The International criteria for reporting study Quality for Sudden Cardiac Arrest/Death tool: IQ-SCA/D.

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What Is New?

- This expert consensus process presents the development of: The **I**nternational criteria for reporting study **Q**uality for **S**udden **C**ardiac **A**rrest/**D**eath tool: **IQ-SCA/D**.
- The IQ-SCA/D is a new tool designed for assessing study quality in incidence studies of SCA/D in athletes, providing an expert-informed framework to support and guide appropriate design and reporting practices in future trials.

What Are the Clinical Implications?

- This tool may assist clinicians, researchers, reviewers, journal editors, and readers in contextualising the methodological quality of past and future studies with varying incidence estimates, ultimately leading to an improved understanding of SCA/D frequency in athletes.

Abstract

Background

Studies reporting on the incidence of sudden cardiac arrest and/or death (SCA/D) in athletes commonly lack methodological and reporting rigour, which has implications for screening and preventative policy in sport. To date, there are no tools designed for assessing study quality in studies investigating the incidence of SCA/D in athletes.

Methods and Results

The **I**nternational criteria for reporting study **Q**uality for **S**udden **C**ardiac **A**rrest/**D**eath tool (IQ-SCA/D) was developed following a Delphi process. Sixteen international experts in sports cardiology were identified and invited. Experts voted on each domain with subsequent moderated discussion for successive rounds until consensus was reached for a final tool. Inter-observer agreement between a novice, intermediate and expert observer was then assessed from the scoring of 22 relevant studies using weighted and unweighted Kappa analyses. The final IQ-SCA/D tool comprises 8 domains with a summated score out of a possible 22. Studies are categorised as low, intermediate and high quality with summated IQ-SCA/D scores of ≤11, 12-16 and ≥17 respectively. Inter-rater agreement was 'substantial' between all three observers for summated IQ-SCA/D scores and study categorisation.

Conclusions

The IQ-SCA/D is an expert consensus tool for assessing the study quality of research reporting the incidence of SCA/D in athletes. This tool may be used to assist researchers, reviewers, journal editors, and readers in contextualising the methodological quality of different studies with varying athlete SCA/D incidence estimates. Importantly, the IQ-SCA/D also provides an expert-informed framework to support and guide appropriate design and reporting practices in future SCA/D incidence trials.

Key words: sudden cardiac death, athletes heart, sports cardiology, SCA/D.

"Non-standard Abbreviations and Acronyms"

SCA/D sudden cardiac arrest/death

ROB risk of bias

IQ-SCA/D International criteria for reporting study Quality for Sudden Cardiac Arrest/Death tool

JBI Joanna-Briggs Institute

Introduction

Sudden cardiac arrest/death (SCA/D) in athletes is a devastating event with wide-spread implications [1]. Although SCA/D is often characterized as infrequent [2–4], a lack of methodological and reporting standardisation has resulted in conflicting and far-ranging estimates of SCA/D events in athletes without the appropriate population and methodological homogeneity across different studies to establish the clear moderators driving these differences in estimates. Studies extensively vary in design (prospective vs retrospective), numerator and denominator calculation, inclusivity of SCA cases, appropriateness of the reporting window (sports-related vs anytime SCA/D), sub-group data reporting practices (sport and ethnicity-specific incidence) and important confounders such as pooling data from different age groups and sexes.

Establishing accurate, context-specific incidence estimates is imperative to understanding the appropriateness of pre-planned screening initiatives and preventative policy in sport, as well as the consideration of defibrillator placement and emergency action planning for on-field SCA/D events. Therefore, estimate inaccuracy carries widespread implications. To date, there are no tools specifically designed for assessing study quality in studies investigating the incidence of SCA/D in athletes. Indeed, previous systematic reviews in this area have resorted to using customised versions or tools that may not accurately reflect risk of bias (ROB) [5,6]. Well-designed study assessment tools can provide insight into the potential accuracy or context-specific interpretation of an incidence estimate. Furthermore, the domains of a relevant assessment tool can provide a comprehensive framework for appropriate design and data reporting practices for future trials.

The objective of this international expert consensus was to develop and validate the inter-observer reliability of a novel tool designed for assessing methodological and reporting quality of incidence studies of SCA/D in athletes. A Delphi process methodology was pre-planned to support the development of The **I**nternational criteria for reporting study **Q**uality for **S**udden **C**ardiac **A**rrest/**D**eath tool (IQ-SCA/D).

Methods

Data Availability Statement

The authors declare that all supporting data are available within the article [and its online supplementary files]. IRB approval and informed consent were not required for this study.

The Delphi process followed in the creation of the IQ-SCA/D can be visualised in Figure 1[7].

Aims of the tool

The primary aims of this tool are two-fold: firstly, to provide a reliable study quality assessment index of incidence estimate trials of SCA/D in athletes and secondly, to provide an expert-informed framework to support and guide appropriate design and reporting practices in future SCA/D incidence trials. The rating scale of this tool is specifically designed to provide the highest quality scoring to those studies with the most accurate incidence estimates of SCA/D in athletes.

Stage one

Stage one involved the development of a preliminary draft tool by the primary authors (JE, J'OD and KH). This preliminary draft tool was produced as an adaptation to the most frequently used prevalence tools, including the Joanna-Briggs Institute (JBI) critical appraisal checklist [6,8–10], with consideration of the frequently cited limitations identified when applying these tools in SCA/D incidence studies. This draft tool can be seen in the supplementary file (Section S1). Following this, a list of global experts and key opinion leaders was subjectively compiled, and each individually contacted to assess interest. Potential experts were considered if they met the following criteria:

- Active clinician and/or academic
- Identifiable evidence of advanced knowledge/expertise in the area of SCA/D in athletes (e.g., through research publications, clinical experience)
- Time availability to engage in the Delphi process

All participants accepted the invitation, with a resulting expert panel of 16 international expert academics/clinicians in sports cardiology.

Stage two

Stage two presented all experts with a copy of the preliminary draft tool in which they were asked to independently review and provide comprehensive written feedback with critical analysis and directional input regarding each domain. The primary authors then adjusted the tool through implementation of the written feedback ready for initialisation of the Delphi process.

Stage three: Delphi Process

Stage three introduced the Delphi process, consisting of two rounds of anonymous panel voting on the newly adjusted expert-informed tool. All experts received a Microsoft Forms document (Section S2) in which they provided anonymous votes on each domain of the tool.

