Tests for the Assessment of Sport-Specific Performance in Olympic Combat Sports: A Systematic Review With Practical Recommendations

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The regular monitoring of physical fitness and sport-specific performance is important in elite sports to increase the likelihood of success in competition. This study aimed to systematically review and to critically appraise the methodological quality, validation data, and feasibility of the sport-specific performance assessment in Olympic combat sports like amateur boxing, fencing, judo, karate, taekwondo, and wrestling. A systematic search was conducted in the electronic databases PubMed, Google-Scholar, and Science-Direct up to October 2017. Studies in combat sports were included that reported validation data (e.g., reliability, validity, sensitivity) of sport-specific tests. Overall, 39 studies were eligible for inclusion in this review. The majority of studies (74%) contained sample sizes <30 subjects. Nearly, 1/3 of the reviewed studies lacked a sufficient description (e.g., anthropometrics, age, expertise level) of the included participants. Seventy-two percent of studies did not sufficiently report inclusion/exclusion criteria of their participants. In 62% of the included studies, the description and/or inclusion of a familiarization session (s) was either incomplete or not existent. Sixty-percent of studies did not report any details about the stability of testing conditions. Approximately half of the studies examined reliability measures of the included sport-specific tests (intraclass correlation coefficient [ICC] = 0.43–1.00). Content validity was addressed in all included studies, criterion validity (only the concurrent aspect of it) in approximately half of the studies with correlation coefficients ranging from $r = -0.41$ to 0.90. Construct validity was reported in 31% of the included studies and predictive validity in only one. Test sensitivity was addressed in 13% of the included studies. The majority of studies (64%) ignored and/or provided incomplete information on test feasibility and methodological limitations of the sport-specific test. In 28% of the included studies, insufficient information or a complete lack of information was provided in the...
INTRODUCTION

Amateur boxing, fencing, karate, judo, taekwondo, and wrestling represent popular combat sports. These combat sports are practiced in the whole world and constitute an important part of the Summer Olympic programme (International Olympic Committee, 2017a). Wrestling and fencing were already part of the first modern Olympic Games in 1896 for males. Females were included in 1924 for fencing and in 2004 for wrestling. In 1904, male amateur boxing was included in the official program of the Summer Olympic Games. It lasted until 2012, until female amateur boxing became part of the Olympic program. In 1964, judo was included in the Olympic program for males and in 1992 for females. Taekwondo was recognized as an Olympic sport in 2000 for both sexes and karate will be introduced for both sexes in the 2020 Olympic Games. In this regard and with reference to the growing interest in Olympic combat sports, it is important to advance scientific knowledge in performance testing to design specifically tailored training protocols and periodization models and to increase the likelihood of success in competition (Bridge et al., 2014; Chaabène et al., 2017a).

The main purposes of sport-specific testing can comprise talent identification and development of young athletes as well as the identification of strengths and weaknesses in young and elite athletes to be used for training purposes (Tabben et al., 2014; Chaabane and Negra, 2015). In addition, there is a consensus in the scientific literature on the importance of assessing physical and physiological qualities to optimize sport performance (Franchini et al., 2011a; Bridge et al., 2014; Chaabène et al., 2015c; Chaabène et al., 2017b) especially for those characterized by complex technical/tactical and physical/physiological demands like striking (e.g., karate, taekwondo, and amateur boxing; Chaabène et al., 2012b, 2015c; Bridge et al., 2014), grappling (e.g., judo and wrestling; Franchini et al., 2011a; Chaabène et al., 2017a), and weapon-based combat sports (e.g., fencing; Roi and Bianchedi, 2008).

However, prior to the design of a test protocol for sport-specific performance assessment, it is recommended to conduct a systematic needs analysis to identify the above-mentioned demands of the specific sport (Kraemer et al., 2012). More specifically, in the context of a need analysis, the metabolic, biomechanical, and injuries profile of the sport could be explored (Kraemer et al., 2012). With the systematically derived information on sport-specific demands from the needs analysis, adequate sport-specific performance tests can be designed and implemented into training practice. Information from these tests allows to identify strengths and weaknesses of athletes and to monitor how athletes’ performance developed over time. These individualized performance profiles of athletes can be used for the planning of training protocols and periodization models. In Olympic combat sports, growing number of researchers have turned their attention to the development of valid sport-specific test protocols that are specifically tailored to the physical, physiological, technical and tactical demands of the respective sport discipline (Santos et al., 2010; Chaabène et al., 2012c; Tabben et al., 2014; San’Ana et al., 2017).

Even though there is a well-accepted advantage of sport-specific performance testing over the application of general physical fitness tests, there is no study available that systematically reviewed the methodological quality (e.g., sample size, inclusion/exclusion criteria, stability of testing conditions), validation data (i.e., reliability, validity, sensitivity), and feasibility (i.e., practicability) of the existing sport-specific tests related to Olympic combat sports. In fact, the majority of the available literature focused on the assessment of physical and physiological attributes of Olympic combat sport athletes in sports like amateur boxing (Chaabène et al., 2015c), fencing (Roi and Bianchedi, 2008), judo (Franchini et al., 2011a), karate (Chaabène et al., 2012b, 2015a), taekwondo (Bridge et al., 2014), and wrestling (Chaabène et al., 2017a). However, these tests assess general physical fitness qualities but not sport-specific performance. To the authors’ knowledge, previous systematic reviews (Robertson et al., 2014; Hulteen et al., 2015) critically appraised the methodological quality and feasibility of performance tests in individual (e.g., golf, tennis, rock climbing) and team sports (e.g., football, rugby, volleyball) but not in Olympic combat sports. Therefore, the purpose of this study was to systematically review the available literature and to critically analyze the methodological quality, validation data, and feasibility of sport-specific tests in Olympic combat sports.

METHODS

The experimental approach comprehended five-steps (Khan et al., 2003): Step 1: Framing questions for the review; Step 2: Identification of relevant works; Step 3: Assessment of the quality of studies; Step 4: Summary the evidence; and Step 5: Interpretation of the findings.

Step 1: Framing Questions for the Review

The research question focused on sport-specific testing in Olympic combat sports (e.g., boxing, fencing, judo, karate, taekwondo, and wrestling). A Boolean search strategy was applied using the operators AND, OR. According to the main topic of the present study, the a-priori-specified inclusion criteria encompassed the following search syntax: [“combat sport” OR karate OR taekwondo OR “amateur boxing” OR...]

Keywords: martial arts, validity, reliability, sensitivity, methodological quality, specific assessment
judo OR wrestling OR fencing) AND (reliability OR validity
OR sensitivity) AND (“physical fitness” OR “physiological
characteristic” OR “physical activity” OR “fitness test” OR
“motor assessment” OR “technical skill” OR “gold standard”).

