Training and development in sport officials: A systematic review

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ABSTRACT

Sport officials make significant contributions to organised sport, yet scientific evidence to inform their specialized training and education at various levels has lagged. While psychological and performance demands of expert sport officials have been well documented, the extent of research about talent and expertise development, training efficacy, and broader developmental trajectories is unclear. This systematic review summarizes 30 years of published findings on the study of training and development of sport officials, including areas of research interest, study designs, and sport official characteristics. A PRISMA systematic review was conducted, utilizing three scientific databases (Web of Science, SportsDiscus, PsycInfo) to identify relevant studies (N = 27). Female participants were generally underrepresented in studies (17%), while football officials were most often represented (79%). Training intervention (59%), retrospective (37%), and cross-sectional comparison (22%) were the main study designs. Expert and near-expert sport officials' training histories and responses to empirically driven isolated-skills training represented the predominant areas of study. Sport-specific, video-based infraction detection tasks was the most frequently used training methods to improve perceptual-cognitive skills for on-field decision-making, however studies lacked retention measures to on-field performance. Psychological skills training programs were found to have mixed effects and used varied criteria for measuring training efficacy. Physical training showed mainly significant effects on physiological measures and aging influences for on-field performance. More rigorous sport-specific evidence, assessments of training transfer, program efficacy, and macro-developmental trajectory and milestone data are needed to inform training programs and developmental plans.

Key words: sport official, referee, umpire, training, development, expertise, performance, talent

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1 | INTRODUCTION

Sport officials (i.e., referee, umpire, judge) occupy an essential role in overseeing and adjudicating organized sport for millions of participants globally. Sport officials are individuals responsible for applying rules in sport competitions and who regulate or control competition activities.[1] Sport officials include central, assistant, and technical official roles encompassing different physical, cognitive, and interactive role demands. Because sport officials are vital contributors to the regulation and feasibility of sport, they hold an integral stake to sport society more generally. Governing sport bodies continue to seek to improve training approaches and deliberate practice programs to help officials better deal with the technical, physical and mental workloads of their performance environments.[2] Improvements in athlete expertise pathways have placed increased pressure on sport officiating training structures to modernize similarly,[3] where sport official training environments can be unstructured as training programs are relatively novel and lack sport-science-supported systems.[4,5] Education and training of sport officials at different levels is often challenged by limited financial (and human) resources and existing empirical evidence compared to that of athlete and coach development.[5] Increased evidence-based knowledge and greater investment into sport officials' training and development is needed and would likely have broad benefits to sport.[6,7]

Much research has been dedicated to highlighting the superior attributes, personal characteristics and skills of elite sport officials,[8,9] as well as setting the standard for the requisite abilities necessary to become an elite official. To date, empirical studies on performance skills that are important to cultivate in sport officials has grown, including perceptual-cognitive skills,[10,11] physical fitness,[12,13] intra-personal skills such as coping with stress,[14] mental resilience,[15] and self-efficacy,[16] and inter-personal skills such as effective communication and

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game management skills[4,17,18] and teamwork abilities.[19,20] This perspective emphasizes isolating sport-specific skills officials should aim to develop and that are requisite of more optimal performance. While there is a growing body of research on the characteristics of expert officials[4,21] and influences on sport officials' performance (e.g., crowd[22]; injury[23]), there is substantially less known about the *development* of sport officials.[7,24] Indeed, while there has been a proliferation of research on expert characteristics, one scoping review found less than one percent of research on football officials is actually dedicated to development (i.e., how officials' skills and characteristics change over time as a result of training and/or experience).[24] There has, however, been progress in the area of sport officials' development.

An expertise model of sport official development and training has generally emerged as a primary perspective for interpreting development. One body of knowledge that has derived from an expertise model has been a deliberate practice view of sport official training.[2,25] Deliberate practice, namely practice that is effortful (physically and cognitively), not immediately rewarding (personally, socially or financially) and purposefully done to improve performance,[26] has been identified as one of the primary influences on the acquisition of sport expertise.[27] The quality of deliberate practice that sport officials participate in, particularly at elite levels, has improved due to the professionalization of their role.[28,29] As a result, areas of training now include physical preparation,[30] nutrition,[31] vision,[32] psychological skills,[33] and decision-making skills.[34] Results have shown that officials report greater relevance for such activities.[25,35] An example of a high-performing football referees' deliberate practice program describes two-thirds of training hours spent on physical fitness and technical lectures, and the remaining third on video match analysis, on-field simulation, and psychological workshops and individual consultation.[2] The influence of deliberate practice on expertise development is well

documented,[36] however, opportunities for deliberate practice training are lamented to be largely non-existent for most sport officials.[35,37] For example, while developing athletes get to practice *at least* a few days, developing officials do not have the luxury of weekly practices. Indeed, elite central and assistant football referees are found to accumulate just over 5,000 deliberate practice hours over an average 20-year career.[35] This amount of accumulated deliberate practice is considerably less than that of elite athletes.[36]

Additional reports find that developmental experiences for officiating skill acquisition occur outside the parameters of the deliberate practice framework. For instance, aspects of sport officials' development are suggested to occur through a 'hidden curriculum', such as match experience, experience outside sport, and informal advice from other officials and mentors.[38] Match officiating experience[35,39] and prior *playing* experience[40] are highly relevant to their development. Officiating development models have also become more common,[1,7,41] demonstrating interest to utilize theoretical frameworks to aid development plan design. While helpful to characterize development and related factors, further testing of these models is needed and clearer theoretical guidelines should address role- and sport-specific attributes. Complicating matters is the fact that such conceptual interpretations of sport official development are varied, there is limited knowledge available about early developing sport officials' experiences, and research directed towards talent identification and development is lacking.[42] Furthermore, there is limited understanding about broader macro-patterns of officials' development, as well as the impacts that skill transfer,[43] career advancement,[44] communities of practice[45] and other organizational and environmental constraints[7,46] have on development. It is also essential to understand what evidence base exists on the development of sport officials. This imbalance

directly impacts the fidelity and efficacy of emergent officiating training approaches and development models and plans.

With a scarcity of information regarding sport officials' skill and expertise progression, the purpose of this systematic review was to provide a state of the science summary of research on the training and development of sport officials, to identify dominant themes in that literature, and to identify gaps and make recommendations for future research. Because of the mixed interpretations of sport official development,[1,7,41] we view development as contributed to by both formal learning (e.g., isolated training, deliberate practice programs)[2,25] and un-mediated and informal types of learning.[40,47] As such, sport official development needs to be better described, detailed, and characterized to account for the myriad of influences on development. Training interventions, and retrospective and longitudinal studies between the years 1990 and 2020 were evaluated where studies must have examined or tracked changes in performance variables or developmental factors in sport officials. This review expands on previous scoping-style reviews of sport official research[24,48] by specifically targeting development and training studies of sport officials.