Each domain had the following three voting options:

- A. "Yes, I support the category and scoring as is"
- B. "I would like to discuss the category or the scoring further"
- C. "No, I do not support the inclusion of the category"

If 80% or more of the expert respondents voted "yes," then the domain was accepted without further discussion. If 80% or more of the respondents voted "no," then the domain was rejected without further discussion. If neither of the above conditions were met, the domain was opened to further moderated discussion in the form of a video call meeting until the 80% yes threshold could be reached. If disagreement had persisted, a primary dissenter or group of dissenters would have been asked to write a short paragraph explaining their position to be published with the paper.

In the first Delphi round, two domains (Section S3) did not meet either acceptance or rejection criteria, and therefore these domains were discussed in a video call meeting where all experts (both dissenters and non-dissenters) provided input. Common discussion points surrounded optimisation of the written descriptions and point weightings for each item listed within a domain. Following the moderated discussion and subsequent tool adjustments, the second Dephi round was methodologically identical to round one, with a repeat of the voting protocol, but only on those domains not accepted in voting round one. The second Delphi round observed that the acceptance criteria was met for both domains. As such, the resulting tool therefore reflects the consensus recommendations made by the panel of experts. Study quality (low, intermediate and high quality) categorisation thresholds were also developed through expert consensus.

Stage Four: Inter-observer reliability assessment

Three observers of varying expertise (Novice, intermediate and expert observer) in the field of SCA/D in athletes were identified as suitable to perform independent study assessments using the IQ-SCA/D tool. The novice, intermediate and expert observers were defined according to their level of engagement with the relevant athlete and SCA/D literature. The novice observer had no research experience in the area, the intermediate had some experience and knowledge in supporting previous work, and the expert has led the development of multiple published studies in the subject area. The observers were separate from the experts who participated in the Delphi process. Twenty-two published SCA/D incidence trials were identified from a local database and distributed to the observers alongside the tool.

Agreement between the observers was statistically assessed using weighted Kappa analyses to take into account the seriousness of the disagreement between observers [11]. Unweighted Cohens Kappa was applied to domain 7 as the only domain to include 2 ordinal categories. Fleiss' Kappa was also used to assess study quality categorisation across the multiple observers in addition to the paired observer analysis. This statistical approach has been applied in the reliability testing and validation process of several previous assessment tools [9,12,13]. Agreement between each observer (1 vs 2, 2 vs 3, and 1 vs 3) was assessed for each individual domain, the total summated study scores, and study quality categorisation. The level of agreement can be described according to Landis and Koch [14], as follows: >0.81 'almost perfect' (a); 0.61–0.80 'substantial' (b); 0.41–0.60 'moderate' (c); 0.21–0.40 'fair' (d); 0.00–0.20 'slight' and 0.00 'poor' (e). All analyses were performed using SPSS (version 28.0.1) and results were considered statistically significant with a $P<0.05$.

Results

The IQ-SCA/D tool is a specialised quality assessment tool for studies reporting incidence of SCA/D in athletes. The final tool contains 8 domains of varying weighting, with a total possible score of 22. A concise summary of the IQ-SCA/D can be found in Table 1 [15–28]. Table 2 [29–50] provides study characteristics and quality categorisation of the 22 scored SCA/D studies.

Domain 1: Study Design

Study design is an important feature related to quality and there are generally accepted levels of evidence ranging from systematic reviews to expert opinion. This category provides scoring based on whether the study design is prospective or retrospective. Examples of search strategies that would fall into each category are provided.

Domain 2: Numerator/Strength of Case Identification

Identifying cases of SCA/D is difficult and often limited by the lack of mandatory reporting systems and ill-defined athlete populations. The methodology employed is important and correlates with the likelihood of capturing all cases. The accuracy of case identification is one of the more important aspects of studies on SCA/D and therefore weighted more heavily with 5-points. This category attempts to rate both the accuracy of case identification and the ability to identify athletes specifically. Examples of methods are provided for each category, but some studies may fit into more than one category. Points should be awarded based on the overall likelihood of the identification of all SCA/D in athletes.

Domain 3: Denominator

The denominator of an incidence proportion is the number of persons at the start of an observation period. Studies of SCA/D should clearly define what population they are studying and how the group is determined. Many studies estimate participation (i.e., “there are about 8,000,000 high school athletes), which can result in either over or under-estimation of risk. The denominator should define the number of individual athletes participating during a defined observation period. Examples of different strategies are provided.

Domain 4: All cases vs. Sports/exercise-related cases

Sports/exercise-related SCA/D versus SCA/D which occurs at any time of the day are different, but this is often not recognized. Sports/exercise-related SCA/D is typically defined as death that occurs during or within an hour of exercise and is a subset of all SCA/D in athletes. Sports/exercise-related SCA/D is an important metric to consider when event planning or creating emergency action plans; however, it should not be conflated with SCA/D that occurs at any time, inclusive of any activity, rest, and sleep.

Domain 5: SCA/D vs. SCD only

Most studies of SCA/D in athletes include only SCD in their analysis; however, the inclusion of SCA with survival is important to understand the scope of the problem. Studies including both SCA and SCD show that as many as 50% of athletes who suffer SCA are successfully resuscitated.

Domain 6: Age Range

Grouping wide age ranges together can lead to inaccurate estimates of the incidence of SCA/D. Population based studies demonstrate a peak in SCA/D in those aged < 1 year followed by a relatively low rate of SCA/D that increases again around age 15 years before rising precipitously at age 25 years due to the increasing contribution of coronary artery disease. In those under age 25 years, the primary causes of SCA/D are inherited structural and electrical cardiac diseases. Many studies of SCA/D group wide swaths of ages (i.e., 12-40 years) with widely varying incidence rates and causes of SCA/D calculated together. For an accurate estimation of the incidence rate, it is important that the age grouping reflects a similar risk of SCA/D in that group.

Domain 7: Sex-specific rates

Studies of SCA/D in athletes and non-athletes alike have consistently shown that males have a higher rate of SCA/D than females. In general, males have 3 – 4 times higher rates of SCA/D. Combining both males and females in the same groups artificially lowers the risk for males and increases the risk for females. As such, there is a need for sex-specific data available for both the numerator and denominator so that an accurate incidence rate can be calculated for both sexes.

Domain 8: Sub-group reporting

There may be important sub-group risks such as sport or race/ethnicity. There needs to be sport-specific or race/ethnicity numbers available for both the numerator and the denominator.