**Step 2: Identification of Relevant Works and Data Extraction**
The present systematic review of the published literature was conducted based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009). A comprehensive literature search of original manuscripts investigating was systematically performed on PubMed (MEDLINE), Google Scholar, and Science Direct. The search was limited to manuscripts published up to October 2017. In this study, the criteria for the inclusion of retrieved articles were: (i) written in English, (ii) published in peer-reviewed journals, (iii) focused on either on amateur boxing, fencing, judo, karate, taekwondo, wrestling, or a combination of these combat sports (iv) evaluate one aspect of the physical fitness and/or physiological characteristic through sport-specific testing, and (v) report at least one aspect of either reliability, validity, or sensitivity related to the applied test protocol. To allow the assessment of the methodological quality, only full-text sources were included, whereas abstracts and conference papers from annual meetings were not considered in the analysis. The first author (HC) coded the studies according to the selection criteria and eliminated duplicates. Relevant articles identified through the searching process were independently evaluated and assessed by two reviewers (e.g., HC and YN) who screened the titles, the abstracts, and the full texts to reach the final decision on the study inclusion or exclusion. In case of uncertainty or disagreement, a third expert was consulted. Additionally, the snowballing technique was applied to the reference lists of retrieved full-text articles to identify additional articles that were not included in the initial electronic search (Figure 1).

For each selected study included in the final list of scientific contributions considered eligible for the detailed examination, data were extracted and examined by two independent reviewers (HC and YN) who conducted data extraction following a predefined template. The template included sample size, demographic information including sex, age, and training background/expertise, type of combat sports, sport-specific test’s name, objective, and duration, and validation data (e.g., reliability, validity, and sensitivity). After completion of data extraction, the two independent reviewers cross-checked the data to confirm their accuracy. Any conflicting results between reviewers resulted in a re-evaluation of the paper in question until a consensus was reached. It is worth noting that information related to the type of reliability (e.g., test-retest reliability and inter/intra-rater reliability; Currell and Jeukendrup, 2008; Robertson et al., 2014), validity (e.g., content or logical, criterion [concurrent/predictive], and construct [discriminative/convergent]) (Currell and Jeukendrup, 2008; Robertson et al., 2014), and sensitivity (Currell and Jeukendrup, 2008; Impellizzeri and Marcara, 2009) with the used corresponding statistical tools were specified.

**Table 1** provides details of items related to the sport-specific tests’ characteristics and feasibility. In addition, the most common statistical analysis approaches used to assess reliability were considered (Hopkins, 2000; Currell and Jeukendrup, 2008; Impellizzeri and Marcara, 2009), which encompassed: coefficient of variation (CV%), intra-class correlation coefficient (ICC), typical error of measurement (TEM), correlation coefficients (r), and 95% limits of agreement (LOA). Additionally, details related to the validity of the sport-specific testing were retrieved. Test sensitivity was assessed through comparing the smallest worthwhile change (SWC) and the typical error of measurement (TEM). Furthermore, the minimal detectable change (MDC95%), was also included (Hopkins, 2002).

**Step 3: Assessment of the Quality of Studies**
Based upon six criteria adapted from a risk-of-bias evaluation in a previously published review of tests examining sport-related skill outcomes (Robertson et al., 2014), two authors (HC and YN) carefully reviewed all eligible articles for quality appraisal (Table 3). These criteria included: (i) sample size, i.e., the number of participants included to establish validity/reliability/sensitivity of the sport-specific test; (ii) details related to study participants (e.g., sex, age, sport background/expertise, and anthropometric details); (iii) presence of clearly established inclusion/exclusion criteria; (iv) presence of familiarization session(s) prior to sport-specific testing or not; (v) presence of clearly established interval between test-retest assessments; and (vi) stability of testing conditions (i.e., whether testing equipment and environmental

![FIGURE 1 | Flow of information through the different phases of the systematic review.](image-url)
TABLE 1 | Details related to sport-specific tests’ characteristics.

| Test characteristics                  | Definition                                                                 | Assessment criteria                                                                 |
|---------------------------------------|---------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| RELIABILITY                           |                                                                           |                                                                                      |
| Test-retest reliability               | The consistency of measurements, or of an individual’s performance over repeated testing sessions or the absence of measurement error (Safrit and Wood, 1989) | Yes: provided and shows good to excellent reliability                                |
|                                       | In the literature several terms have been used interchangeably with reliability such as repeatability, reproducibility, consistency, agreement, concordance, and stability (Atkinson and Nevill, 1998) | Partial: provided, but (a) relative or absolute reliability not reported or (b) poor to average reliability level was established |
| Inter/intra-rater reliability         | Inter-rater: the degree of agreement between assessments outcomes when undertaken by two or more testers (Baumgartner and Jackson, 1998) | Yes: either or both examined                                                                 |
|                                       | Intra-rater: the agreement among two or more trials undertaken by the same tester (Baumgartner and Jackson, 1998) | Partial: reported, but (a) no reliability coefficient provided or (b) poor to average reliability shown |
|                                       |                                                                           | Not provided                                                                         |
|                                       |                                                                           | Not applicable                                                                        |
| VALIDITY                              |                                                                           |                                                                                      |
| Content                               | How well a specific test measures what it intends to measure (Currell and Jeukendrup, 2008; Thomas et al., 2015) | Yes: logical and/or content validity results established                                |
| Criterion (concurrent/predictive)     | Concurrent: means that the performance protocol is correlated with a gold standard measure (Thomas et al., 2015) | Yes: predictive or concurrent validity results established                              |
|                                       | Predictive: Sport-specific outcome can predict sport performance (Thomas et al., 2015) | Not provided                                                                         |
| Construct (discriminative/convergent) | Construct: whether a sport-specific test can measure a quality or attribute that cannot be operationalized | Yes: discriminative and/or convergent validity results established                    |
|                                       | Discriminative: ability to assess performers of different ability (as rated by another measure) (Russell et al., 2010; Streiner et al., 2015) | Not provided                                                                         |
|                                       | Convergent: relation of a sport-specific test with another measure of the same construct or associated measures (Barrow et al., 1989; Russell et al., 2010) | Not provided                                                                         |
| Responsiveness (sensitivity)          | The sport-specific test is able to detect small, but meaningful changes in performance (Currell and Jeukendrup, 2008) | Yes: outcomes related to test responsiveness were established                         |
| Minimal detectable change             | An estimation of the smallest change in score that can be detected objectively for a test, i.e., the amount by which the subject’s performance needs to be changed to be sure the change is bigger than the measurement error (Haley and Fragala-Pinkham, 2006) | Yes: outcomes related to test minimal detectable change were established                |
| UTILITY AND LIMITATIONS               |                                                                           |                                                                                      |
| Feasibility and limitations           | How well the sport-specific test is easy to be undertaken, administered, and scored (Stevens and Gibbins, 2002; Ali et al., 2008). Limitations relating to outcomes and interpretability of the test acknowledged and clarified in the study (Braeken et al., 2011) | Yes: practicability and limitations discussed                                         |
|                                       | Partial: practicability and limitations not fully discussed                | Not provided                                                                         |
| Test background                       | Information relating to the expected use and context of the test detailed (Fliess-Douer et al., 2010) | Yes: information relating to test background established                              |
|                                       | Partial: test background not fully discussed                               | Not provided                                                                         |
| Test duration                         | Expected or actual duration of the testing protocol established (Streiner, 1993) | Yes: expected or actual duration of test/trial established                             |
|                                       |                                                                           | Not provided                                                                         |

conditions remained stable between sessions or not) as well as participants between sessions.