2 | METHODS

A systemic review was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement guidelines[49] to examine empirical studies on sport official development and training. Studies were included in the final review if they met the following criteria:

1. *Sport official participants.* Only studies where sport officials were the primary participant were included in the review. Non-officials and other 'outsider' viewpoints

(sport official development managers/administrators, coaches, mentors) about sport officials' training and development patterns and processes were excluded.

2. *Development: Time-based and/or volume-based comparison*. Included studies must have tracked a training or performance variable over time. This could have been assessed by prospective or longitudinal education or training approaches, as well as short-term interventions/training studies that focus on improving a specific skill or ability (i.e., micro-training, short-term approaches). Retrospective studies of development, including developmental milestones, pathways, and training volume (i.e., macro-development) were also included. Studies that measured performance differences based solely on expertise level, or utilized an expertise-approach design to compare skills and abilities (i.e., cross-sectional comparison of skill groups), were excluded.
3. *Empirical studies*. Only primary, empirical research was the subject of the present review. This included data-driven studies (quantitative and/or qualitative). Secondary research was not included, such as other systematic reviews, meta-analyses, book chapters, conference proceedings or abstracts, or commentaries.

The strategy used three review phases: 1) a broad search of electronic databases (attending to PRISMA recommendations); 2) a search of additional sources; and 3) a researcher consensus stage. Phase 1 involved a search of three databases: Web of Science, SportDiscus, and PsycInfo with a time window from January 1990–October 2020. These databases were deemed exhaustive resources for sport official learning, development and education studies, particularly considering their frequent use in previous sport official research reviews.[24,50] Two categories for search terms

were used to accommodate the range of commonly-used language to describe sport officials and developmental and skill group terminologies.[1] First, role-specific descriptors of the sport officials included: '*sport official*', '*sport referee*', '*sport judge*', '*sport umpire*'. Second, concepts and descriptions central to the review topic of development were used, including: '*training*', '*development*', '*deliberate practice*', '*expertise*', '*elite*', '*career*', and '*talent*'. Combinations of these terminology categories were then employed in our search, for example, '*sport official*' AND '*training*', '*sport umpire*' AND '*deliberate practice*'. For Phase 2, a secondary search of external sources was conducted, such as the reference list of articles found from the database(s) search, references in books, and additional website searches (i.e., Google Scholar). Following these phases, an Excel spreadsheet was prepared to record studies' author(s), title, year of publication and abstract, and records were then sorted in order to eliminate duplicates. From the list of unique records, publications' titles and abstracts were read to discern whether the articles were written in English, concerned sport officials and their development or training, and originated from a peer-reviewed journal (i.e., 'reviews', 'commentaries', 'abstracts' or 'conference proceedings' were not included). From this reduced list, a more comprehensive evaluation occurred, which involved obtaining the full-text articles. All full-text articles were then distributed among the research team and assessed for the necessary descriptive data.

Each study's author(s), publication year, study design, and main findings, along with participants' age(s), gender, sport, experience level, and role as an official were procured. Where possible, standardized effect sizes for main findings are reported. However, this was not always possible due to the descriptive and/or qualitative nature of some studies, and the absence of sufficient information in others. To ensure consistency in categorizing skill level of sport officials sampled in studies, Baker et al.'s skill taxonomy[51] was used to classify samples as

beginner, developing, and/or expert. Training intervention studies were classified based on their short- (<1 week), medium- (multiple weeks within one sport season), and long-term timing (one sport season or longer). Study designs were classified as cross-sectional (comparing developmental variables of different skill groups), retrospective (long-term tracking of developmental variables), and/or training interventions (evaluating impacts of training exposures on developmental variables). A series of consensus-based discussions took place amongst the research team to reach agreement for article inclusion and accuracy in descriptive data.

Quality assessment of articles was carried out using Version 18 of the Mixed Methods Appraisal Tool (MMAT).[52] This tool was designed to assess the quality of five types of empirical studies (i.e., qualitative, nonrandomized quantitative, mixed methods, randomized control trials, and quantitative descriptive studies) using five evaluative criteria per type of study. Although MMAT metrics have limited utility and should be interpreted cautiously, studies were scored from 0% (i.e., 0 out of 5 criteria met) to 100% (5 out of 5 criteria met) as a crude measure of study quality. Three reviewers assessed the quality of the papers independently for interrater reliability and scores were compared. All three reviewers came to a consensus on the final scores.

3 | RESULTS

Phase 1 identified 3,924 articles following database searches using keywords. An additional 19 articles were identified through external sources, totaling 3,943 articles. Removal of duplicates resulted in a total of 2,096 articles. After reviewing the titles and abstracts, 1,980 of these records were eliminated, leaving 116 studies identified for full-text evaluation. Following this comprehensive assessment, 89 articles were removed as they either did not include a training aim, utilized neither a longitudinal nor retrospective design, or sport officials were not the

primary participant. This left a total of 27 articles following screening that remained in the final study selection (Figure 1 provides a flow diagram of the PRISMA process).

*** *Figure 1 about here* ***

The MMAT quality assessment of the 27 articles resulted in three studies being classified as Qualitative, four as Randomized Control Trials, 10 as Non-randomized Studies, eight as Quantitative Descriptive, and two studies as Mixed Method. Based on these classification categories, the MMAT Quality Scores for each study are presented in Table 1. 17 studies received a score of 100%, five studies a score of 80%, and five more a score of 60%.

3.1 | Descriptive Results

27 articles were included in the review (see Table 1), 17 of which used short- and medium- to long-term training interventions, while ten studies used retrospective designs. Of all studies reviewed, six studies used cross-sectional data and three studies implemented longitudinal design (across one or multiple sport seasons). All studies were published within the 20-year period between 2000 and 2020 (n = 10 from 2001-2010; n = 17 from 2011-2020). The studies included in this review were predominantly comprised of samples from European countries (n = 20; 74%), inclusive of the United Kingdom, Belgium, Germany, and the Netherlands, with three studies from Australia, three from Israel, and one from the USA. The sport that had the greatest representation (in single and multiple sport studies) was football (n = 21), followed by rugby union (n = 2) and Australian rules football (n = 2). Three studies included multiple sports (an average of three sports per study and all were retrospectively designed).