Inter-observer Agreement

Inter-observer agreement for each domain, the total summative scoring, and the study quality categorisation can be seen in Table 3. Domain agreement ranged from 'fair' to 'almost perfect', while agreement for both total summated scores (Observer 1 vs 2: 0.610k ± 0.06., 2 vs 3: 0.660k ± 0.06., 1 vs 3: 0.616k ± 0.08) and the study quality categorisation (Observer 1 vs 2: 0.753k ± 0.11., 2 vs 3: 0.763k ± 0.11., 1 vs 3: 0.641k ± 0.14) was consistently 'substantial' across all observers. This was further supported by the 'substantial' study quality categorisation from the Fleiss kappa analysis (0.655 ± 0.093, 95% CI= 0.473-0.837). The 'substantial' agreement in total scoring and quality categorisation across the observers supported the categorisation of studies as low, intermediate or high quality with summated IQ-SCA/D scores of ≤11, 12-16 and ≥17 respectively.

Observers 1 and 2 achieved 'substantial' agreement for 3/8 domains, 'moderate' for 2/8 domains, and 'fair' for 3/8 domains. Observers 2 and 3 achieved 'almost perfect' agreement for 1/8 domains, 'substantial' for 4/8 domains and 'moderate' for 3/8 domains. Observers 1 and 3 achieved 'almost perfect' agreement for 1/8 domains, 'substantial' for 2/8 domains and 'moderate' for 5/8 domains. In practice, this tool should be applied by two observers independently and disagreements should be resolved with the help of a third reviewer.

Discussion

This international expert consensus presents the development and inter-observer reliability of the IQ-SCA/D, a novel tool designed for assessing study quality in studies investigating the incidence of SCA/D in athletes. The IQ-SCA/D provides an expert-informed framework to support and guide appropriate design and reporting practices in future SCA/D incidence trials. This tool may also assist researchers, reviewers, journal editors, and readers in contextualising the methodological quality of different studies with varying athlete SCA/D incidence estimates. The overarching aim of this tool is to improve our understanding of SCA/D in athletes, which carries global implications for preventative initiatives and responder policy in sport.

Owing to inter-study heterogeneity in methodology and reporting practices, incidence estimates of SCA/D in athletes remain variable. Studies with greater methodological rigour and reporting transparency are necessary to better understand athlete SCA/D risk. Tools commonly employed to assess incidence studies, such as the JBI critical appraisal checklist [8], do not include important components specific to the context of SCD/A incidence research. For example, the JBI checklist would not provide any assessment of inappropriate population grouping such as age, sex, and race/ethnicity, thereby generating confounded incidence estimates with no quality scoring penalisation. As such, this work addresses a substantial gap in sports cardiology research whereby no current assessment tools are well-equipped for SCA/D incidence studies. Indeed, any researchers who may have attempted to perform systematic review and meta-analysis research in this area will agree that the degree of variability between methods and reporting make any form of data pooling and interpretation of the wider literature a near-impossible task.

The IQ-SCA/D also has implications for the design and development of future incidence estimate trials of SCA/D, where this tool can be applied as a general framework as for guiding design and reporting practices of future research. Future studies may consider the relevant domains for study design, including the numerator and denominator quality, in their development and written contextualisation of incidence estimates. Similarly, the reporting domains, including age range, sex-specific and sub-group reporting, may serve as reference points for appropriate data reporting practices to minimise confounding and improve context of reported incidence estimates. Ultimately, the encouragement of researchers to appropriately consider these domains in the development of future incidence estimate trials of SCA/D in athletes is aimed towards improving the quality of research in this field.

The inter-observer agreement analysis performed in this work varied from 'fair' to 'almost perfect' across the individual domains but was consistently 'substantial' for the total summated scores and study quality categorisation. The complexity and variability of many SCA/D studies certainly adds difficulty in achieving consistency throughout the scoring process; however, our evidence of agreement between observers with different levels of expertise in the area, and without any a-priori familiarisation or training, supports the potential for wider application of this tool.

Limitations

While we attempted to minimise limitations at all stages, the Delphi process carries significant inherent limitations with risks of specious consensus [17]. Separately, due to the wide range of methodologies within the athlete SCA/D literature, the expert panel explicitly recognize that there is not going to be any one set of criteria that will effectively encompass all studies and therefore the aim is to accurately capture most. This tool is specific and purposefully limited to assessing the overall incidence of SCA/D in athletes. This interpretation is important when considering some of the domains within this tool; for example, Domain 4 penalises studies that only looked at sports-related SCA/D, even if that is the a-priori aim of the work. It is also important to note that there is a significant lack of sensitivity data available to inform the domains of the tool and thus this tool relies almost entirely on expert opinion. Finally, future validation work, ideally performed externally by independent researchers, is needed.

Conclusion

Following a Delphi process, this work presents the development and inter-observer reliability of the IQ-SCA/D tool, an international expert consensus tool for assessing the study quality of research reporting incidence of SCA/D in athletes. This tool may be implemented to assist in the methodological quality assessment of relevant studies and provide an expert-informed framework to support and guide appropriate design and reporting practices in future SCA/D incidence trials.

Conflict of Interest Disclosures: None

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Figure Legends

Figure 1: The Delphi process followed in the creation of the IQ-SCA/D. Abbreviations: IQ-SCA/D: International criteria for reporting study Quality for Sudden Cardiac Arrest/Death tool., SCA/D: sudden cardiac arrest/death.

