability were eligible for inclusion. The following types of studies were eligible for inclusion in the study: randomized control trials (RCTs), non-RCTs, quasiexperimental designs, and case studies. The following types of studies were excluded: cross-sectional research, qualitative research, and expert opinion/theoretical perspective.

INFORMATION SOURCES

To identify pertinent peer-reviewed literature, a layered search strategy was used. First, a basic preliminary search of scholarly articles was conducted using 3 databases: PubMed, SPORTDiscus, and CINAHL to optimize key words and mesh terms. Next, a comprehensive search strategy was formulated and tested through consultation with the faculty librarian. Using this optimized search strategy, a literature search of electronic databases was conducted in PubMed, CINAHL, Embase, SPORTDiscus ProQuest, and Google Scholar. The databases were searched from their inception to June 6, 2020.

The initial search strategy was formatted, with syntax appropriate for PubMed and can be found in Table 1. All search strategies for other databases were developed using a translated version of the initial search strategy using the Polyglot tool (11) and can be found in Supplemental Digital Content 1 (see Appendix 1, http://links.lww.com/SCJ/A310). Finally, the search was supplemented by scanning the reference lists of the included studies for other relevant articles.

SELECTION OF SOURCES OF EVIDENCE

Screening was conducted concurrently in duplicate; whereby 2 reviewers (T.D. and M.S.) used separate EndNote libraries to individually screen all articles. Any disagreements were resolved immediately during the screening process. If consensus could not be attained, a third reviewer (J.F.) was brought in to resolve any difference of opinion.

The search results were exported into EndNote (EndNote X9, Clarivate Analytics), and duplicates were removed. After the removal of duplicates, articles captured by the search strategy were screened based on the title and abstract for eligibility. Remaining articles were further screened by full text to confirm eligibility and sorted based on the resource type. Reasons for full-text articles that were excluded were provided. References of articles meeting the full eligibility criteria were further examined for additional relevant data.

CRITICAL APPRAISAL

Peer-reviewed literature. A critical appraisal was conducted for individual articles included in this review to assess the quality and strength of the studies (T.D. and M.S.). The Checklist for Quasi-Experimental Studies by the JBI (32) was used and adapted to meet current research aims. This tool can be found in Supplemental Digital Content 1 (see Appendix 2, http://links.lww.com/SCJ/A310). The tool consisted of 10 questions, and a binary grading was used to create a raw score, with a "yes" receiving a score of "1" and a "no" receiving a score of "0" for each question. To assess surfing performance, one additional question was added, "were both field and lab-based measures used in the outcome?" As per previous research by Kennelly (33) and McArthur et al. (39), a quality grade was assigned to

Table 1
Search strategy for PubMed and Google Scholar

Data base	Search strategy
PubMed	(surfing[Title/Abstract] OR "surfboarding"[Title/Abstract] OR "short boarding"[Title/Abstract]) OR "surf sports"[Title/Abstract]) AND (training[Title/Abstract] OR "strength training"[Title/Abstract] OR strength[Title/Abstract] OR "max strength"[Title/Abstract] OR power[Title/Abstract] OR strengthening[Title/Abstract] OR "resistance training"[Title/Abstract] OR "weight lifting"[Title/Abstract] OR "functional training"[Title/Abstract] OR "balance training"[Title/Abstract] OR "functional balance"[Title/Abstract] OR "cross-training"[Title/Abstract] OR "core training"[Title/Abstract] OR "program design"[Title/Abstract] OR periodization[Title/Abstract] OR exercise[Title/Abstract] OR plyometrics[Title/Abstract] OR "endurance training"[Title/Abstract] OR "flexibility"[Title/Abstract] OR conditioning [Title/Abstract] OR anaerobic[Title/Abstract] OR "high intensity training"[Title/Abstract] OR "high intensity interval training"[Title/Abstract] OR "sprint interval training"[Title/Abstract] OR aerobic[Title/Abstract] OR development [Title/Abstract] OR repetitions[Title/Abstract] OR reps[Title/Abstract] or sets[Title/Abstract] OR "drills"[Title/Abstract] OR "flexibility training"[Title/Abstract] OR proprioception[Title/Abstract] OR development[Title/Abstract] OR "training method"[Title/Abstract] OR "physical conditioning"[Title/Abstract] OR "circuit based exercise"[Title/Abstract] OR "performance development"[Title/Abstract])

each study. A score equal to or greater than 74% was considered "good" quality, a score between 55 and 73.9% was considered "fair" quality, and a score less than 54.9% was considered "poor" quality. The finalized scores and associated quality grades can be found in Supplemental Digital Content 1 (see Appendix 3, http://links.lww.com/SCJ/A310).