In terms of sample participants' characteristics, 26 of the studies involved samples with ages of 18+ years, while studies with a sample under 18 years of age only accounted for one study. Gender of participants was primarily male, although over half of the studies (n = 15) did not report gender (although not explicitly indicated). Only five studies reported female participant samples, in which females made up 17% of the total sample for studies reporting gender. 23 studies included 'expert' samples (e.g., international and national competition, professional sport league), while 'developing' officials (i.e., semi-professional, metropolitan, regional, club, senior divisional) were sampled in 14 studies (12 of the total studies reviewed included both skill groups). 'Beginner' sport officials (i.e., youth, elementary school, community sport) accounted for samples in only two studies[53,54] (one of which also included 'expert' and 'developing'). Eleven studies reported central officials' experience to be on average 11.7 years, while four studies reported assistant officials' experience to be 5 years, on average. Five studies reported sport officials having experience functioning in both roles and one study used number of matches officiated as a criterion for experience.[55]

*** *Table 1 about here* ***

The 27 studies included in this review were subdivided into four thematic categories according to the types of variables they examined: (i) perceptual-cognitive skills, (ii) physical fitness, (iii) psychological skills, and (iv) practice history and macro-developmental pathways. The first category, *perceptual-cognitive skills*, included 11 studies. All studies used video-based testing and training methods, and eight studies utilized 'medium- to long-term' training interventions ranging from 2.5 to 13 weeks in duration (mean = 6.5 weeks) involving 4 to 13 training sessions

(mean = 7.7) separated by an average of five days. The remaining three studies were considered 'short-term' ranging from one to three days and averaging one training session/day. All studies demonstrated statistically significant improvements in sport officials' decision accuracy as a result of training, as measured by video-based infraction detection decision task. Seven studies assessed decision accuracy changes in central officials' subjective judgements of one-on-one player contact decisions (football, n = 3; Australian Rules football, n = 2; rugby union, n = 1) and of novice students' subjective decisions regarding player contact situations ('Swirl ball', n = 1). Of the six central official training studies, four studies yielded an average percentage accuracy improvement of 5.9% (min = 4%[56], max = 8.4%[37] using video-based methods). One study showed an 8.1% improvement in decision accuracy in context-specific decisions compared to not,[5] while two other studies found significant differences in decision accuracy improvement between skill groups (17.4%, low-ranked developing and 3.6%, high-ranked expert officials[37]; 8%, less-experienced and 2%, more-experienced sport officials[55]). One study showed additional improvements in decision accuracy across different testing points following training.[55]

The remaining four studies examined assistant officials' response accuracy improvement on closed-skill, signal detection decision test (i.e., flag vs. no-flag errors for offside decisions in football). One main aim of training was to improve assistant referees' ability to differentiate spatial positioning in players' movements through a frame recognition task through web-based training.[57,58] Three studies used video simulations and computer animation,[57,58,59] while another tested influences of video speeds on off-side decisions.[60] Compared to no training, training groups mainly showed significant results, yielding 12.5%[60] to 17%[57] improvement rates in response accuracy, while some other studies showed only marginally significant[59] or no significant improvement[60] depending on training mode. For all perceptual-cognitive training

studies for sport officials, decision analysis and training protocols ranged in format from web-based[57,58,61] to in-person groups[55,62] to individually completed.[37] Of the four assistant official decision training studies, only one examined transfer of training to on-field performance.[57]

The second category, *physical fitness*, examined the effects of physical training programs on changing aerobic and anaerobic capacity (n = 2), and longer-term, retrospective tracking of physiological performance indicators as a consequence of instituted training programs (n = 2). All studies were from football, and involved elite football officials. As such, two out of four studies involved samples of older officials (39+) concerned with mitigating age-related declines in physical performance.[63-64] Most common physical output and performance measurements evaluated included max heart rate (n = 3), distance covered (n = 3), running intensity (n = 2), top running speed (n = 2), VO_2 max (n = 2), blood lactate concentration (n = 2), and average distance from on-field fouls (n = 1). These measures were influenced by high-intensity intermittent training[65] and interval training[66] in both lab-based[65,66] and on-field training simulations.[64] Evaluative measures used in studies differed between on-field performance indicators[63,64] to more off-field, structured physiological tests (i.e., the Yo-Yo intensity recovery test[65,66]; 12-minute run[66]). Two studies incorporated physical training with perceptual-cognitive testing.[5,62] Physical training programs for elite football officials showed significant improvements in the Yo-Yo recovery test from 31% (off-field[65]) to 46.5% improvement (on-/off-field[66]), while retrospective studies found no significant age effects on changes in VO_2 max over time[64]. Additionally, although older officials (43-48 years of age) might experience age-related declines in physical fitness during matches compared to officials ten years younger (28.4% and 35% decreases in high intensity running and sprint count, respectively), they are found to be equally close to match play as their junior counterparts to make calls effectively (reflecting a

potential ability to better adapt to fast-paced matches).[63] Training was mostly performed in groups of sport officials, while one study relied on individualized training plans to be followed.[66] In sum, findings of the efficacy of physical training programs were generally positive, but there are indications of age-related differences on physical outputs after training.[63]

A third category, *practice histories and macro-developmental pathways*, explored domain-specific training activities and histories among sport officials (n = 8). The primary focus of these studies was on officials' engagement with deliberate practice, as well as the influence of their participation histories as athletes and officials in their sport development. Four studies documented the types of training and deliberate practice and modes of learning that officials can engage in, including their accumulated practice volumes, and the relevance of these activities to expertise development.[25,35,47,67] Two studies concentrated on non-training or 'unmediated' practices that occupy important informal experiences in development.[47,68] One study concerned developmental milestones/events influencing sport officials' developmental pathways, which reported that officials had non-linear developmental trajectories.[40] Match-experience was frequently identified as a crucial and positive influence on expertise development.[25,35,43,68] Match experience was calculated in studies based on estimated years[68] or number of matches,[55] and also operationalized match competition context ('friendly' vs. 'league'[25]). Other developmental factors addressed in studies included specialization age into sport officiating[68] and transfer of skills to sport officiating from prior playing experience.[40,43] For example, higher skill level referees started refereeing at younger ages than lower skill-level officials.[25] Four of the studies used quantitative approaches to approximate previous volumes of deliberate practice hours and match experience,[25,35,67,68] two studies used qualitative methods to describe and conceptualize

pathways of development,[40,43] while the one remaining study used mixed methods.[47] Five of the eight studies conducted cross-sectional comparisons of sport official skill level and role.