References

1. Mannakkara NN, Sharma S. Sudden cardiac death in athletes. *Trends in Urology & Men's Health*. 2020;11(4):10–14a.
2. Peterson DF, Kucera K, Thomas LC, Maleszewski J, Siebert D, Lopez-Anderson M, Zigman M, Schattenkerk J, Harmon KG, Drezner JA. Aetiology and incidence of sudden cardiac arrest and death in young competitive athletes in the USA: a 4-year prospective study. *British Journal of Sports Medicine*. 2021;55(21):1196–1203.
3. Harmon KG, Drezner JA, Wilson MG, Sharma S. Incidence of sudden cardiac death in athletes: a state-of-the-art review. *Heart*. 2014;100(16):1227–1234.
4. D'Ascenzi F, Valentini F, Pistoresi S, Frascaro F, Piu P, Cavigli L, Valente S, Focardi M, Cameli M, Bonifazi M, Metra M, Mondillo S. Causes of sudden cardiac death in young athletes and non-athletes: systematic review and meta-analysis: Sudden cardiac death in the young. *Trends in Cardiovascular Medicine*. 2022;32(5):299–308.
5. Lear A, Patel N, Mullen C, Simonson M, Leone V, Koshiaris C, Nunan D. Incidence of Sudden Cardiac Arrest and Death in Young Athletes and Military Members: A Systematic Review and Meta-Analysis. *Journal of athletic training*. 2022;57(5):431–443.
6. Couper K, Putt O, Field R, Poole K, Bradlow W, Clarke A, Perkins GD, Royle P, Yeung J, Taylor-Phillips S. Incidence of sudden cardiac death in the young: a systematic review. *BMJ Open*. 2020;10(10):e040815.
7. Dalkey N. An experimental study of group opinion: The Delphi method. *Futures*. 1969;1(5):408–426.
8. Anon. Chapter 5: Systematic reviews of prevalence and incidence. *JBI Manual for Evidence Synthesis*. 2020.
9. Hoy D, Brooks P, Woolf A, Blyth F, March L, Bain C, Baker P, Smith E, Buchbinder R. Assessing risk of bias in prevalence studies: modification of an existing tool and evidence of interrater agreement. *Journal of clinical epidemiology*. 2012;65(9):934–939.
10. Lear A, Patel N, Mullen C, Simonson M, Leone V, Koshiaris C, Nunan D. Incidence of Sudden Cardiac Arrest and Death in Young Athletes and Military Members: A Systematic Review and Meta-Analysis. *Journal of Athletic Training*. 2022;57(5):431.
11. Sim J, Wright CC. The Kappa Statistic in Reliability Studies: Use, Interpretation, and Sample Size Requirements. *Physical Therapy*. 2005;85(3):257–268.
12. Smart NA, Waldron M, Ismail H, Giallauria F, Vigorito C, Cornelissen V, Dieberg G. Validation of a new tool for the assessment of study quality and reporting in exercise training studies: TESTEX. *International Journal of Evidence-Based Healthcare*. 2015;13(1):9–18.
13. Hartling L, Milne A, Hamm MP, Vandermeer B, Ansari M, Tsertsvadze A, Dryden DM. Testing the Newcastle Ottawa Scale showed low reliability between individual reviewers. *Journal of clinical epidemiology*. 2013;66(9):982–993.
14. Landis JR, Koch GG. The Measurement of Observer Agreement for Categorical Data. *Biometrics*. 1977;33(1):159.
15. Suchmacher M, Geller M. Study Type Determination. *Practical Biostatistics*. 2012:3–15.
16. Chugh SS, Reinier K, Teodorescu C, Evanado A, Kehr E, Al Samara M, Mariani R, Gunson K, Jui J. Epidemiology of Sudden Cardiac Death: Clinical and Research Implications. *Progress in cardiovascular diseases*. 2008;51(3):213.
17. Yousuf MI. Using Experts` Opinions Through Delphi Technique. *Practical Assessment, Research, and Evaluation*. 2019;12(1):4.
18. Emery MS, Kovacs RJ. Sudden Cardiac Death in Athletes. *JACC: Heart Failure*. 2018;6(1):30–40.

19. Chandra N, Bastiaenen R, Papadakis M, Sharma S. Sudden Cardiac Death in Young Athletes: Practical Challenges and Diagnostic Dilemmas. *Journal of the American College of Cardiology*. 2013;61(10):1027–1040.
20. Corrado D, Basso C, Schiavon M, Pelliccia A, Thiene G. Pre-Participation Screening of Young Competitive Athletes for Prevention of Sudden Cardiac Death. *Journal of the American College of Cardiology*. 2008;52(24):1981–1989.
21. Maron BJ, Doerer JJ, Haas TS, Tierney DM, Mueller FO. Sudden Deaths in Young Competitive Athletes. *Circulation*. 2009;119(8):1085–1092.
22. Risgaard B, Winkel BG, Jabbari R, Behr ER, Ingemann-Hansen O, Thomsen JL, Ottesen GL, Gislason GH, Bundgaard H, Haunsoø S, Holst AG, Tfelt-Hansen J. Burden of sudden cardiac death in persons aged 1 to 49 years: nationwide study in Denmark. *Circulation. Arrhythmia and electrophysiology*. 2014;7(2):205–211.
23. Asif IM, Harmon KG. Incidence and Etiology of Sudden Cardiac Death: New Updates for Athletic Departments. *Sports Health*. 2017;9(3):268.
24. Harmon KG, Asif IM, Klossner D, Drezner JA. Incidence of Sudden Cardiac Death in National Collegiate Athletic Association Athletes. *Circulation*. 2011;123(15):1594–1600.
25. Drezner JA, Rogers KJ, Zimmer RR, Sennett BJ. Use of automated external defibrillators at NCAA Division I universities. *Medicine and science in sports and exercise*. 2005;37(9):1487–1492.
26. Han J, Lalario A, Merro E, Sinagra G, Sharma S, Papadakis M, Finocchiaro G. Sudden Cardiac Death in Athletes: Facts and Fallacies. *Journal of Cardiovascular Development and Disease*. 2023;10(2).
27. Landry CH, Allan KS, Connelly KA, Cunningham K, Morrison LJ, Dorian P. Sudden Cardiac Arrest during Participation in Competitive Sports. *New England Journal of Medicine*. 2017;377(20):1943–1953.
28. Petek BJ, Churchill TW, Moulson N, Kliethermes SA, Baggish AL, Drezner JA, Patel MR, Ackerman MJ, Kucera KL, Siebert DM, Salerno L, Zigman Suchsland M, Asif IM, Maleszewski JJ, Harmon KG. Sudden Cardiac Death in National Collegiate Athletic Association Athletes: A 20-Year Study. *Circulation*. 2024;149(2):80–90.
29. Bohm P, Scharhag J, Meyer T. Data from a nationwide registry on sports-related sudden cardiac deaths in Germany. *European journal of preventive cardiology*. 2016;23(6):649–656.
30. Chatard JC, Espinosa F, Donnadieu R, Grangeon JP, Sabot JM, Guivarch C, Dacquin R, Raby FX, Papouin G, Viali S, Braunstein C, Gerbay A, Roche F, Isaaz K, Barthélémy JC, et al. Pre-participation cardiovascular evaluation in Pacific Island athletes. *International journal of cardiology*. 2019;278:273–279.
31. Corrado D, Basso C, Rizzoli G, Schiavon M, Thiene G. Does sports activity enhance the risk of sudden death in adolescents and young adults? *Journal of the American College of Cardiology*. 2003;42(11):1959–1963.
32. Corrado D, Basso C, Pavei A, Michieli P, Schiavon M, Thiene G. Trends in sudden cardiovascular death in young competitive athletes after implementation of a preparticipation screening program. *JAMA*. 2006;296(13):1593–1601.
33. Drezner JA, Rogers KJ, Zimmer RR, Sennett BJ. Use of automated external defibrillators at NCAA Division I universities. *Medicine and science in sports and exercise*. 2005;37(9):1487–1492.
34. Drezner JA, Rao AL, Heistand J, Bloomingdale MK, Harmon KG. Effectiveness of emergency response planning for sudden cardiac arrest in United States high schools with automated external defibrillators. *Circulation*. 2009;120(6):518–525.