Data charting and data items. The JBI Methodology Guidance for Scoping Review was used to frame the data charting process (32). Key areas were identified such as study citation details (author, date, and study design), key study characteristics (outcome measures assessed, dose, intensity, duration of intervention, and results), and overall findings. This initial tool was used and applied to all included studies and adapted to ensure all measures were included. In addition, the level of evidence was determined using the National Health and Medical Research Council template (NHMRC) (13).

A data extraction table was created to address the previously established research questions. This table was piloted on 2 studies initially and adapted to include all relevant measures. The data extraction process was completed by 2 researchers (T.D. and M.S.).

Data synthesis. A descriptive narrative synthesis is associated with all tables and diagrams to address the research questions and objectives of the article. In addition, synthesis of the results was conducted by summarizing the literature according to the data items listed above.

RESULTS

SELECTION OF SOURCES OF EVIDENCE

After the removal of duplicates, a total of 935 articles were identified from searches of the electronic peer-reviewed databases and the reference lists of included studies. Based on title and abstract screening, 877 articles were excluded, whereas 58 were retrieved and assessed for eligibility. Of these, 50 were excluded for the following reasons: 5 government documents, 2 books without an intervention focus, 4 expert opinions, 8 magazines, 5 videos, 18 non-intervention–based studies, and 2 articles without a surfing population, 5 articles with full text unavailable, and 1 article that was not relevant. An illustration of search results is presented by the PRISMA flow diagram below (Figure 1).

STUDY CHARACTERISTICS

Study aim and population are highlighted for each of the 8 studies in this scoping review. Each study was assessed and graded for quality of study design according to the NHMRC (13). Two studies contained a control group (15,55), 2 contained a comparison group (23,61), and 4 lacked either a control or comparison group (5,8,53,62). These 4 studies were categorized as level IV which is qualified as the lowest level of evidence as per the NHMRC. Of the 8 studies, 7 received a quality score ranging between 70 and 80% with an associated rating of "good" as per previous research (33,39). One study received a quality score of 50% and an associated quality score of "fair" (8). One study (15) included recreational surfers in the study design, whereas all other studies only examined competitive athletes. A summary of these findings can be found in Table 2 below and Supplemental Digital Content 1 (see Appendix 4, http://links.lww.com/SCJ/A310). Detailed descriptions of the tools used to assign quality grades can be found in Supplemental Digital Content 1 (see Appendix 3, http://links.lww.com/SCJ/A310).

COMPARISON OF STUDY OUTCOME MEASURES AND INTERVENTIONS

Only 2 studies examined field-based surfing outcome measures, 1 study highlighted an improvement in 5, 10, and 15 m sprint paddling performance and 400 m endurance paddle performance after a 5-week upper-body maximal strength training program (15). The other demonstrated an improvement in 15 m repeat sprint paddle performance as well as 400 m paddle endurance performance after 5 weeks of either high-intensity interval paddle training (HIIT) or sprint interval paddling training (SIT) (23). The remaining studies (5,8,53,55,61,62) demonstrated improvements in countermovement jump (CMJ) and squat jump (SJ) variables such as peak force, peak velocity (PV), as well as isometric midthigh pull (IMTP), time to stabilization (TTS), and rotational acceleration after various resistance training interventions. Outcomes were measured using force plate technology and accelerometers. One study (55) found that IMTP, CMJ PV, and SJ PV improved with no associated increase in jump height. These findings are summarized in Figures 2 and 3 and within Table 3.

DISCUSSION

The primary purpose of this scoping review was to outline the literature available surrounding training methods for recreational and competitive surfers. The objectives were to (a) identify training methods for these surfing populations in peer-reviewed literature, (b) evaluate the effectiveness of these methods, and (c) highlight limitations with respect to the findings.