The fourth category, *psychological skills*, examined the benefits of educational programs and training effects on mental skill characteristics and attributes in sport officials (n = 4). Psychological characteristics in sport officials, including self-efficacy[69,70] and mental resilience,[70,71] were the explicit focus of these training studies. Two studies trained officials' visualization skills (imagery), use of in-performance self-talk and distraction coping, and pre-performance routines and plans.[70,71] Three studies used multi-stage educational programs concerning psychological and performance skills,[70-72] while another two studies used an in-situ, within-match design.[69,70] Also, video footage of officials' performance and self-reflection on performance provided an important method for developing certain psychological skills.[69-72] One study showed no clear significant benefits,[69] while the remaining three studies lacked an explicit measurement criterion, instead using number and level of matches appointed,[72] assessor reports,[70,71] and officials' self-evaluations[70] to evaluate training efficacy. Qualitative feedback from sport officials indicated a general relevance for psychological skills training and its benefit to their performance.[69,72]

4 | DISCUSSION

The aim of this study was to review empirical studies on the training and development of sport officials between the years 1990 and 2020. Unexpectedly, this review found that published articles on sport official training and development only began to emerge in the early 2000s. This finding in itself illustrates the infancy of this research field and relative disparity in progress to that of athlete and sport coaching development. Overall, sport official training and development research used a variety of study designs from micro-training interventions, to longitudinal

tracking of responses to training programs, and sport officials' retrospective recall of their training volume and type, including descriptions of and mediators in their developmental pathways. Studies mostly sampled high-performing and experienced sport officials, and mainly focussed on developing perceptual-cognitive skills through video-based methods. Specifically, perceptual-cognitive training was found to be beneficial for lower-level skill groups, yet yielded small to nonsignificant improvements in more expert officials.[37,55] While some studies provided evidence for the efficacy of training modalities,[56,58,66] others did not.[62,65,69] Physiological training programs, as assessed by changes in a variety of biological[66] and physical response measures to training[65] were generally impactful. Improvement of sport officials' psychological attributes occurred through in-situ training methods[69] and through more long-term learning programs (e.g., 'mental toughness' education[70,71]), but these and other training programs lacked longitudinal retention tests to evaluate training outcomes, sometimes relying only on qualitative feedback or performance indicators (i.e., officiating appointments[72]). A far smaller collection of studies confirmed sport officials' consensus for the importance of match experience,[25,35,40,43,68] transfer of skills from playing sport,[40,43] and influences of other career and developmental milestones.[40,53,68] Overall, there is a relatively modest number of empirical studies on sport officials' training and development, resulting in fragmented areas of research and underdeveloped representation in a diverse range of sports, skill levels, and demographics.

4.1 | Sport, skill and demographic diversity

The review found a general lack of heterogeneity in the participant samples used in studies. Reporting of participant gender was generally absent in many studies (57%; although it is highly likely that in these cases samples were male), and those studies that did report gender had limited female participants in their samples. An underrepresentation of female sport officials

in empirical studies have been more broadly confirmed elsewhere,[48] and might be a consequence of few females to recruit from, as especially at elite ranks, males make up the majority of participant pools. Nonetheless, future training and development research should find ways to incorporate more female representation in studies, and explore gender differences in responses to training, training and participation milestones, and career histories, as well as barriers to successful development.[7]

The majority of studies focused on football officials from European countries, or sampled football officials in studies where multiple sports were involved.[43,68] Weston et al.'s[63,64,66] and Put et al.'s[57,58,60] collective works provide foundations for developing central officials' physical preparation programs and perceptual-cognitive training tools for assistant officials in *football*, respectively. Deliberate practice and training histories of high-performance football official skill groups are also accounted for by MacMahon et al.[25] and Catteeuw et al.[35] Research designs and topics explored in football officials need to be replicated in different contexts and in sports where role-specific demands for officials may differ.[1,7] For instance, interceptive sports (e.g., baseball) or dual sports (e.g., tennis) will each require a deeper understanding of their sport-specific training and development. Not only do different sports have different officiating demands, they can involve different dynamics between officials, and also have different implicit and explicit conventions about the enforcement of rules.

Another imbalance found in this review was that the development of non-expert sport officials was vastly unstudied. Importantly, these skill groups make up a greater volume of sport official populations, yet there is a paucity of evidence-based knowledge about developmental histories and practice volumes, and the efficacy of training programs and interventions among this population. Continued challenges of high drop-out rates and documented stressful

experiences in early participation heightens a need to address their training and development supports more explicitly. Possible ancillary benefits of training novice sport officials could include improved performance, skill acquisition, self-efficacy, and stress and coping, although these require further analysis.[7]

4.2 | Modelling macro-development and developmental histories

There was an emphasis in reviewed studies on testing short-term, micro-training interventions, with relatively few studies on macro-developmental (practice and training) histories, trajectories and milestones. More opportunities to participate in deliberate practice is perceived as valuable training to reach and maintain expertise levels, where more comprehensive physical preparation programs and decision-making training are found to exist.[2,35] In contrast, this review showed an observed need for better understanding of milestones and developmental training and trajectory data. Development frameworks for sport officials have begun to emerge recognizing this need,[1,7,41] however, how they accommodate sport-specific requirements and characteristics of officials' advancement and turnover patterns needs further detailing. Additional research encompassing more diverse skill groups and sports is needed to inform such frameworks. More realistic impressions of patterns in sport officials' development (their development histories and milestones) could aid modelling of participation and non-elite pathways. In particular, more clarity is needed about types of development activities and experiences most beneficial to entry-level structures in order to support the ongoing challenge of retention and talent development. As research and support programs develop, it might also be necessary to explore how development is influenced by recruitment and talent identification within sport officiating.

Eight studies were found in this review that can inform stage-based development plans by revealing some constraints on officiating development that need further insight. Past athletic history, the age of specialization as both an athlete and sport official, and officiating advancement opportunities might affect aspects of one's practice history and developmental milestones. Acquired 'experiences' as an official (matches officiated), as a player, and transfer of skills from outside sport, were non-training activities frequently identified as essential contributors to development. Notably, there are mixed reports from sport officials about the contributing effects of being a former player in rugby union[40] compared to football refereeing.[25] Future research might benefit from investigating if or how playing experience contributes to early phases of learning and entry into sport officiating (e.g., motivation, knowledge of rules, fitness, predicting and reading match play, and communicating with players). Implicit forms of learning need further differentiation from formalized deliberate practice within developmental processes and at each point of development. 'Unmediated' practice (e.g., peer-to-peer learnings, watching other officials, watching sport) is said to be important to learning,[47] but is generally untested in regard to how it might mediate or moderate the influence of deliberate practice.