35. Drezner JA, Harmon KG, Marek JC. Incidence of sudden cardiac arrest in Minnesota high school student athletes: the limitations of catastrophic insurance claims. *Journal of the American College of Cardiology*. 2014;63(14):1455–1456.
36. Gräni C, Chappex N, Fracasso T, Vital C, Kellerhals C, Schmied C, Saguner AM, Trachsel LD, Eser P, Michaud K, Wilhelm M. Sports-related sudden cardiac death in Switzerland classified by static and dynamic components of exercise. *European journal of preventive cardiology*. 2016;23(11):1228–1236.
37. Harmon KG, Asif IM, Maleszewski JJ, Owens DS, Prutkin JM, Salerno JC, Zigman ML, Ellenbogen R, Rao AL, Ackerman MJ, Drezner JA. Incidence, Cause, and Comparative Frequency of Sudden Cardiac Death in National Collegiate Athletic Association Athletes: A Decade in Review. *Circulation*. 2015;132(1):10–19.
38. Harmon KG, Asif IM, Maleszewski JJ, Owens DS, Prutkin JM, Salerno JC, Zigman ML, Ellenbogen R, Rao AL, Ackerman MJ, Drezner JA. Incidence and Etiology of Sudden Cardiac Arrest and Death in High School Athletes in the United States. *Mayo Clinic proceedings*. 2016;91(11):1493–1502.
39. Holst AG, Winkel BG, Theilade J, Kristensen IB, Thomsen JL, Ottesen GL, Svendsen JH, Haunsø S, Prescott E, Tfelt-Hansen J. Incidence and etiology of sports-related sudden cardiac death in Denmark--implications for preparticipation screening. *Heart rhythm*. 2010;7(10):1365–1371.
40. Malhotra A, Dhutia H, Finocchiaro G, Gati S, Beasley I, Clift P, Cowie C, Kenny A, Mayet J, Oxborough D, Patel K, Pieles G, Rakhit D, Ramsdale D, Shapiro L, et al. Outcomes of Cardiac Screening in Adolescent Soccer Players. *New England Journal of Medicine*. 2018;379(6):524–534.
41. Marijon E, Tafflet M, Celermajer DS, Dumas F, Perier MC, Mustafic H, Toussaint JF, Desnos M, Rieu M, Benameur N, Le Heuzey JY, Empana JP, Jouven X. Sports-related sudden death in the general population. *Circulation*. 2011;124(6):672–681.
42. Maron BJ, Doerer JJ, Haas TS, Tierney DM, Mueller FO. Sudden deaths in young competitive athletes: analysis of 1866 deaths in the United States, 1980-2006. *Circulation*. 2009;119(8):1085–1092.
43. Maron BJ, Haas TS, Ahluwalia A, Rutten-Ramos SC. Incidence of cardiovascular sudden deaths in Minnesota high school athletes. *Heart rhythm*. 2013;10(3):374–377.
44. Maron BJ, Haas TS, Duncanson ER, Garberich RF, Baker AM, Mackey-Bojack S. Comparison of the Frequency of Sudden Cardiovascular Deaths in Young Competitive Athletes Versus Nonathletes: Should We Really Screen Only Athletes? *The American Journal of Cardiology*. 2016;117(8):1339–1341.
45. Peterson DF, Kucera K, Thomas LC, Maleszewski J, Siebert D, Lopez-Anderson M, Zigman M, Schattenkerk J, Harmon KG, Drezner JA. Aetiology and incidence of sudden cardiac arrest and death in young competitive athletes in the USA: a 4-year prospective study. *British journal of sports medicine*. 2021;55(21):1196–1203.
46. Risgaard B, Winkel BG, Jabbari R, Glinge C, Ingemann-Hansen O, Thomsen JL, Ottesen GL, Haunsø S, Holst AG, Tfelt-Hansen J. Sports-related sudden cardiac death in a competitive and a noncompetitive athlete population aged 12 to 49 years: data from an unselected nationwide study in Denmark. *Heart rhythm*. 2014;11(10):1673–1681.
47. Roberts WO, Stovitz SD. Incidence of sudden cardiac death in Minnesota high school athletes 1993-2012 screened with a standardized pre-participation evaluation. *Journal of the American College of Cardiology*. 2013;62(14):1298–1301.
48. Steinvil A, Chundadze T, Zeltser D, Rogowski O, Halkin A, Galily Y, Perluk H, Viskin S. Mandatory electrocardiographic screening of athletes to reduce their risk for sudden death proven fact or wishful thinking? *Journal of the American College of Cardiology*. 2011;57(11):1291–1296.

49. Toresdahl BG, Rao AL, Harmon KG, Drezner JA. Incidence of sudden cardiac arrest in high school student athletes on school campus. *Heart rhythm*. 2014;11(7):1190–1194.
50. Camp SPV, Bloor CM, Mueller FO, Cantu RC, Olson HG. Nontraumatic sports death in high school and college athletes. *Medicine and Science in Sports and Exercise*. 1995;27(5):641–647.
51. Drezner JA, Rao AL, Heistand J, Bloomingdale MK, Harmon KG. Effectiveness of emergency response planning for sudden cardiac arrest in United States high schools with automated external defibrillators. *Circulation*. 2009;120(6):518–525.

Table 1. The IQ-SCA/D.