Of the 935 peer-reviewed articles identified, 58 (6%) were eligible for full-text review. Of these, 8 (0.8%) met the inclusion criteria. These results were consistent with the authors' knowledge of the paucity of scientific literature regarding the topic. These findings highlight the limited literature in the field for surfers to access. Furthermore, 4 of the 8 studies (5,8,53,62) were classified as the lowest level of evidence as per the NHMRC (13) as they were lacking any form of comparator or control group. This contributes to the overall low level of evidence of the articles identified.

Six of the 8 studies involved an adolescent surfing population (5,8,23,55,61,62). A single study included recreational

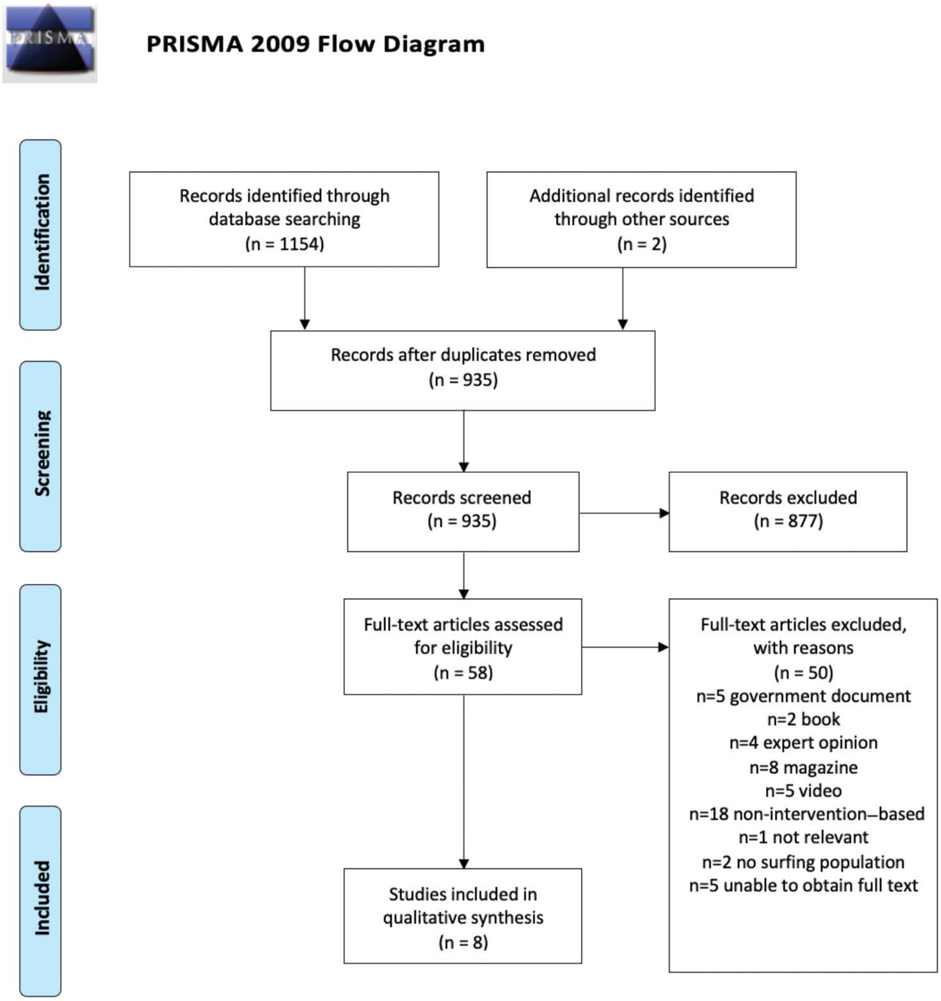

Figure 1. PRISMA flow diagram showing literature search, screening, and eligible studies. PRISMA = Preferred Reporting Items for Systematic Reviews and Meta-Analysis.

surfers (15). In addition, only 6 of the 113 subjects among all studies in this review were female (8,23). This highlights a potential underrepresentation of mature, recreational, and female surfers in the published literature surrounding training methods in the sport of surfing. Furthermore, the application of the present research on male surfers to female surfers may be limited because of the inherent physical and physiological differences between the sexes.