Going forward it will useful to either test macro-developmental models or collect data that can inform the implementation of such models. Some interpretations of development observe various interconnected pathway types (to participate in sport, seek an active lifestyle, achieve expertise) and hierarchical stages sport officials' pass through based on promotion or competition level.[1] There are other suggestions of non-linear processes[40] and holistic influences on career progress.[41] Mechanisms for sport official learning and development should not be arbitrarily separated from the context they occur in and should consider sport officials' backgrounds, motivations, or cultural dispositions.[46] Questions remain concerning how female

sport officials navigate their progression opportunities compared to their male counterparts and the degree of transparent female developmental pathways in different sport contexts.[73] Addressing the complexity of development for sport officials can be informed in future research through accounting for interactions among the individual, sport and environmental factors explained by a constraints-based approach.[7] Based on reviewed studies, there is still great differentiation among developmental models and need for more empirical testing. Entry age into sport officiating,[68] transfer of skills,[40] and other change-events[53] encompass broader developmental influences that need to be studied in larger cross-sections of sport officials. Given the potential importance of prior participation as an athlete on officiating development, it may also be useful to consider whether or not athlete and officiating developmental plans should be mutually exclusive or conjoined. As officiating development programs continue to emerge and evolve, in-depth exploratory case studies of these programs might offer valuable insight into sport and/or organization-specific developmental processes and outcomes.

4.3 | Representativeness and transfer in decision-making training methods

Off-field, video-based training methods were the main approach used to improve perceptual-cognitive skills in sport officials. A common hypothesis underpinning training studies was that off-field practices contribute to on-field, decision-making accuracy and consistency. However, only one study employed a retention test[55] and one evaluated on-field transfer.[57] Studies primarily used isolated video decision situations (from 3rd person perspective) as the mode through which to train perceptual-cognitive skills. Some training studies manipulated perceptual information presented through such video stimulus (e.g., blurred perceptual information[56]); contextualized to matches,[5] providing opportunity for other types of video manipulation in training design (e.g., video speed[60]); decision difficulty,[34] and visual search strategies.[74]

Going forward it may be useful to explore decision-making training paradigms that are more representative of actual officiating tasks. Indeed, conventional approaches for perceptual-cognitive training have been critiqued as overly focused on improving proxy factors, such as vision, attention, memory, and decision-making in an isolated manner.[75] Such decontextualized training approaches have been criticized for their limited representativeness of actual on-field performance demands.[46] Match broadcast perspectives of decisions were commonly used as video stimuli for officials making perceptual judgements in training studies. This can possibly neglect actual perceptual cues used in competition. Projection screens and computer tools for central official training may be necessary (which have economic benefits for training), while assistant officials' first-person perspective, decision-making video training can be used in perceptual judgement interventions.[57-59]

This review finds that physical demands have begun to be incorporated into perceptual-cognitive training,[5,62] however, few studies embed other performance constraints within decision-making training (psychological/emotional factors, match interactions with players). Similarly, this shifts traditional decision-making training from relying on an accurate 'standard' to more individualized approaches for improving adequacy and contextual judgements in decision-making. There is tremendous potential to incorporate 3D virtual environments[76] and computerized simulators where financial viability allows, however 360°VR has emerged as a more ecologically valid and potentially more superior training tool for officials.[77] Incorporating such technology can train stronger behavioural correspondence and allow participants to reflect on their own performance or another's first-person recordings. Sport officials report greater enjoyment for such training and increased immersion in perceptual-cognitive demands, and are

shown to enhance their reflection-on-action.[78] Future training studies for central officials could test use of mobile recordings of match performance and increase use of first-person views in training to increase representativeness through reinforced perception-action coupling. Testing new approaches to training sport officials' cognitive performance other than context-specific video may be an interesting challenge for future training studies. Naturally, researchers and administrators must weigh the financial costs associated with creating more representative training tools.[79]

Importantly, benefits of isolated perceptual-cognitive training structures in expert and near-expert skill groups were found in this review. Perceptual-cognitive skill development and training in early developing sport official skill groups could act as methods to help accelerate needed perceptual-judgment experience.[68] Apart from rule knowledge and experimentation with rule application, questions remain about how sport officials can improve composite skills in their decision-making, and what progressive focuses might be relevant across officials' development phases and participation levels. A more comprehensive view of sport official development and skill acquisition might benefit from evaluating the appropriateness of different traditional and ecological pedagogies.

4.4 | Strengthening psychological skills education and performance skills training

A small number of studies (n = 4) were aimed at improving sport officials' psychological characteristics and skills to better cope with pressures of officiating participation and support performance. Training studies aimed to improve officials' self-efficacy beliefs through feedback exercises within-performance[69] and longer, more isolated resilience (or 'mental toughness') education training programs.[70,71] Training activities addressed mental characteristics (e.g.,

concentration,[70,72] self-efficacy,[69-72] mental skills (e.g., imagery[70,72]), coping during performance (e.g., self-talk, distraction control[69,70,72]), pre-competition routine[70,72], and other psychosomatic training (e.g., progressive muscle relaxation, biofeedback[70]). Certain study variable measurements were unclear, including an indirect assessment of training efficacy, whose most common measurement criteria was selection for advancement[72] and other times officials' own self-evaluation of their mental skill performance.[70] Some other studies provided more explicit theoretical underpinnings for training,[69,71] while others provided greater rigor for mental skill intervention design.[72] Considering the mixed findings for training efficacy, further clarity about beneficial types of training and longer-term learning retention is required.