**Step 4: Summary the Evidence**

From each included study, the following information was extracted: author(s), year of publication, country, aim of the study, research design: Then, detailed tables reporting major characteristics of the selected studies were created.

**Step 5: Interpretation of the Findings**

A synthesis of major findings reported in the included articles was submitted to a thematic analysis deemed relevant for generating inferences.

**RESULTS**

The preliminary systematic search resulted in 4,755 hits. After careful examination of titles and abstracts, 428 articles remained and were reviewed for eligibility. Full texts of these 428 articles were screened in regards of the previously defined inclusion/exclusion criteria. Finally, 39 articles were eligible to be included in this systematic review (**Figure 1**). **Table 2** illustrates the main characteristics of the 39 eligible scientific contributions in terms of the applied sport-specific test, the tested physical and/or physiological attributes, the measured outcomes, and the number of female and male participants and their athletic background/expertise. Publication years ranged
TABLE 2 | Characteristics of the eligible studies.

| Combat sport discipline | References                                      | Test name                                           | Physical/physiological attribute(s) tested | Outcomes (measure unit) | Participants’ athletic background |
|--------------------------|-------------------------------------------------|----------------------------------------------------|--------------------------------------------|-------------------------|----------------------------------|
| Karate                   | Chaabène et al., 2015b                         | Karate specific aerobic test                       | Maximal aerobic power                     | Time (s)                | Male international level (n = 12) |
|                          |                                                 |                                                    |                                            |                         | Female international level (n = 3) |
| Karate                   | Chaabène et al., 2012c                         | Karate specific aerobic test                       | Maximal aerobic power                     | Time (s)                | Male national level (n = 16)     |
| Karate                   | Chaabène et al., 2012b                         | Karate specific aerobic test                       | Maximal aerobic power                     | Time (s)                | Male national and regional level (n = 43) |
| Karate                   | Sertić et al., 2011                           | Movement change in karate position (MKUKS)         | Agility                                   | Time (s)                | Male club level (n = 65)         |
| Karate                   | Tabben et al., 2014                            | Karate Specific Test                               | Maximal aerobic power                     | V̇O₂peak (ml/ kg/ min)  | Male international Level (n = 14) |
|                          |                                                 |                                                    |                                            | Time (s)                | Female international Level (n = 3) |
| Karate                   | Nunan, 2006                                    | Karate specific aerobic test                       | Maximal aerobic power                     | Time (s)                | Male national Level (n = 5)      |
| Karate                   | Sterkowicz and Franchini, 2009                 | Hip turning speed test                            | Speed and coordination                    | Time (s)                | Male Kyokushin of various competitive levels (n = 219) |
|                          |                                                 | Speed punches test                                | Speed and coordination                    | Time (s)                |                                    |
|                          |                                                 | Flexibility test                                  | Speed and coordination                    | Time (s)                |                                    |
|                          |                                                 | Rapid kicks test                                  | Speed and coordination                    | Time (s)                |                                    |
|                          |                                                 | Agility test                                       | Agility                                   | Time (s)                |                                    |
|                          |                                                 | Evasion action test                                | Agility                                   | Time (s)                |                                    |
| Taekwondo                | Araujo et al., 2017                           | Specific Taekwondo exercise test (TKDtest)         | Maximal aerobic power and capacity        | V̇O₂peak (ml/ kg/ min)  | Male black belt athletes (n = 14) |
|                          |                                                 |                                                    |                                            | HRpeak (batt/min)       |                                    |
|                          |                                                 |                                                    |                                            | Ventilatory thresholds (VT1 and VT2 [ml/ kg/ min]) |                                    |
| Taekwondo                | Sant’Ana et al., 2017                         | Progressive specific taekwondo test (PSTT)        | Maximal aerobic power                     | V̇O₂peak (ml/ kg/ min)  | Male national and regional level (n = 18) |
| Taekwondo                | Chen et al., 2015                             | Dual task test                                     | Reaction time and skill proficiency in roundhouse kick | Time (s)                | Male elite athletes (n = 12) Male sub-elite athletes (n = 12) |
| Taekwondo                | Rocha et al., 2016                            | Taekwondo specific anaerobic test (TSAT)           | Anaerobic power                           | W and W/kg              | Male elite level (n = 17)        |
|                          |                                                 |                                                    | Anaerobic capacity                        | W and W/kg              |                                    |
|                          |                                                 |                                                    | Fatigue index                             | %                       |                                    |
| Taekwondo                | Sant’Ana et al., 2014                         | Taekwondo anaerobic test (TAT)                     | Anaerobic power and capacity              | Number of Repetition (n) | Male elite level (n = 10)         |
|                          |                                                 |                                                    | AKC                                       | Time (s)                |                                    |
|                          |                                                 |                                                    | MKT                                       | Time (s)                |                                    |
|                          |                                                 |                                                    | BKT                                       | Time (s)                |                                    |
|                          |                                                 |                                                    | MKI                                       | Kick impact (g)         |                                    |
|                          |                                                 |                                                    | HKI                                       | Kick impact (g)         |                                    |
| Taekwondo                | Oliveira et al., 2015                         | Adapted anaerobic kick test (AAKT)                 | Anaerobic power and capacity              | Kicks/s                 | Male club level (n = 10)          |
|                          |                                                 |                                                    | Higher kick frequency (higher frequency of kicks performed during 3 s) | Kicks/s                 | Female club level (n = 5)          |
|                          |                                                 |                                                    | Lower kick frequency (lower frequency of kicks performed during 3 s) | Kicks/s                 |                                    |
|                          |                                                 |                                                    | %                                        | Time (s)                |                                    |