Training methods identified included resistance training (5,8,15,53,55,61,62) and cardiovascular training (23). Coyne et al. (15) found that strength training with 1–5 repetition maximum (RM) of the upper-body improved 5, 10, 15, and 400 m paddling times in competitive and recreational male surfers. Although paddling is not judged in a surfing competition, it is integral to tactical positioning and adjusting to ever-changing environmental conditions (20).

For the lower body, Secomb et al. (53) found that a program of combined strength, plyometric, and gymnastics training improved IMTP variables as well as CMJ PV. A later study by Secomb et al. (55) differentiated the effects of strength training against plyometric and gymnastics training independently and found that only resistance training improved IMTP variables and SJ PV with no associated increase in jump height. Conversely, plyometric and gymnastic training was found to improve eccentric leg stiffness with no increase in IMTP variables or jump height. Previous research has shown that initial lower-body strength levels can greatly affect the improvements in jump height after a plyometric-based or power-based intervention (12,51). The short training time frame (2 sessions a week for 7 weeks) may not have allowed for adequate development of lower-body strength to maximize these adaptations, potentially explaining the lack of increase in jump height. The authors acknowledge the importance of developing lower-body eccentric stiffness in jumping performance as per previous

Table 2
Key study characteristics of included studies ($n = 8$)

Author	Aim	Level of evidence (8)	Population	Control/comparison group	Grade/quality score
Coyne et al. (15)	Report on the effect of a 5-week (2x per week) maximal upper-body strength training intervention on surfboard sprint (5, 10, and 15 m) and endurance (400 m) paddling performance in competitive and recreational surfers.	III-2	Six competitive and 11 recreational male surfers (29.7 ± 7.7 years of age)	Y	80%/good
Secomb et al. (55)	To compare training-specific adaptations in lower-body strength (IMTP), jumping performance (CMJ), and muscle structure (ultrasound) after a 7-week (2x per week) resistance training versus gymnastics and plyometric training and nontraining interventions.	III-2	16 junior competitive surf athletes aged (14.8 ± 1.8 years of age)	Y	80%/good
Farley et al. (23)	Determine the effect of a 5-week (2x per week) sprint or high-intensity interval paddle training intervention on 400 m and repeated 15 m paddle performance.	III-2	24 competitive adolescent surfers (19 male, 5 female) (14 ± 1.3 years of age)	Y	70%/good
Tran et al. (61)	Report on the effect of a 7-week (2x per week) unstable versus stable resistance training intervention on strength (IMTP), power (CMJ and SJ), and sensorimotor abilities (TTS) in adolescent surfers.	III-2	10 competitive male and female high-school surfers (14 ± 1.1 years of age)	Y	70%/good
Axel et al. (5)	Report on an effect of an 8-week core strength training program (CSTP) on CMJ, rotational acceleration and power, core strength, and endurance in junior competitive surfers.	IV	19 junior competitive surf athletes (15.7 ± 1.01 years of age)	N	70%/good
Tran et al.(62)	Examine the effect of 4 weeks of detraining on strength (IMTP), power (SJ), and sensorimotor ability (TTS) of adolescent surfers after 7 weeks of periodized resistance training.	IV	19 adolescent competitive surfers (13.8 ± 1.7 years of age)	N	70%/good
Secomb et al. (52)	Report on the training-specific adaptations (CMJ, SJ, and IMTP) after a short block (6 weeks/3 times per week) of combined strength, plyometric, and gymnastic training.	IV	Seven international competitive male surfers aged (22.8 ± 4.1 years of age)	N	70%/good
Caballes et al. (8)	Report on the effect of a 7-month periodized ASCA youth resistance training program on a competitive female surfer's strength and reported surfing ability.	IV	One elite junior female surfer (15 years of age)	N	50%/fair