Domain	Context	Scoring
Domain 1: Study design score	Study design is an important feature related to quality and there are generally accepted levels of evidence ranging from systematic reviews to expert opinion [15,16]. This category provides scoring based on whether the study design is prospective or retrospective. Examples of search strategies that would fall into each category are provided.	**3 points -** Prospective (i.e., prospective active monitoring and collection of new SCA/D cases with defined search strategy) **2 points -** Prospective and retrospective (i.e., uses both prospective monitoring for new cases and retrospective review of previous cases) **1 point -** Retrospective (i.e., retrospective search of media reports; retrospective application of a search strategy; retrospective review of autopsy records) **0 points** - Retrospective survey (i.e., survey to report past cases of SCA/D)
Domain 2: Numerator/Strength of Case Identification	Identifying cases of SCA/D is difficult and often limited by the lack of mandatory reporting systems and ill-defined athlete populations [18]. The methodology employed is important and correlates with the likelihood of capturing all cases [19,20]. Research [28] has shown the variable sensitivity of different case identification approaches (e.g. media reports and insurance claims identifying only 62% and 19% of cases, respectively), highlighting the importance of mandatory systems/the use of multiple case identification sources. The accuracy of case identification is one of the more important aspects of studies on SCA/D and therefore weighted more heavily with 5-points. This category attempts to rate both the accuracy of case identification and the ability to identify athletes specifically. Examples of methods are provided for each category, but some studies may fit into more than one category. Points should be awarded based on the overall likelihood of the identification of all SCA/D in athletes.	**5 points -** Mandatory reporting system for all cases of SCA/D in athletes. The mandatory reporting system does not have to be athlete-specific, however, if there is mandatory reporting of a larger population, there should be a reliable way to identify the precise number of competitive athlete cases. **4 points** - Use of multiple search strategies that increase the likelihood of case identification (2 or more): (Post-internet (after 2005) media reports - Other databases or registries - Death certificate records review - Other non-mandatory reporting methods) **3 points -** Media reports post-internet (after 2005) in an athlete population likely to be documented (professional, collegiate athletes) but without the use of other case identification methods **2 points** - Media reports in a population that is unlikely to be well-documented (i.e., middle-school, high school, recreational/non-competitive athletes) **1 point -** Reliant on recall (i.e., survey) Mandatory reporting (death certificate) with unclear designation of athlete status (i.e., population database where it is difficult to accurately identify which cases are in competitive athletes) **0 points -** Methods that are unlikely to identify the majority of SCA/D in athletes (Media reports pre-internet (2005 or before) in isolation - Catastrophic insurance claims - Limited sources (i.e., newspapers) unlikely to identify all cases - Review of autopsy reports where not all SCD cases have autopsies - Does not state how cases were identified)

Domain 3: Denominator	The denominator of an incidence proportion is the number of persons at the start of an observation period. Studies of SCA/D should clearly define what population they are studying and how the group is determined. Many studies estimate participation (i.e., "there are about 8,000,000 high school athletes [21,22]) which can result in either over or under-estimation of risk. The denominator should define the number of individual athletes participating during a defined observation period [23,24]. Examples of different strategies are provided.	**3 points** - Precisely defined (i.e., registered athletes in a database, known number of participants in a league) **2 point** - Defined population but numbers may not be exact (i.e. estimates of the number of athletes in a league) **1 point -** Use of a multiplier with a precisely defined population (multipliers are sometimes used to account for multi-sport athletes in a known athletic population) **0 point -** Estimate (i.e., estimated number of participants per year, general population statistics, based on reported physical activity surveys)
Domain 4: All vs. SR-SCD	Sports/exercise-related SCA/D versus SCA/D which occurs at any time of the day are different, but this is often not recognized. Sports/exercise-related SCA/D is typically defined as death that occurs during or within an hour of exercise and is a subset of all SCA/D in athletes. Sports/exercise-related SCA/D is an important metric to consider when event planning or creating emergency action plans, however, it should not be conflated with SCA/D that occurs at any time, inclusive of any activity, rest, and sleep.	**2 points -** All SCA/D at any time regardless of activity or physical exertion **1 point -** Only sports/exercise-related SCA/D (occurring within an hour of sports or exercise) or SCA/D that occurs during a specific time portion of the day (i.e., school or work day) **0 points -** Unclear whether included cases are all SCA/D or sports/exercise-related SCA/D
Domain 5: SCA/D vs. SCD only	Most studies of SCA/D in athletes include only SCD in their analysis, however, the inclusion of SCA with survival is important to understand the scope of the problem. Studies including both SCA and SCD show that as many as 50% athletes who suffer SCA are resuscitated [25,51].	**3 points -** Inclusive of both SCA with survival and SCD with reliable reporting mechanisms for both SCA and SCD (i.e., prospective study with mandatory reporting of both SCA and SCD) **2 points -** Inclusive of both SCA and SCD but mechanisms for identification (of either SCA or SCD) may not be robust **1 point** - Clearly defines whether study includes only SCA or SCD **0 points -** Does not define inclusion criteria

Domain 6: Age Range	Grouping wide age ranges together can lead to inaccurate estimates of the incidence of SCA/D. Population based studies demonstrate a peak in SCA/D in those < 1 year of age followed by a relatively low rate of SCA/D that increases again around age 15 before rising precipitously at age 25 due to the increasing contribution of coronary artery disease [3,19,26]. In those under 25 years old, the primary causes of SCA/D are inherited structural and electrical cardiac diseases [3]. Many studies of SCA/D group wide swaths of ages (i.e., 12-40 years old) with widely varying incidence rates and causes of SCA/D calculated together (See Table 2). For an accurate estimation of the incidence rate, it is important that the age grouping reflects a similar risk of SCA/D in that group.	**2 points -** Age groups are generally aligned with risk (i.e., high school, college, 12-14, >14-18, >18-25, >25-35, >35 years old; or child, adolescent, young adult, adult) **1 point -** Age groups include varying risk but don't include overlapping primary etiologies (i.e., age 12-25) **0 points -** Wide age range with varying risk or ages grouped with different predominant etiologies (inherited disorders vs. coronary artery disease) combined. (i.e., 12 – 40)
Domain 7: Sex-specific rates	Studies of SCA/D in athletes and non-athletes alike have consistently shown that males have a higher rate of SCA/D than females. In general, males have 3 – 4 times higher rates of SCA/D. Combining both males and females in the same groups artificially lowers the risk for males and increases the risk for females [3,19,26]. There need to be sex-specific numbers available for both the numerator and denominator so that an incidence rate can be calculated for both sexes.	**2 points -** Sex-specific groups and incidence calculations possible (including if study is only one sex, i.e., male) **0 point -** It is not possible for sex-specific rates to be calculated
Domain 8: Sub-group reporting	There may be important sub-group risks such as sport or ethnicity [3,24,27]. There needs to be ethnicity or sport-specific numbers available for both the numerator and the denominator.	**2 points -** Sport and racial/ethnic incidence rates are reported or can be calculated (including if study was only done in one sport) **1 point -** Incidence rates are reported/can be calculated for sport (including if study was only done in one sport) but not race/ethnicity or race/ethnicity but not sport. **0 point -** There is no sub-group data reporting

Note: SCA: sudden cardiac arrest., SCD: sudden cardiac death., SCA/D: sudden cardiac arrest/death.