(Continued)
| Combat sport discipline | References                        | Test name                                                                 | Physical/physiological attribute(s) tested                                                                 | Outcomes (measure unit)                                      | Participants’ athletic background |
|-------------------------|-----------------------------------|---------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------|----------------------------------|
| Taekwondo               | da Silva Santos and Franchini, 2016 | Frequency speed of kick test (FSKT) Multiple frequency speed of kick test (MFSKT) | Anaerobic power and capacity                                                                                 | Number of repetition (n)                                      | Male black-belt (n = 4) Female black-belt (n = 4) |
| Taekwondo               | Chaabene et al., 2017b            | Taekwondo-specific agility test                                           | Planned agility                                                                                              | Time (s)                                                      | Male elite level (n = 20) Female elite level (n = 7) |
| Amateur boxing          | Smith et al., 2000                | Sport-specific boxing dynamometer                                         | Maximal punching force                                                                                      | Newton (N)                                                   | Male elite level (n = 7) Male Intermediate level (n = 8) Male novice level (n = 8) |
| Amateur boxing          | Obinski et al., 2011              | Shut put test                                                              | Explosive strength                                                                                          | Centimeter (cm)                                              | Male elite level (n = 6) Female elite level (n = 7) |
| Judo                    | Santos et al., 2010               | Santos test                                                                | Maximal aerobic power and capacity                                                                           | VO_{2peak} (ml/ kg/ min) HR (batt/min) Blood lactate (mmol/l) | Male national level (n = 8) |
| Judo                    | Santos et al., 2012               | Santos test                                                                | Maximal aerobic power and capacity                                                                           | VO_{2peak} (ml/ kg/ min) HR (batt/min) Blood lactate (mmol/l) | Female elite level (n = 8) |
| Judo                    | Santos et al., 2011               | Santos test                                                                | Maximal aerobic power and capacity                                                                           | VO_{2peak} (ml/ kg/ min) HR (batt/min) Blood lactate (mmol/l) | Male elite level (n = 8) |
| Judo                    | Sogabe et al., 2015               | Uchikomi shuttle run test                                                  | Judo-specific endurance                                                                                     | Number of Uchi-komi (n) HR (batt/min) Rating of perceived exertion | Competitive athletes Gender NP (n = 18) |
| Judo                    | Tavra et al., 2016                | Santos test Uchi-komi fitness test Tern station judo ability test Special judo fitness test (SJFT) | Maximal aerobic power and capacity Anaerobic capacity Judo specific ability Anaerobic performance | VO_{2peak} (ml/ kg/ min) HR (batt/min) Blood lactate (mmol/l) Nombre d’Uchi-Komi Time (s) SJFT index | Female elite and sub-elite level (n = 14) |
| Combat sport discipline | References | Test name | Physical/physiological attribute(s) tested | Outcomes (measure unit) | Participants’ athletic background |
|-------------------------|------------|-----------|-------------------------------------------|--------------------------|----------------------------------|
| Judo                    | Sterkowicz and Franchini, 2001 | Special judo fitness test (SJFT) | Anaerobic performance | SJFT index | Male elite level (n = 33) Male novice level (n = 47) |
| Judo                    | Franchini et al., 1998 | Special judo fitness test (SJFT) | Anaerobic performance | SJFT index | Male regional and state level (n = 17) |
| Judo                    | Franchini et al., 2011b | Judogi grip strength test | Strength endurance | Time (s) Number of repetition (n) | Male elite level (n = 16) Male regional level (n = 12) |
| Judo                    | Lidor et al., 2005 | Judo-specific test | Judo specific ability | Time (s) | Male club level (n = 10) |
| Judo                    | Azevedo et al., 2007 | Lactate minimum intensities for judo | Aerobic capacity | HR (batt/min) Blood lactate (mmol/l) Drills/s | Male regional and international level (n = 6) |
| Judo                    | Morales et al., 2016 | Randori maximal time to exhaustion | Aerobic capacity | Time (min) | Male international level (n = 7) Female international level (n = 4) |
| Judo                    | Del Vecchio et al., 2014 | Hikidashi uchi-komi test | Anaerobic performance | Repetition (n) | First study: Male regional and state level (n = 10) Second study: Male regional and state level (n = 24) and female regional and state level (n = 6) |
| Judo                    | de Azevedo et al., 2014 | Judo specific incremental test (JSIT) | Aerobic capacity | Respiratory compensation threshold VO\textsubscript{2} (ml/kg/min), HR (batt/min) blood lactate (mmol/l) | Male well-trained (n = 8) |
| Judo                    | Almansiba et al., 2012 | Uchikomi Fitness Test (UFT) | Judo specific fitness | Number of Uchi-komi (n) HR (batt/min) | Male of various competitive level (n = 7) |
| Judo                    | Franchini et al., 2005 | Special judo fitness test (SJFT) | Anaerobic performance | SJFT index | Male elite level (n = 23) Male non-elite level (n = 53) |
| Wrestling               | Shyan, 2011 | Special endurance test | Special endurance | Special endurance coefficient | Elite level Gender NP (n = NP) |
| Wrestling               | Wright et al., 2015 | Sandbag test | Sport-specific fitness | Score (T/T [time to finish each round/number of throws]) Fatigue (%) | Male national level (n = 15) |
| Wrestling               | Utter et al., 1997 | Pittsburgh wrestling performance test | Sport-specific performance | Time (s) | Male university level (n = 7) |
TABLE 2 | Continued

| Combat sport discipline | References | Test name | Physical/physiological attribute(s) tested | Outcomes (measure unit) | Participants’ athletic background |
|-------------------------|------------|-----------|------------------------------------------|-------------------------|----------------------------------|
| Fencing | Bottoms et al., 2013 | Laboratory based protocol (LBP) | Sport-specific performance | HR (batt/min) Rating of perceived exertion | Male club level (n = 6) |
| Fencing | Weichenberger et al., 2012 | Fencing-specific endurance test (FET) | Aerobic capacity | HR (batt/min) Blood lactate (mmol/l) | Validation study: elite level male (n = 15) and elite level female (n = 13) Discrimination study: male international level fencers (n = 19) and male national level fencers (n = 20) |
| Fencing | Turner et al., 2016 | Elite level male (n = 15) and elite level female (n = 13) | Change of direction speed | Time (s) | Male elite level (n = 49) Female elite level (21) |
| Fencing | Tsolakis and Vagenas, 2010 | Time of lunge test | Muscular power | Time (s) | Male and female elite level (n = 14) |
| | | Time of shuttle test | change of direction speed | Time (s) | Male and female sub-elite level (n = 19) |

NP, not provided; AKC, number of kicking cycles; MKT, mean kicking time; BKT, best kicking time; MKI, mean kicking impact; HKI, highest kicking impact; HR, heart rate; VO_{2peak}, peak oxygen uptake; W, watt; kg, kilogram, s, second.

from 1997 (Utter et al., 1997) to 2017 (Araujo et al., 2017; Chaabene et al., 2017b; Sant’Ana et al., 2017), with an increasing trend starting from 2007 (Figure 2). Judo was represented in 15 articles (39%), whereas the relative picture for taekwondo, karate, fencing, wrestling, and amateur boxing was 8 (20%), 7 (18%), 4 (10%), 3 on (8%), and 2 (5%), respectively. The number of participants ranged from 5 to 219, with the majority of studies (74%) including <30 participants, whereas the proportion of studies including 30–49, 50–99, and >100 participants was 5, 13, and 3%, respectively. It is noteworthy that one study (Shiyan, 2011) did not include any information about participants’ number. Detailed information on participants’ characteristics were reported in 67% of the eligible studies with 31% providing a partial description, and another 2% lacking information regarding the recruited participants (Table 2). The proportion of studies including athletes competing at national or international level was 41%, that including mixed samples of national/international and regional/sub-elite level athletes was 33%, and that recruiting club/regional level participants was 26%. The sex representation of the participants was 61% for male athletes, 5% for female athletes, and 28% for both sexes. No information on the sex of the participants was present for 6% of the studies.