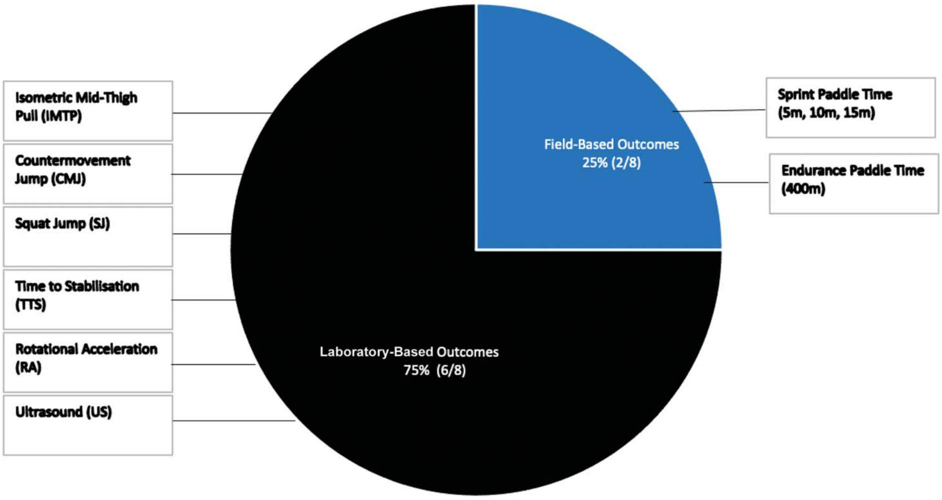

Figure 2. Comparison of study outcome measures.

research (10,36). Based on the findings of these studies, the authors recommend the implementation of a comprehensive upper-body strength training program in the 1–5RM range to improve paddling speed and endurance. In addition, plyometrics or gymnastics may be used as an adjunct to a lower-body strength training program; however, more research is needed to substantiate the effect of these methods on surfing performance.

In addition, one article examined the effect of unstable and stable surfaces on resistance training for improving strength (IMTP), power (CMJ), and sensorimotor abilities (TTS by drop and stick) among 10 competitive adolescent surfers (61). All outcome measures were calculated using the force plate technology. This article found similar improvements in strength and sensorimotor abilities between stable and unstable surfaces for resistance training. It should be highlighted that the participants of this study were inexperienced with respect to resistance training. This may explain the strength improvement in the unstable surface group as neuromuscular adaptation occurs in untrained individuals with minimal stimulus (9). However, lower-body power output was improved relative to baseline after the stable surface intervention and reduced from baseline for the unstable surface intervention. These findings are in line with other research demonstrating that unstable surface training interventions attenuate force and power development (6,40). It is also important to note that balance training may be important for enhancing proprioception, as competitive surfers have been shown to have increased postural control and balance compared with recreational surfers (26,30,31,46). Given these findings, the use of unstable surfaces to develop strength and power to improve surfing performance is not recommended; however, it may serve as an important adjunct to improve postural control and balance.

Two studies examined outcomes in the water; however, only one used a cardiovascular training intervention. Farley et al. (23) found that a twice per week 5-week intervention of SIT paddling improved repeated 15 m sprint paddle time, whereas the HIIT paddling group decreased their 400-m endurance paddling time. Program variables for both interventions such as sets, reps, and work-to-rest ratios (see Appendix 4, http://links.lww.com/SCJ/A310) mirrored paddling bouts reported by previous time motion analysis (20,54). This study further delineated that HIIT paddling intervals enhanced aerobic capacity, whereas repeated SIT paddling demonstrated more improvements in the anaerobic system. The findings of this study demonstrate the ability of SIT and HIIT training methods to enhance key cardiovascular aspects of the sport that should be included in a surf-training program.

Interestingly, none of the peer-reviewed articles examined mobility or flexibility training despite the finding that professional surfers have increased lumbar extension, trunk rotation, shoulder and hip internal rotation (28), and dorsiflexion (25,38) compared with recreational surfers. These aspects may play a crucial factor in performing maneuvers such as snapping and cutbacks which require a surfer to oppose the momentum of a wave and turn the surfboard rapidly (18). Furthermore, when positioning inside the airspace underneath the breaking part of the wave, colloquially known as a "barrel," a surfer may need to crouch to accommodate their bodies into this space. Based on the qualitative analysis, successful completion of this high-scoring maneuver may require a high level of lower-body mobility (18). This may highlight the need for future studies to examine the effect of mobility and flexibility training on surfing performance.