Other identified psychological characteristics and skills important to sport official development and performance are not always identified in training. Self-efficacy is frequently cited as important to sport official performance, motivation and commitment to the role,[80] and acts as a buffer to external pressures such as abuse. Developing support structures to improve sport officials' efficacy should consider ways task-specific efficacy (e.g., making confident and critical decisions, interacting with players, handling pressure[81]) are addressed in training design and mastery experiences afforded to sport officials. Improving perceived organizational support, commitment, and resilience in sport officials would permit more comprehensive self-reported perceptions and efficacy in their training programs and educational support. One example is self-regulated learning processes[82] that might contribute to how readily early developing officials learn technical officiating skills and advanced officials adapt to their training demands. Self-regulated learning plays a crucial role in expert development in athletes by helping optimize their practice.[83,84] Within reviewed studies, training diaries and individual or group performance reflection workshop formats were implemented[70-72] and reflective practices were frequently

identified as vital outcomes and aspects of training.[47,71] These tools were also identified as useful in the training histories of expert sport officials.[25]

Development programs aimed to enhance officials' capacities to manage external stresses (e.g., deal with abuse) and emotional labor of their role were generally absent. Problem- and emotional-focused coping strategies,[14] emotional self-regulation abilities[85] (including benefits of rational emotive behavior therapy on officials' performance[86]), distraction control and other cognitive reframing,[87] pre-match preparation,[88] and post-match debriefing[89] could constitute program testing areas worth exploration. There is evidence that sport officials can experience mental health distress and disorder at elite ranks,[90] ushering forward a need to evaluate mental health factors and education literacy programming for larger sport official populations.[91,92] For example, youth participants represent vulnerable populations developing as officials where self-detection, prevention, and management of mental health associated to their role need strengthening. Additionally, knowledge about the influence of mental health on development patterns and drop-out rates in officials is generally non-existent.[92] As a possible remedy, time-based tracking of stress and burnout in sport officials in relation to their developmental patterns, match-performance, commitment and motivation, and responses to training would be worthwhile. How sport officials' psycho-emotional wellbeing and mental health are associated with early specialization, skill acquisition, and talent development comprise some of the next steps in psychological skills development research.

Over half of the reviewed studies (n = 15) focused on explicit micro-training programs to improve sport official performance. However, a number of performance-related skills were missing from reviewed studies. Communication skills are consistently linked to effective officiating performance, although this review found no explicit training intervention aimed to

improve communication competencies, interactions with players and other game management education. Individual differences in communication capacities weigh on sport official evaluation, selection, and development,[93] and sometimes improving these skills are said to happen through more implicit processes.[38,40] Effective body language and decision communication techniques such as [rule] explanation giving,[38,94] and higher-order interactive skills such as active listening,[8,95] social monitoring skills[17,96] and conflict management style[33] or behavioural management[97] are identified areas for development. Also, evaluating training efficacy for improving sport official teamwork processes through enhancing group cohesion[98], shared team mental models,[19] and coordination preoccupations between central and assistant officials[20] could be sought. Different training modes, methods of learning, and training periodization to design appropriate training protocols or systems, such as in-situ forms of learning within-performance, also might help to more readily bridge off-field knowledge to in-match performance.[69]

4.5 | Physical development and sport-specific fitness programming

A main emphasis on physical training of more elite football officials was found, reaffirming a lack of demographic diversity in sport official development and training research. Studies focused on training standards in expert skill groups and mitigating aging effects on football-specific physical match performance.[63] With some differences in training methods, length, and frequency identified in the review, studies mainly focused on football officials' cardiovascular fitness and strength for varying workloads and movement demands experienced in-match. Models of high-performance approaches can aid in structuring development plans in physical training and fitness programmes for non-expert groups and other sports. However, less is known about how officials are affected by the physical constraints and functions required of their sport and level. For example, cited differences in distance covered by officials in football have been

544 estimated to be up to 12 km[99] but only 6 km for basketball officials.[100] Also, there can be fewer
545 requirements for physical fitness in officials from other sports.[1]

546 With some detail of physical training programmes available, broader physical
547 development and more sport-specific evaluation measures are missing. Knowledge about current
548 approaches used by early developing sport officials to stay fit, when and how certain
549 characteristics of physical training should be introduced for optimal development, and which
550 anthropometric types and individual factors are favoured should be further investigated. Physical
551 fitness development in sport officials can help align and contribute to evaluative standards, both
552 progressively and representatively in sport official pathways. How physical fatigue influences
553 sport officials' decision-making processes is not fully understood,[101] but understanding how
554 physical fitness training is involved in the acquisition and learning of perceptual-cognitive skills
555 could be a question for future research.

556 **4.6 | Limitations of the review**

557 This systematic review provides the first comprehensive synthesis of sport official training and
558 development literature, although a few limitations should be discussed. We focused on sport
559 official study participants, thus one possible limitation is the exclusion of other 'grey literature'
560 possibly informative of non-official samples or perspectives (officiating developers'
561 commentary, description and documentation of education programming approaches). Future
562 research could distill concepts from such studies to generate dimensions of officiating education
563 programme planning at different levels. Sport organizations might also have data on the efficacy
564 of their training programs, accreditation testing, workshops and camps that could add to our
565 understanding of expertise development. Additionally, the inclusion of English-language-only
566 peer reviewed studies means that there might be evidenced-based research on the development of

567 sport officials not captured by this review. Because the focus of this review was on development,
568 research on tangential topics, such as injury risk and prevalence, were beyond the scope of this
569 review. Naturally, these topics can have a moderating and/or mediating influence on training,
570 performance, and developmental trajectories.

571 **4.7 | Perspectives**

572 Given training and developmental supports are paramount to sport officials' retention, talent
573 identification, and expertise development, empirical knowledge to inform efficacious education
574 and sport-specific development programming for sport officials is in high demand. In contrast to
575 past scoping reviews of sport official research,[24,48] this systematic review built on our current
576 knowledge by providing details about specific forms of isolated skills training and macro-
577 development in sport officials. The research might be useful for sport official governing bodies,
578 administrators, and coaches in designing and planning sport- and skill-specific deliberate practice
579 protocols, training support, and development structures. However, before specific protocols and
580 practical recommendations can be made, additional research is needed on different sports, and
581 officials from non-expert skill groups.

582 **5 | CONCLUSIONS**

583 The results of this systematic review draw attention to many gaps in the current body of research
584 on the training and development of sport officials. As decision-making skills are recognized as
585 central to sport officials' performance, it is unsurprising that perceptual-cognitive skills were a
586 dominant focus of reviewed studies. Increased empirical evidence in sport- and role-specific
587 aspects for developing psychological attributes, decision-making skills, and physiological
588 capabilities in officials require further defining. Knowledge concerning non-expert, and macro-
589 developmental patterns and histories of sport officials could provide important knowledge to

inform and strengthen future designs of talent advancement pathways for different officiating skill groups. The associations between drop-out, self-efficacy, sport commitment and deliberate practice programs for grassroots and early developing officials are still unknown.[7,80,89] In expanding on the findings in this review, we conclude that a deeper investigation into approaches to sport official learning and development processes (e.g., retention, talent identification/development) needs to be undertaken in more diverse populations, sports and contexts. From a research standpoint, the modest volume of research on the training and development of sport officials suggests that there are numerous avenues for future research in this area.