Methodological Quality of the Eligible Studies
The methodological characteristics of the included studies are shown in Table 3. Whilst only 28% of the included studies provided detailed inclusion/exclusion criteria, 26% provided a partial description and 46% did not include any information. Only 38% of the studies scheduled one or more familiarization sessions for their participants and 2% provided partial details on this relevant aspect, whereas the majority of the studies (60%) presented a lack of information. Studies focusing on reliability (61%) included intervals between experimental trials ranging from 1 day to 11 weeks, with 57% of them adopting a 1-week interval. However, information on this issue was lacking in 39% of studies. Only 28% of the studies provided detailed information on stability of testing conditions, with 59% of them not presenting any information and 13% providing partial information.

Reliability
Table 4 illustrates detailed information on validation data of the respective sport-specific tests. From the 39 included studies,
TABLE 3 | Methodological quality of eligible studies.

| Combat sport discipline | References | Sample size | Details related to study participants | Inclusion/exclusion criteria | Acquainting sessions | Test-retest interval | Stability of testing conditions |
|-------------------------|------------|-------------|---------------------------------------|-------------------------------|----------------------|---------------------|-----------------------------|
| Karate                  | Chaabène et al., 2015b | § | Yes | Yes | Yes | Reliability NS | Yes |
|                         | Chaabène et al., 2012c | § | Yes | Yes | Yes | 1 week | Yes |
| Karate                  | Chaabène et al., 2012b | §§ | Yes | Yes | Yes | 1 week | Yes |
| Karate                  | Sertić et al., 2011 | §§§ | Partial | NP | Partial | NP | NP |
| Karate                  | Tabbén et al., 2014 | § | Yes | Yes | Partial | NP | 1 week | NP |
| Karate                  | Nunan, 2006 | § | Yes | Partial | NP | 1 week | NP |
| Karate                  | Sterkowicz and Franchini, 2009 | §§§§ | Partial | NP | NP | NP | NP |
| Taekwondo               | Araújo et al., 2017 | § | Yes | Yes | Yes | 2–7 days | Yes |
| Taekwondo               | Sant’Ana et al., 2017 | § | Yes | Partial | NP | Reliability NS | NP |
| Taekwondo               | Chen et al., 2015 | § | Yes | Partial | NP | 1 days | NP |
| Taekwondo               | Rocha et al., 2016 | § | Partial | Partial | Partial | Yes | 1 week | Yes |
| Taekwondo               | Sant’Ana et al., 2014 | § | Yes | Yes | NP | Reliability NS | NP |
| Taekwondo               | Oliveira et al., 2015 | § | Yes | Partial | NP | Reliability NS | NP |
| Taekwondo               | da Silva Santos and Franchini, 2016 | § | Partial | NP | NP | 11 weeks | NP |
| Taekwondo               | Chaabène et al., 2017b | § | Yes | Partial | Yes | 1 week | Yes |
| Amateur boxing          | Smith et al., 2000 | § | Yes | Yes | Yes | NP | NP |
| Amateur boxing          | Obminski et al., 2011 | § | Partial | NP | Yes | NP | NP |
| Judo                    | Santos et al., 2010 | § | Yes | Yes | NP | 1 week | Yes |
| Judo                    | Santos et al., 2012 | § | Yes | Yes | NP | 1 week | Yes |
| Judo                    | Santos et al., 2011 | § | Yes | Yes | NP | Yes | Partial |
| Judo                    | Sogabe et al., 2015 | § | Partial | Partial | NP | Reliability NS | NP |
| Judo                    | Tavara et al., 2016 | § | Yes | Yes | Yes | NP | Reliability NS | Yes |
| Judo                    | Sterkowicz and Franchini, 2001 | §§§ | Yes | NP | NP | Reliability NS | NP |
| Judo                    | Franchini et al., 1998 | § | Partial | NP | NP | Reliability NS | NP |
| Judo                    | Franchini et al., 2011b | § | Yes | NP | NP | Reliability NS | NP |
| Judo                    | Lidor et al., 2005 | § | Yes | Partial | NP | Reliability NS | NP |
| Judo                    | Azevedo et al., 2007 | § | Yes | NP | NP | Reliability NS | NP |
| Judo                    | Morales et al., 2016 | § | Yes | NP | NP | 48–72h | NP |
| Judo                    | Del Vecchio et al., 2014 | §§ | Yes | NP | NP | 48h | Partial |
| Judo                    | de Azevedo et al., 2014 | § | Yes | Yes | NP | Reliability NS | Partial |
| Judo                    | Almansba et al., 2012 | § | Yes | NP | NP | 48h | Yes |
| Judo                    | Franchini et al., 2005 | §§§ | Partial | NP | NP | Reliability NS | NP |
| Wrestling               | Shiyan, 2011 | NP | NP | NP | NP | Reliability NS | NP |
| Wrestling               | Wright et al., 2015 | § | Yes | Partial | Yes | NP | Partial |
| Wrestling               | Utter et al., 1997 | § | Partial | NP | Yes | NP | NP |
| Fencing                 | Bottoms et al., 2013 | § | Partial | NP | NP | Reliability NS | NP |
| Fencing                 | Weichenberger et al., 2012 | §§ | Partial | NP | NP | Reliability NS | NP |
| Fencing                 | Turner et al., 2016 | §§§ | Yes | Partial | Yes | NP | Partial |
| Fencing                 | Tsolakis and Vagenas, 2010 | §§ | Yes | Partial | Yes | NP | NP |

NP, Not provided; NS, not studied; §, less than 30 participants; §§, between 30 and 49 participants; §§§, between 50 and 99 participants; §§§§, more than 100.