Six of the 8 interventions had a positive effect on the outcome measures used (CMJ, IMTP, TTS, VJH, and rotational

Table 3
Comparison of study interventions and outcomes for included studies (n = 8)

Author	Results	Field-based outcome	Laboratory-based outcome	Translation to surfboarding performance
Coyne et al. (15)	Five weeks (3x per week) maximal upper-body strength (1–5RM) training for pull-ups and dips demonstrated improvements in surfing paddling sprint (5, 10, and 15 m) and paddling endurance performance (400 m).	✓	✓	✓
Farley et al. (23)	Five weeks (2x per week) HIIT paddle training intervention demonstrated significant improvement in aerobic (400 m) paddle performance. SIT paddle training significantly improved 15 m repeat sprint paddle performance.	✓	✖	✓
Tran et al. (61)	Seven-week (2x per week) unstable and stable periodized resistance training effective in developing strength, but no significant effect on sensorimotor abilities for either intervention. However, unstable training found to be inferior for the development of lower-body power.	✖	✓	✖
Axel et al. (5)	Eight weeks (2x per week) of a periodized core strength training program demonstrated improvement in rotational power, time to peak acceleration, maximal CMJ height, estimated peak CMJ power, core strength, and rotational flexibility.	✖	✓	✖
Tran et al. (62)	Four weeks of detraining after 7 weeks of resistance training demonstrated that the absence of resistance training (detraining) is not a sufficient training stimulus to maintain physical abilities in CMJ, isometric strength, and sensorimotor abilities.	✖	✓	✖
Secomb et al. (52)	A 6-week (3x per week) strength, plyometric, and gymnastics-based intervention demonstrated improvements in lower-body muscle structure (ultrasonography), strength (IMTP), and jumping performance (CMJ).	✖	✓	✖
Caballes, 2015	A 9-month periodized resistance training (calisthenics, free-weights, medicine balls, and bands) as per the ASCA Child and Youth resistance training model demonstrated improvements in IMTP, CMJ, and self-reported surfing ability in one single 15-year-old competitive female surfer.	✖	✓	✖
Secomb et al. (55)	Seven weeks (14 sessions) of resistance training demonstrated increases in IMTP peak force, DSD ration, SJ peak velocity, and vastus lateralis (VL) fascicle length (FL). Gymnastics and plyometrics demonstrated increases in VLFL and eccentric leg stiffness.	✖	✓	✖

ASCA = Australian Strength and Conditioning Association; CMJ = counter movement jump; CSTP = core strength training program; DSD = dynamic strength deficit; HIIT = high-intensity interval training; IMTP = isometric midthigh pull; SIT = sprint interval training; RM = repetition maximum; SJ = squat jump; TTS; time to stabilization; ✖ = study did not have outcome; ✓ = study did have outcome.

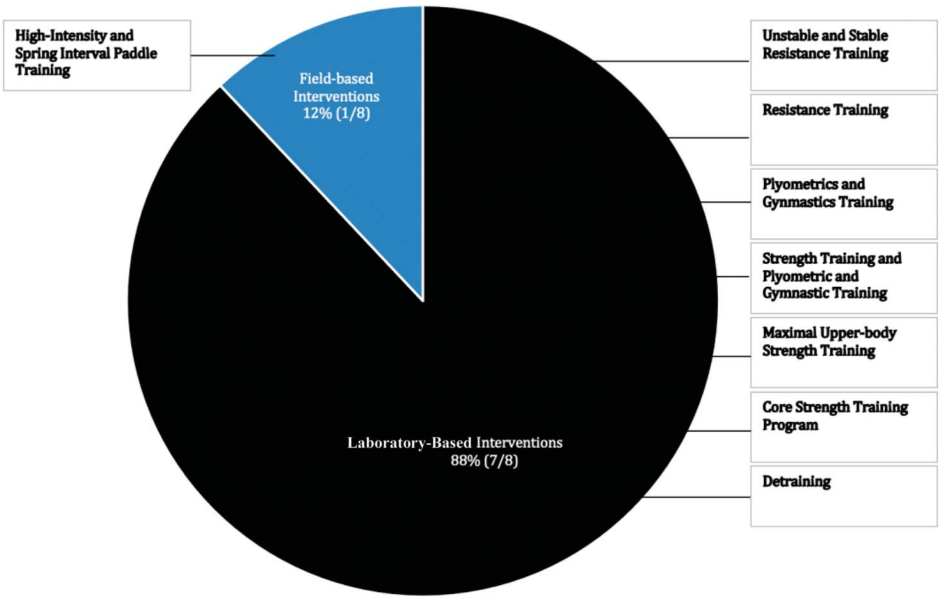

Figure 3. Comparison of study interventions.