Table 2. SCA/D incidence studies scored for inter-observer reliability.

Study	Study Design and Population	Case Identification (Numerator)	Population Definition (Denominator)	Sports-related SCD or All SCD?	SCD or All SCA/D?	Study Years	Age Range; Number of Cases	Annual Incidence	Study Quality
Bohm 2016 [29]	Prospective cohort; sports-related SCD in all persons in Germany	Voluntary reporting to German National Registry, web-based media search, regional institutes	Physical activity estimated from the German Health Update study and extrapolated to population data from the German Federal Statistical Office	Sports-related SCD	SCD	2012-2014	10-79 N=144	*Sports Participants* 1:1,200,000	Low
Chatard 2018 [30]	Prospective, Pacific Island athletes who were screened	Prospectively followed	Defined cohort of 1450 athletes		SCD	2012-2015	10-40 N=3	*Pacific Island Athletes* 1:2,416	Low
Corrado 2003 [31]	Prospective cohort; athletes and non-athletes in the Veneto Region of Italy	Mandatory reporting of sudden death	Registered athletes in the Sports Medicine Database of the Veneto Region of Italy and the Italian Census Bureau	All	SCD	1979-1999	12-35 N=51 12-35 N=208	Athletes Overall 1:47,000 Male 1:41,000 Female 1:93,000 Non-Athletes Overall 1:143,000	High
Corrado 2006 [32]	Prospective cohort; athletes and non-athletes in the Veneto Region of Italy	Mandatory reporting of sudden death	Registered athletes in the Sports Medicine Database of the Veneto Region of Italy and the Italian Census Bureau	All	SCD	1979-2004	12-35 N= 55 12-35 N=265	*Athletes* Overall: 1:53,000 Non-Athletes Overall: 1:127,000	High
Drezner 2005 [33]	Retrospective survey; college athletes	Survey of NCAA Division I institutions (244/326 responded)	Reported number of athletes	All	SCD	—	N=5	*College* Overall 1:67,000	Low
Drezner 2009 [34]	Cross-sectional survey; high school athletes	Survey of 1710 high schools with AEDs	Reported number of student athletes	All cases occurring on campus	SCA + SCD	2006-2007	14-17 N=14	*High School* 1:23,000 (SCA + SCD) 1:64,000 (SCD)	Low
Drezner 2014 [35]	Retrospective cohort; Minnesota high school athletes	Public media reports	Minnesota State High School League statistics (Sum of unduplicated athletes 2003-04 through 2011-12 school years)	All	SCA + SCD	2003-2012	14-18 N=13	*High School* Overall 1:71,000 Female 0 Male, basketball 1:21,000	Intermediate
Grani 2016 [36]	Retrospective; sports-related SCD in all persons in German-speaking Switzerland	Forensic reports	Physical activity estimated from survey on sports participation by the Swiss Federal Office of Sports	Sports-related SCD	SCD	1999-2010	10-39 N=69	*Sports Participants* Competitive: 1:90,000 Recreational: 1:192,000	Low
Harmon 2015 [37]	Retrospective cohort; college athletes	Parent Heart Watch database, NCAA Resolutions list, catastrophic insurance claims	Participation data from the NCAA	All	SCD	2003-2013	17-26 N=79	*College* Overall 1:53,000 Male 1:38,000 Female 1:122,000 Black 1:21,000 White 1:68,000	High

								Football 1:36,000 Male, soccer 1:24,000 Male, black 1:16,000 Male, basketball 1:9,000 Male, black, basketball 1:5,300 Male, Div. I basketball 1:5,200	
Harmon 2016 [38]	Retrospective cohort, US high school athletes	Media reports	National Federation of State High School Associations participation statistics	All	SCA/SCD	2007=2013	14-18 N=104	*High School* Overall 1:67,000 Male 1:45,00 Female 1:237,000 Male, basketball 1:37,000	Intermediate
Holst 2010 [39]	Retrospective cohort; athletes and general population in Denmark	Review of death certificates, Cause of Death Registry, and National Patient Registry in Denmark	Interview data of people age 16-35 years from the National Danish Health and Morbidity Study	Sports-related SCD in athletes versus all SCD in the general population	SCD	2000-2006	12-35 N=15 12-35 N=428	*Athletes* 1:83,000 *General Population* 1:27,000	Low
Malhotra 2018 [40]	Prospective,	Followed from time of screen to 2016	Defined cohort of 11,168 elite soccer athletes	All	SCD	1996-2016	15-17 N=8	*Elite Male Soccer Athletes* 1:14,794	Intermediate
Marijon 2011 [41]	Prospective cohort; general population in France	Data from emergency medical system	General population statistics, data from the Minister of Health and Sport to estimate young competitive athlete population	Sports-related SCA or SCD with moderate or vigorous exercise	SCA + SCD	2005-2010	10-75 N=820 10-35 N=50	*General Population* *1:217,000* *Young Competitive Athlete* *1:102,000* *Young Non-competitive Athlete* *1:455,000*	Intermediate
Maron 2009 [42]	Retrospective cohort; amateur and competitive athletes	U.S. Registry for Sudden Death in Athletes	An estimated 10.7 million participants per year ≤ 39 years of age in all organized amateur and competitive sports	All	SCA + SCD	1980-2006	8-39 N=1046	*Athletes* 1:164,000	Low
Maron 2013 [43]	Retrospective cohort; Minnesota high school athletes	U.S. Registry for Sudden Death in Athletes	Minnesota State High School League statistics (Estimated using conversion factor of 2.3 to account for multisport athletes)	All	SCD	1986-2011	12-18 N=13	*High School* Overall 1:150,000 Male 1:83,000 Female 0	Intermediate
Maron 2016 [44]	Retrospective cohort	Records of the Medical Examiner	Data from the Minnesota Department of Education, National Center for Education Statistics, and the Minnesota State High School League for Hennepin County, Minnesota	All	SCD	2000-2014	14-23 N=27	*Non-athlete* 1:39,000 *Athlete* 1:121,000	Low