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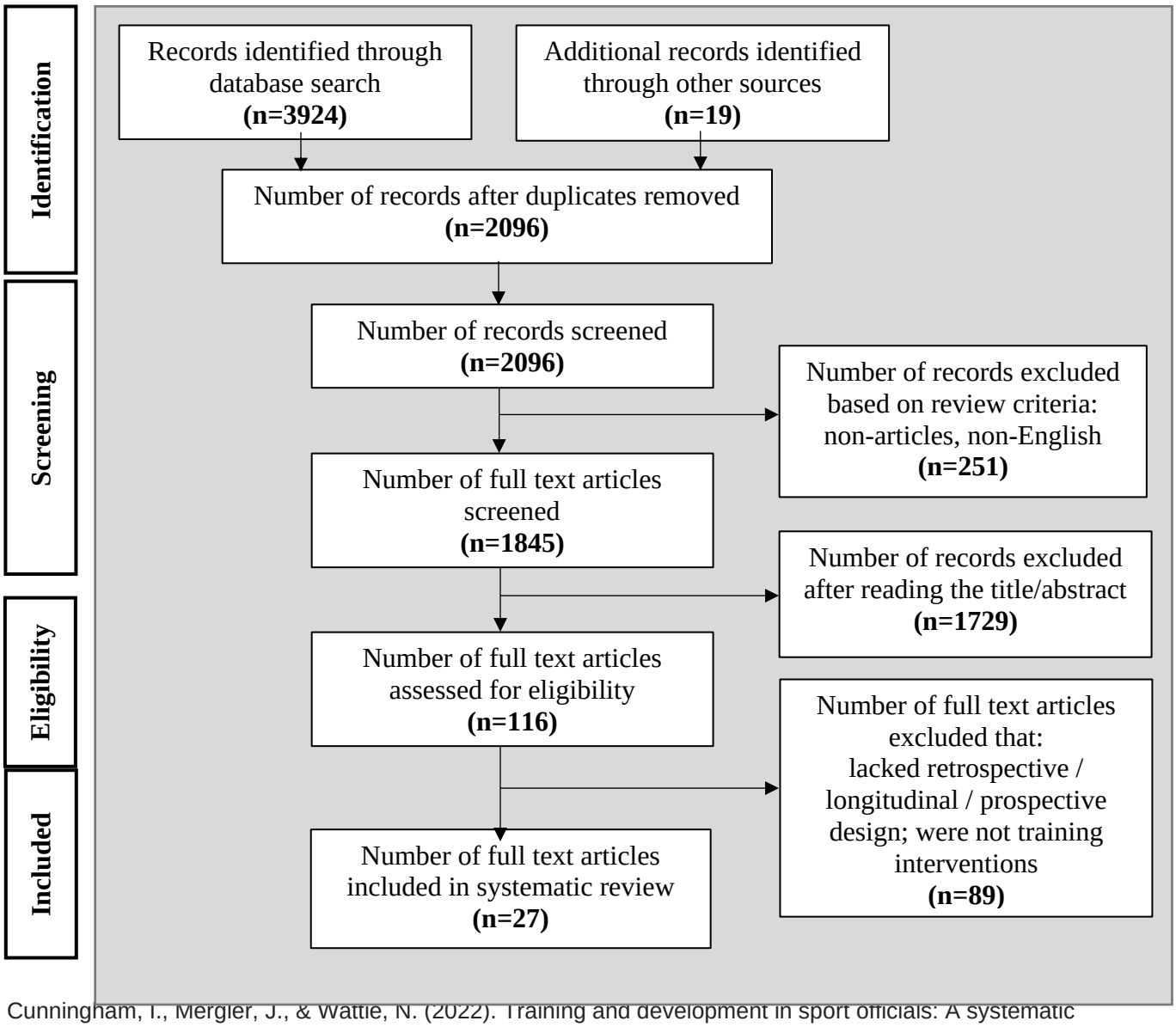

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Figure 1: PRISMA flow chart showing number of citation records collected and number of eligible records after the screening process. *PRISMA*: Preferred Reporting ITEMS for SYSTEMATIC Reviews and Meta-Analyses[49].

Table 1 Characteristics of sport official training and development studies included in the review

Reference	Sample Characteristics					Design	MMAT Quality Score	Results
	N	Age	Role	Sport	Skill level			
Perceptual-cognitive skills								
Mascarenhas et al. 2005 [37]	56	Adult	R	Rugby Union	Expert; Developing	Training intervention	100%	Video-based, decision training (involving analysis of decision situation recordings with expert 'model' interpretation) helped improve group consistency and coherence in decision correctness. Lower ranking referees showed the most significant improvements.
Catteeuw et al. 2010 [59]	40	Adult	AR	Football	Expert	Training intervention	100%	Video simulation ($\eta_p^2 = 0.20$) and computer animation ($\eta_p^2 = 0.29$) decision training intervention using immediate feedback improved referees' decision accuracy and decreased flag errors on a video-based, signal detection task. Video simulation training provided higher fidelity for referees than computer animations.
Schweizer et al. 2011 (Experiment 2) [61]	53 (4)	Adult	R	Football	Expert; Developing	Training intervention	60%	Web-based, decision training tools that provide learners with immediate feedback ($d = 0.93$) helped improve referees' signal detection of fouls.
Put et al. 2013 [57]	18	Adult	AR	Football	Developing	Training intervention	100%	Improved response accuracy and a decrease in flag errors in both an on-field ($r = 0.69$ & 0.69) and off-field ($\eta_p^2 = 0.41$ & 0.40) offside decision-making test following training. This included recall and recognition accuracy of the position of the receiving attacker at the moment of the pass.
Layne and Hastie, 2014 [54]	40 (18)	U18	R	'Swirl Ball' (student-created game)	Beginner	Longitudinal	80%	Grade 4 students improved their decision-making accuracy ($\eta^2 = 0.84$) and active involvement ($\eta^2=0.89$) in the referee role following a 3-phased, 13-lesson physical education program.
Put et al. 2016a [58]	20	Adult	AR	Football	Expert	Training intervention	100%	Web-based (video and computer animation) offside training sessions increased referees' response accuracy to signal an offside decision in a frame recognition test ($r = 0.56$ to 0.84).
Put et al. 2016b [60]	96	Adult	AR	Football	Expert	Training intervention	60%	Video-based decision-making training that sequentially decreases video speed exposure improved decision-making performance ($r = 0.50$), while increased or random speeds did not.