trunk acceleration) (5,15,53,55,61,62). Although these outcomes were measured in the laboratory, previous research has also identified a positive correlation between lower-body strength and power on turning maneuvers (52). This study included subjective measures of wave-riding ability, and although wave riding is judged subjectively, objective measures may be used to complement and inform our understanding of how these scores were derived. Incorporating technology such as board-integrated accelerometers to measure acceleration, force plates to measure power output, GPS units to measure speed, and video-analysis software to quantify aerial height will allow researchers to objectively measure surfing performance variables. These measures may correlate to the subjective judging criteria from the WSL, in particular, speed and power (3). With this information, causal relationships may be made between training methods and objective surfing performance variables, for example, how is aerial height and magnitude of turning maneuver performance affected by a 6-week maximal lower-body strength program? Moreover, wave pool technology is becoming increasingly available. This allows for control of ever-changing environmental variables found in the ocean such as swell period, wave height, wave shape, as well as current. With this, consistent reproducible waves can be created, setting the stage for a well-controlled experiment. Collectively, these aforementioned factors will allow future studies to investigate potential complementary correlations and or causational relationships between training, objective riding variables, and the subjective performance measures on which surfing is judged.

The findings of this scoping review demonstrate both a paucity and insufficiency in high-quality peer-reviewed literature surrounding training methods for the sport of surfing. One explanation for this may be the lack of valid and reliable tools available for researchers to objectively measure field-based outcomes such as speed, power, and acceleration while surfing waves. The authors believe that lower-body resistance training focused on building strength and power should be included in a surfing program, as a positive relationship has been identified between lower-body strength and power and surfing performance (52); however, further research is required to support this relationship.

To the best of the authors' knowledge, this is the first scoping review that highlights the gap between training methods and wave-riding performance. Other strengths of this review include the use of 2 reviewers to reduce bias and the inclusion of broad eligibility criteria. This review was limited by only including sources published in English, which may have excluded key sources in other languages. To the best of the authors' knowledge, no confounding factors exist that may have impacted these study findings. The findings of this scoping review may influence future studies by highlighting the need to examine the direct relationship between training methods and wave-riding performance for both competitive and recreational surfers.

CONCLUSION

The findings of this scoping review demonstrate a paucity in the peer-reviewed literature with respect to training methods for improving surfing performance. Two of the 8 studies found in this review demonstrated an improvement from either upper-body maximum strength training or SIT and HIIT on paddling performance (15,23). The remaining 6 reported improvements in laboratory-based outcome measures after training input but demonstrated no improvement on wave-riding performance. Moreover, the quality of these studies was relatively low. A lack of available field-based technology and shortage of participants may explain the low number and lack of high-quality research in this context; however, with continued growth in the sport of surfing, there is a need for proven training methods that have demonstrated improvements in performance as in other sports (16,58,59).

Based on these findings, the authors would recommend a surf training program that focuses on maximal strength training of the upper body to improve sprint and aerobic paddling performance, HIIT and SIT paddling to improve aerobic capacity and repeat sprint paddle ability, and lower-body resistance training focused on building strength and power to potentially improve surfing performance. These suggestions are in line with previous research which has found that competitive surfers have greater upper-body strength (14,28,48,56) and produce more power aerobically (14,21,47,52,57,60) and anaerobically (19,27) compared with recreational surfers. Furthermore, greater lower-body strength was found to be correlated to improved surfing performance (52). Gymnastics and plyometric training may also be considered an adjunct to a comprehensive strength training program. More research is required to examine the effects of mobility and balance training on surfing performance as these characteristics have also been found to be increased in competitive surfers (25,26,28,31,46). In addition, more research is required to highlight the direct impact of physical training on objective markers of wave-riding ability. Future studies that implement the use of modern technology such as high-speed cameras, board-integrated accelerometers and GPS units, and wave pool technology may serve to fill the gap in research between training and wave riding performance. This study is a call to action for future researchers to investigate objective, measurable outcomes specific to surfing performance and explore how different training methods affect them.

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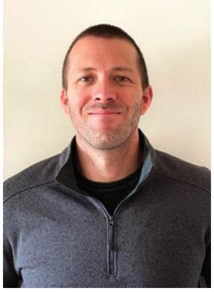

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