Peterson 2021 [45]	Prospective	National Center for Catastrophic Sports Injury Research	Has defined cohort for high school and college athletes	All	SCA/SCD	2014-20181:	14-18 N=204 18-24 N=39	*High School* Overall 1:66,000 Male 1:44,00 Female 1:204,000 Male Ice Hockey 1:24,000 Male Basketball 1:40,000 *College* Overall 1:51,000 Male 1:35,000 Female 1:123,000 Black Male 1:18,000 White Male 1:39,000 Black Male Basketball 1:4,800 White Male Basketball 1:15,000 Black Football 1:28,000 White Football 1:20,000	High
Risgaard 2014 [46]	Retrospective cohort; competitive and non-competitive athletes in Denmark	Review of death certificates and the Danish National Patient Registry	Competitive and non-competitive athlete populations in Denmark estimated based on survey data from the Danish National Institute of Public Health	Sports-related SCD in competitive versus non-competitive athletes	SCD	2007-2009	12-35 N=44	*Competitive Athlete* 1:213,000 *Non-competitive Athlete* 1:233,000	Low
Roberts 2013 [47]	Retrospective cohort	Catastrophic insurance records	Minnesota State High School League statistics (Sum of unduplicated athletes 1993/1994 through 2011-12 academic years)	Sports-related SCD in high school practice or games	SCD	1993/1994-2011-12	12-19 N= 4	*High School Athlete* 1:417,000	Low
Steinvil 2011 [48]	Retrospective cohort; athletes in Israel	Retrospective review of two Israeli newspapers	Competitive athletes registered in the Israel Sport Authority in 2009; extrapolated this data for prior 24 years based on the growth of the Israeli population (age 10-40) from the Central Bureau of Statistics; allowed for a presumed doubling of the sporting population over 24 years	All	SCD	1985-2009	12-44 N=24	*Athletes* 1:38,000	Low
Toresdahl 2014 [49]	Prospective observational; high school students and student-athletes	2149 high schools monitored for SCA events on school campus	Reported number of students and student-athletes	All cases occurring on school campus	SCA + SCD	2009-2011	14-18 N=44	*Student-athlete* Overall 1:88,000 Male 1:58,000 Female 1:323,000 *Student Non-athlete* Overall 1:326,000 Male 1:286,000 Female 1:357,000	High

Van Camp 1996 [50]	Retrospective cohort; high school and college athletes	National Center for Catastrophic Sports Injury Research and media reports	Data from NCAA, NFHS, NAIA, and NJCAA, added together with conversion factor (1.9 for high school and 1.2 for college) used to account for multisport athletes "based on discussions with representatives from the national organizations".	Sports-related	SCD	1983-1993	13-24 N=160	<u>*College + High School*</u> Overall 1:188,000 Male 1:134,000 Female 1:752,000 <u>*High School*</u> Overall 1:213,000 Male 1:152,000 Female 1:861,000 <u>*College*</u> Overall 1:94,000 Male 1:69,000 Female 1:356,000	Low

Note: NAIA: national association of intercollegiate athletics., NCAA: national collegiate athletics association., NFHS: National Federation of State High School Associations., NJCAA: national junior college athletic association., SCA: sudden cardiac arrest., SCD: sudden cardiac death., SCA/D: sudden cardiac arrest/death., U.S: United States.

Table 3. Inter-observer agreement analysis results.

IQ-SCA/D Domain	Observer 1 vs. 2	Observer 2 vs. 3	Observer 1 vs. 3
Domain 1: Study Design	0.770 (SE= 0.089, 95%CI= 0.596-0.944)	0.911 (SE= 0.060, 95%CI= 0.793-1.028)	0.693 (SE= 0.093, 95%CI= 0.511-0.875)
Domain 2: Numerator/Strength of Case Identification	0.780 (SE= 0.107, 95%CI= 0.570-0.990)	0.779 (SE= 0.120, 95%CI= 0.544-1.015)	0.813 (SE= 0.110, 95%CI= 0.597-1.029)
Domain 3: Denominator	0.526 (SE= 0.125, 95%CI= 0.281-0.772)	0.588 (SE= 0.136, 95%CI= 0.321-0.855)	0.447 (SE= 0.124, 95%CI= 0.204-0.689)
Domain 4: All cases vs. Sports-related cases	0.298 (SE= 0.186, 95%CI= -0.067-0.662)	0.548 (SE= 0.187, 95%CI= 0.182-0.914)	0.403 (SE= 0.190, 95%CI= 0.032-0.775)
Domain 5: SCA/D vs. SCD	0.345 (SE= 0.131, 95%CI= 0.089-0.602)	0.498 (SE= 0.153, 95%CI= 0.197-0.798)	0.575 (SE= 0.098, 95%CI= 0.382-0.768)
Domain 6: Age Range	0.494 (SE= 0.134, 95%CI= 0.232-0.756)	0.745 (SE= 0.124, 95%CI= 0.503-0.988)	0.639 (SE= 0.116, 95%CI= 0.412-0.867)
Domain 7: Sex-Specific Rates	0.648 (SE= 0.149, 95%CI= 0.356-0.940)	0.624 (SE= 0.170, 95%CI= 0.292-0.956)	0.472 (SE= 0.173, 95%CI= 0.133-0.811)
Domain 8: Sub-Group Reporting	0.320 (SE= 0.169, 95%CI= -0.011-0.650)	0.644 (SE= 0.122, 95%CI= 0.404-0.883)	0.482 (SE= 0.173, 95%CI= 0.143-0.820)
Total Summative Scores	0.610 (SE= 0.057, 95%CI= 0.499-0.721)	0.660 (SE= 0.060, 95%CI= 0.541-0.779)	0.616 (SE= 0.083, 95%CI= 0.453-0.778)
Quality Category Agreement	0.753 (SE= 0.110, 95%CI= 0.537-0.969)	0.763 (SE= 0.112, 95%CI= 0.543-0.983)	0.641 (SE= 0.138, 95%CI= 0.371-0.912)
Quality Category Fleiss' Kappa	0.655 (SE=0.093, 95% CI= 0.473-0.837)		

Data reported as Kappa, SE (Standard Error) and 95%CI (Confidence Intervals). Observers 1, 2 and 3 represent the expert, intermediate and novice observers, respectively.

Figure 1. IQ-SCA/D Development Process.