Larkin et al. 2018 [55]	52	Adult	U	Australian Rules Football	Expert; Developing	Training intervention	100%	Less experienced umpires showed significant improvements compared to more experienced umpires following a video-based, decision exposure training without explicit instruction ($\eta^2 = 0.20$). Referees improved significantly after 3-week retention test compared to 1-week.
van Biemen et al. 2018 [56]	22	Adult	R	Football	Expert	Training intervention	60%	Referees who received blurred video footage training (i.e., exposure to video decisions with superficial visual information removed) showed greater foul/no foul response accuracy than referees who did not ($d = 0.86$). Effects of training were not influenced by referees' decision response time or bias.
Kittel et al. 2019 [62]	20 (2)	Adult	U	Australian Rules Football	Developing	Training intervention	80%	No clear benefit of combining physical condition training (HIIT) with video-based, decision-making training on decision-making skills.
Samuel et al. 2019 [5]	22	Adult	R	Football	Expert	Training intervention	80%	Contextualized simulator designs that simultaneously measure mental and physical strain are favoured over non-representative formats. Referees improved in attributing yellow and red cards to broadcasted football matches. Referees were better at the sequential, contextualized decision-making task (Hedges' g = 0.65) compared to when video situations were mixed.
Physical fitness								
Krustrup and Bangsbro 2001 [65]	8	Adult	R	Football	Expert; Developing	Training intervention	80%	No significant improvements shown in aerobic output of referees following progressive short and long interval training sessions lasting 3-4 days/week for 12 weeks. Significant improvements found in select match activities, including high-intensity running (+23%) and the average distance from infringements, particularly during the 2nd half of play.
Weston et al. 2004 [66]	18	Adult	R	Football	Expert; Developing	Training intervention	100%	Four intermittent high-intensity training sessions (i.e., pitch- and track-training) over 16-weeks improved referees' performance by 46.5% in a Yo-Yo intermittent recovery test.
Weston et al. 2010 [63]	22	Adult	R	Football	Expert	Longitudinal, Retrospective	100%	Older, professional referees (43+) experienced significant physical performance declines (negative correlations between age and physical performance; r = -0.26 to -0.53), but such declines did not interfere with referees' ability to keep up with match play. Findings introduce questions about forced retirement age for officials.
Weston et al. 2011 [64]	1	Adult	R	Football	Expert	Longitudinal, Retrospective	100%	Referees' training shifted from high-intensity and endurance aerobic exercise to strength training and representative, on-field speed development over an 8-year period. Speed, power, and strength provided a protective effect on referees' age-related decrements.

Practice histories and macro-development pathways								
Ollis et al 2006 [40]	25*	Adult	R, AR	Rugby Union	Expert; Developing	Retrospective	100%	Non-linear patterns found in referee development processes and pathway. Prior playing experience (transfer of skills) and match-officiating experience (deliberate experience) identified as critical for expertise development.
MacMahon et al. 2007 (Study 2) [25]	26	Adult	R	Football	Expert	Retrospective, Cross-sectional	100%	Elite referees began referring younger than sub-elites (d = 1.02) and, as they developed, they engage in greater volumes and types of training. Competitive match refereeing was rated a significant activity for skill acquisition and refinement.
Blake et al. 2009 [67]	89	Adult	R	Football	Expert	Retrospective, Cross-sectional	100%	Referees participated in 3-4 games and 2-3 aerobic training sessions per week, on average.
Catteeuw et al. 2009 [35]	54	Adult	R, AR	Football	Expert	Retrospective, Cross-sectional	100%	Years of officiating experience (β= 0.46), and accumulated practice hours (β= -0.55) differentiated national vs international referees. Matches officiated and physical preparation were rated the most relevant forms of training.
Pizzera and Raab, 2012 [68]	370	Adult	R, AR, J	Mixed	Expert; Developing	Retrospective, Cross-sectional	100%	Years of officiating experience (football: β= -0.49; Handball: β= 0.18) and prior motor experience (ice hockey: β= 0.23) positively influenced officials' perceptual-judgement expertise (except for football). There was an inverted-U relationship between a) years of officiating and visual experience, and b) officiating performance.
Giske et al. 2016 [47]	83 (10)	Adult	R, AR	Football	Expert; Developing	Retrospective, Cross-sectional	80%	Compared to sub-elite referees, elite referees showed greater use of mental skills training for visualization, concentration strategies, and self-talk. No differences were found in physical training volume and type, or unmediated learning (i.e., watching sport, informal interactions with referees, coaches).
Samuel et al. 2017 [53]	154	Adult	R AR	Football	Beginner; Developing; Expert	Retrospective, Cross-sectional	100%	Professional level and role predicted rates of occurrence of change-events in referees' careers (M = 10.4, SD = 4.5). Most reported change-events were transition to a higher league (97%), excelling in a big match (86%), and a poor performance or decision error in an important match (74%). Impacts of change-events on referee pathways was influenced by openness to consult with others and use of coping strategies.
Mack et al. 2018 [43]	18	Adult	R, U	Mixed	Expert; Developing	Retrospective	100%	Prior playing experience and match-officiating identified as critical activities for expertise development.

Psychological characteristics and skills								
Mahoney et al. 2008 [69]	40	Adult	U	Netball	Expert; Developing	Training intervention	60%	In-situ feedback did not result in clear improvements in officiating self-efficacy.
Mathers and Brodie 2011 [72]	1	Adult	R	Football	Expert	Training intervention	100%	Multistage mental skills intervention positively influenced number of top tier refereeing appointments.
Blumenstein and Orbach 2014 [70]	10 (1)	Adult	R	Football	Expert, Developing	Training intervention	60%	A 3-stage, psychological preparation program was shown to improve officials' self-evaluated 'mental toughness', use of pre-performance strategies and in-match distraction control.
Slack et al. 2015 [71]	4**	Adult	R	Football	Expert	Training intervention	100%	Referees improved on mental resilience areas and improved self-reflection, match-day confidence, and use of cognitive refocusing strategies following an eight-week 'mental toughness' education program.

For study's total sample total (i.e., *N)*, brackets () indicate female participants; For sport officiating role: R = *Referee*; U = *Umpire*; J = *Judge*; AR = *Assistant Referee* (including 'linesman'); NR = *Not reported*; MMAT = Mixed Methods Appraisal Tool;*d* = Cohen's d effect size; β = standardize regression coefficient; η_p^2 = partial eta squared effect size

*An indeterminant (> 10) number of this sample were assessors/coaches.
**1 participant occupied a dual role ('referee/coach')