51% reported reliability data of the sport-specific test. Test-retest reliability was examined in 85% of the studies that conducted reliability analysis, with 15% dealing with inter/intra-rater reliability. The ICC (range 0.43–1) was used in 80% of the studies and constituted, therefore, the most frequently applied statistical approach to assess reliability in sport-specific tests of Olympic combat sports. The SEM was used in 30% of the identified studies, the CV in 5%, the 95% LoA in 15%, and correlation coefficients in 5% of the studies. Other statistical approaches (i.e., paired sample t-tests and Wilcoxon signed rank tests) were used to establish reliability in 15% of the studies. Only 40% of the studies applied mixed statistical approaches.
| Combat sport discipline | References | Reliability type (statistical approach used and results) | Validity type (statistical approach used) | Sensitivity (statistical approach used) | Minimal detectable change | Feasibility and limitations | Test background | Test duration (s) |
|-------------------------|------------|----------------------------------------------------------|-----------------------------------------|----------------------------------------|--------------------------|-----------------------------|-----------------|------------------|
| Karate                  | Chaabène et al., 2015b | Test – retest NP (Inter/intra-rater reliability NP) | Yes Content (concurrent) (r = 0.14) | NP | NP | Yes | Yes | Yes |
| Karate                  | Chaabène et al., 2012c | Yes (test–retest) (ICC = 0.982) (SEM = 29.37 s) (Inter/intra-rater reliability NA) | Yes Content | NP | NP | Yes | Yes | Yes |
| Karate                  | Chaabène et al., 2012b | Yes (test–retest) (ICC = 0.98) (SEM = 28.5 s) (95% LOA = 9.5 ± 78.8 s) (Inter/intra-rater reliability NA) | Yes Content | NP | NP | Yes | Yes | Yes |
| Karate                  | Sertić et al., 2011 | Yes Test – retest NP (Inter/intra-rater reliability ICC = 0.96) | Yes Content (concurrent) (r = 0.36–0.60) | NP | NP | Yes | Yes | Yes |
| Karate                  | Tabben et al., 2014 | Yes (test–retest) (ICC = 0.99) (SEM = 2.22 s) (Inter/intra-rater reliability NA) | Yes Content (concurrent) (r = 0.81–0.83) | NP | NP | Yes | Yes | Yes |
| Karate                  | Nunan, 2006 | Yes (test–retest) (Wilcoxon signed-rank test) (Inter/intra-rater reliability NA) | Yes Content | NP | NP | Yes | Yes | Yes |
| Karate                  | Sterkowski and Franchini, 2009 | Yes (test–retest) (ICC = 0.82–0.96) (Inter/intra-rater reliability NA) | Yes Content (concurrent) (r = 0.31–0.43) | NP | Partial | Yes | Yes | Yes |
| Taekwondo               | Araujo et al., 2017 | Yes (test–retest) (ICC = 0.70–0.85) (Inter/intra-rater reliability NA) | Yes Content (concurrent) (Paired T-test; 2-way ANOVA; 95% LOA) | NP | NP | Yes | Yes | Yes |
| Taekwondo               | Sant’Ana et al., 2017 | Test– retest NP (Inter/intra-rater reliability NP) | Yes Content (concurrent) (Paired T-test and 95% LOA) | NP | NP | Yes | Yes | Yes |
| Taekwondo               | Chen et al., 2015 | Yes (test–retest) (ICC = 0.43–0.95) (Inter/intra-rater reliability NP) | Yes Content (concurrent) (independent sample t-test). | NP | NP | Partial | Yes | Yes |
| Taekwondo               | Rocha et al., 2016 | Yes (test–retest) (ICC = 0.80–0.93) (Inter/intra-rater reliability NA) | Yes Content (concurrent) (r = 0.55–0.88) (95% LOA) | NP | NP | Partial | Yes | Yes |
| Combat sport discipline | References | Reliability type (statistical approach used and results) | Validity type (statistical approach used) | Sensitivity (statistical approach used) | Minimal detectable change | Feasibility and limitations | Test background | Test duration (s) |
|-------------------------|------------|---------------------------------------------------------|----------------------------------------|--------------------------------------|--------------------------|----------------------------|----------------|-----------------|
| Taekwondo               | Sant’Ana et al., 2014 | Test-retest NP Inter/intra-rater reliability NP | Yes Content Criterion (concurrent) ($r = 0.70-0.89$) | NP | NP | Partial | Yes | Yes |
| Taekwondo               | Oliveira et al., 2015 | Test-retest NP Inter/intra-rater reliability NP | Yes Content Criterion (concurrent) ($r = 0.31-0.86$) | NP | NP | Partial | Partial | Yes |
| Taekwondo               | da Silva Santos and Franchini, 2016 | Yes Test-retest NP (intra-rater) (ICC = 0.99–1.0) | Yes Content | Yes | NP | Yes | Yes | Yes |
| Taekwondo               | Chaabene et al., 2017b | Yes Test-retest (ICC = 0.97) (SEM = 1.82%) Inter/intra-rater reliability NP | Yes Content Criterion (concurrent) ($r = 0.71$) Construct (discriminative) (ROC analysis: area under the ROC curve = 0.94) | Yes | (SWC) | Yes | Yes | Yes |
| Amateur boxing          | Smith et al., 2000 | Test-retest NP Inter/intra-rater reliability NP | Yes Content Construct (discriminative) (Two-way repeated ANOVA) | NP | NP | NP | NP | NP |
| Amateur boxing          | Obminski et al., 2011 | Test-retest NP Inter/intra-rater reliability NP | Yes Content | NP | NP | Partial | Partial | NP |
| Judo                    | Santos et al., 2010 | Yes (test-retest) (Paired sample T-test) Inter/intra-rater reliability NA | Yes Content Criterion (concurrent) (Paired sample T-test) | NP | NP | Partial | Yes | NP |
| Judo                    | Santos et al., 2012 | Yes (test-retest) (Paired sample T-test) Inter/intra-rater reliability NA | Yes Content Criterion (concurrent) (Paired sample T-test) | NP | NP | Partial | Yes | NP |
| Judo                    | Santos et al., 2011 | Test-retest NP Inter/intra-rater reliability NP | Yes Content Criterion (concurrent) (Paired sample T-test) | NP | NP | Partial | partial | NP |
| Judo                    | Sogabe et al., 2015 | Test-retest NP Inter/intra-rater reliability NP | Yes Content Criterion (concurrent) ($r = -0.56$) | NP | NP | Yes | Partial | NP |
| Judo                    | Tavra et al., 2016 | Test-retest NP Inter/intra-rater reliability NP | Yes Content Construct (discriminative) (Independent t-test) | NP | NP | Partial | Partial | Yes |
| Judo                    | Sterkowicz and Franchini, 2001 | Test-retest NP Inter/intra-rater reliability NP | Yes Content Construct (discriminative) (2-way ANOVA) | NP | NP | Partial | Yes | Yes |

(Continued)
| Combat sport discipline | References | Reliability type (statistical approach used and results) | Validity type (statistical approach used) | Sensitivity (statistical approach used) | Minimal detectable change | Feasibility and limitations | Test background | Test duration (s) |
|-------------------------|------------|--------------------------------------------------------|------------------------------------------|----------------------------------------|--------------------------|-----------------------------|----------------|------------------|
| Judo                    | Franchini et al., 1998 | Test-retest NP Inter/intra-rater reliability NP | Yes Content Construct (discriminative) (one way ANOVA) | NP | NP | NP | Partial | Yes |
| Judo                    | Franchini et al., 2011b | Test-retest NP Inter/intra-rater reliability NP | Yes Content Construct (discriminative) (ANOVA) | NP | NP | Partial | Yes | Yes |
| Judo                    | Lidor et al., 2005 | Test-retest NP Inter/intra-rater reliability NP | Yes Content Criterion (predictive) \( r = -0.11 \text{--} -0.31 \) | NP | NP | Partial | Yes | NP |
| Judo                    | Azevedo et al., 2007 | Test-retest NP Inter/intra-rater reliability NP | Yes Content Criterion (concurrent) (Wilcoxon signed rank test) | NP | NP | Partial | Yes | Yes |
| Judo                    | Morales et al., 2016 | Yes Test-retest \( (ICC = 0.91; \ SEM = 0.53 \text{min, and 95\% LOA}) \) Inter/intra-rater reliability NA | Yes Content Criterion (concurrent) \( r = 0.66 \) | NP | NP | Partial | Yes | Yes |
| Judo                    | Del Vecchio et al., 2014 | Yes Test-retest \( (ICC = 0.71 \text{--} 0.93; 95\% LOA) \) Inter/intra-rater reliability NA | Yes Content Criterion (concurrent) \( r = 0.37 \text{--} 0.80 \) Construct (discriminative) (independent sample t-test) | NP | NP | Partial | Yes | Yes |
| Judo                    | de Azevedo et al., 2014 | Test-retest NP Inter/intra-rater reliability NP | Yes Content Criterion (concurrent) (paired sample t-test; \( r = 0.90 \)) | NP | NP | Partial | Yes | NP |
| Judo                    | Almansba et al., 2012 | Yes Test-retest \( (ICC = 0.88 \text{--} 0.99; \ SEM = 0.6 \text{--} 2.1\%) \) Inter/intra-rater reliability NA | Yes content | NP | NP | Partial | Yes | Yes |
| Judo                    | Franchini et al., 2005 | Test-retest NP Inter/intra-rater reliability NP | Yes Content Construct (discriminative) (ANOVA) | NP | NP | NP | NP | Yes |
| Wrestling               | Shiyan, 2011 | Test-retest NP Inter/intra-rater reliability NP | Yes Content | NP | NP | Partial | Partial | NP |
| Wrestling               | Wright et al., 2015 | Yes (test-retest) \( (ICC = 0.95 \text{--} 0.96; \ CV = 9.3 \text{--} 34.3\%) \) Inter/intra-rater reliability NA | Yes Content | NP | NP | Yes | Yes | Yes |

(Continued)
TABLE 4 | Continued

| Combat sport discipline | References | Reliability type (statistical approach used and results) | Validity type (statistical approach used) | Sensitivity (statistical approach used) | Minimal detectable change | Feasibility and limitations | Test background | Test duration (s) |
|-------------------------|------------|--------------------------------------------------------|----------------------------------------|----------------------------------------|------------------------|---------------------------|----------------|-----------------|
| Wrestling               | Utter et al., 1997 | Yes (test-retest) (r = 0.97) Inter/intra-rater reliability NA | Content | NP | NP | Yes | Yes | Yes |
| Fencing                 | Bottoms et al., 2013 | Test-retest NP Inter/intra-rater reliability NA | Content (two-way ANOVA) | | | | | |
| Fencing                 | Weichenberger et al., 2012 | Test-retest NP Inter/intra-rater reliability NA | Content | NP | NP | Yes | Yes | NP |
| Fencing                 | Turner et al., 2016 | Yes Test-retest NP Intra-rater (ICC = 0.95) | Content | NP | NP | Yes | Yes | Yes |
| Fencing                 | Tsolakis and Vagenas, 2010 | Yes Test-retest (ICC = 0.93–0.98) Inter/intra-rater reliability NA | Content | NP | NP | NP | NP | Yes |

NP, not provided; NA, not applicable; ICC, intraclass correlation coefficient; SEM, standard error of measurement; CV, coefficient of variation; SWC, smallest worthwhile change; r, correlation coefficient; LOA, limits of agreement; ROC, Receiving operator characteristic; ANOVA, Analysis of variance; ANCOVA, Analysis of covariance.

To examine relative and absolute reliability as recommended by previous research (Atkinson and Nevill, 1998) and the greater part of them (60%) adopted only one statistical approach (most often ICC [67%]).

Validity and Sensitivity

All reviewed studies presented at least one aspect of test validity. Of note, content validity was addressed in all identified studies. Criterion validity was determined in 54% of the eligible studies, with 95% addressing concurrent validity (r = −0.41 to 0.90) and 5% predictive validity. From the studies that addressed concurrent validity, 60% applied correlation coefficients only, whereas 10% used mixed correlation coefficients with other methods (e.g., 95% LOA, regression analysis), and 30% applied other approaches (e.g., Wilcoxon signed rank test, paired sample T-test, 95% LOA). Construct validity was examined in 31% of the identified 39 studies, with the discriminative side of it (i.e., the ability of the sport-specific test to differentiate performance according to expertise level) being the most important aspect in all studies. This was realized by computing receiver operator characteristic (ROC) analyses, independent sample t-tests, and two-way repeated measures ANOVA. Only 23% of the identified studies addressed content validity, 77% examined mixed aspects (e.g., content with criterion validity, content with construct validity or content with the criterion and construct validity). One of the three sport-specific testing aspects (e.g., content, criterion, and construct validity) was investigated in only 8% of the studies. The sensitivity of sport-specific testing was investigated in 13% of the reviewed studies. These studies mainly calculated the SWC and compared it with SEM (Chaabène et al., 2012a; Chaabene et al., 2017b; Tabben et al., 2014) and one study (da Silva Santos and Franchini, 2016) used data recorded after a 9-week training period to appraise sensitivity of the respective sport-specific test. The MDC50% of the sport-specific test was addressed in 8% of the reviewed studies.

Utility and Limitations

Feasibility and methodological limitations of the sport-specific tests were sufficiently explored in 36% of the included studies, with 51% providing partial details and 13% ignoring this aspect. Information related to the expected use and context of the test was adequately pointed out in 72% of the included studies. Eighteen percent reported limited information on this aspect and 10% ignored this relevant sport-specific aspect. Sport-specific test duration was described in detail in 74% of the included studies and the remaining 26% did not report any information on this issue.

DISCUSSION

The main goal of this study was to examine the methodological quality, validation data, and feasibility of sport-specific tests...
in Olympic combat sports. This is the first study detailing the different methodological approaches adopted so far with sport-specific tests in Olympic combat sports. Results of this study highlighted: (1) emerging academics conversation on sport-specific tests in Olympic combat sports; (2) a disparity in the gender representation of participants; and (3) several methodological gaps in the study of sport-specific testing in Olympic combat sports.

Since 2006 a substantial increase in publication activity has been observed, coherently with the quest of sport-specific testing procedures to evaluate Olympic combat sport athletes. At present, research in sport-specific testing of Olympic combat sports could be considered entering its intermediate stage (Edmondson and McManus, 2007), being characterized by not fully established theories and several methodological shortcomings. In particular, a lack of a “gold standard” technique to assess sport-specific outcomes in peculiar combat sport contexts and valid and reliable tools suited to large-scale assessments limits the generalizability of findings. Furthermore, in considering that ∼40% of the eligible studies focused on judo, the need to develop valid sport-specific tests for athletes practicing other Olympic combat sports emerged.

Overall, a major challenge for the interpretation of sport-specific test data to be used for training periodization is due to methodological limits. Even though researchers have attempted to develop and validate sport-specific tests in Olympic combat sports, future studies should carefully address methodological aspects. More specifically, further research should focus on i) tests that accurately reflect athletes’ sport-specific performance strengths and weaknesses and ii) present good level of predictive validity. Particularly, special attention should be directed toward the recruitment of a wide range of athletes, detailing clear inclusion/exclusion criteria of participants, and presenting sufficient description of their characteristics such as anthropometrics, age, and expertise level. This issue is crucial to guarantee the test-specificity for different populations of athletes, which allows coaches to programme sound individualized training plans. Furthermore, clear and comprehensive information on test procedures is needed so the protocol can be easily reproduced (Morrow et al., 2015). Another aspect to be considered is the provision of information on test-retest reliability, including test-retest intervals, intra- and inter-rater reliability, and the stability of testing conditions, which could determine problems in the interpretation of results (Atkinson and Nevill, 1998; Morrow et al., 2015).

In general, validity, reliability and sensitivity are basic criteria for a test able to assess sport performances. When examining validation data, approximately half of the included studies examined reliability of the sport-specific test using test-retest as the most frequently applied reliability aspect and ICCs were most often computed (80%). Content validity was addressed in all identified studies. Criterion validity and more specifically the concurrent side was assessed in approximately half of the studies, while construct validity received less attention (31% of the studies). Of note, predictive validity was surprisingly neglected. In fact, only one study that examined this test characteristic (Lidor et al., 2005) has been identified. Additionally, few studies examined test sensitivity (13%). Feasibility and methodological limitations were partially reported and/or ignored in the majority of the reviewed (64%) studies. Detailed information related to the expected use and context of the protocol were either partially reported or ignored in 28% of the studies.

**Methodological Quality of the Included Studies**

One major point related to the methodological quality is the limited sample size recruited in the majority of the reviewed studies. It is consensual that sample size is the most critical aspect decoding study's outcome quality and applicability (Hopkins et al., 2009). In this contest, 5 studies included between 50 and 99 participants (Sterkowicz and Franchini, 2001; Sertić et al., 2011; Weichenberger et al., 2012; Turner et al., 2016), one study included more than 100 participants (Sterkowicz and Franchini, 2009), and one study did not provide participants’ number (Shiyan, 2011). This observation seems to be due to the limited number of coaches agreeing their athletes to be involved in such studies. One more issue that may prevent and/or question sport-specific tests to be applied with other population, for instance, amateur and beginner practitioners, is the recruitment of national/international level athletes in most of the studies. Compared with males, females were recruited in two studies (Santos et al., 2012; Tavra et al., 2016), with 28% of the studies recruiting combat sport athletes of both sexes (Tsoulakis and Vagenas, 2010; Obminski et al., 2011; Weichenberger et al., 2012; Del Vecchio et al., 2014; Tabben et al., 2014; Chaabene et al., 2015b; Chaabene et al., 2017b; Oliveira et al., 2015; da Silva Santos and Franchini, 2016; Morales et al., 2016; Turner et al., 2016). This seems to be mainly due to the limited interest and/or opportunity of females in combat sports, as only recently female competitions were included in Olympic boxing and wrestling, for instance. Also, cultural constraints to female participation in combat sports (Miarka et al., 2011) may determine the gender-related discrepancies in the sport sciences literature, which does not mirror the increased participation of women in the last editions of the Olympic Games (International Olympic Committee, 2017b). Therefore, the sports scholars are urged to intensify their efforts to bridge this imbalance between women’s sport participation and scientific information on this specific population.

Details related to the recruited participants were either partially reported or ignored in 33% of the studies (Utter et al., 1997; Franchini et al., 1998, 2005; Sterkowicz and Franchini, 2009; Obminski et al., 2011; Sertić et al., 2011; Shiyan, 2011; Weichenberger et al., 2012; Bottoms et al., 2013; Oliveira et al., 2015; Sogabe et al., 2015; da Silva Santos and Franchini, 2016; Rocha et al., 2016). This issue markedly affects the quality of the study and prevents the sport-specific test of being replicated and used. There is a lack (26% of the studies) and most often absence (46% of the studies) of any inclusion/exclusion criteria and only 28% of the studies sufficiently detailed this aspect. Therefore, future investigations are encouraged to consider clarifying this important research aspect. Despite their relevance in reducing measurement error, mainly systematic bias in terms of learning...
effects (Atkinson and Nevill, 1998), familiarity sessions were considered in only 38% of the studies with the most of them (60% of the studies) neglected this aspect and 2% provided limited details. This may increase sport-specific measurement bias and affect, thereafter, the accuracy of the test. The most adopted test-retest interval in 61% of the reviewed studies was 1 week. It should be noted that the test-retest interval should not be too short to avoid insufficient recovery between tests (Atkinson and Nevill, 1998) or too long to avoid being affected by participant’s skill enhancement between the test and retest (Robertson et al., 2014). However, the exact test-retest interval is mainly dependent on the sport-specific test’s characteristics in terms of complexity, duration, and type of effort required. Regarding the stability of testing conditions, most of the studies did not provide any (59%) or provided partial (13%) details. Again, this may affect the quality and accuracy of the sport-specific outcomes as different environmental conditions, for instance, may considerably influence testing results (Hachana et al., 2012).

Reliability
Reliability is the ability of the testing protocol to provide similar outcomes from day to day when no intervention is used (Atkinson and Nevill, 1998). It is an important testing aspect as it provides indications about the biological as well as technical variation of the protocol (Bagger et al., 2003). From the three main aspects of reliability (i.e., test-retest, intra-, and inter-rater reliability, for in-depth details see Table 1), test-retest reliability represents the most studied sport-specific property (85% of studies that examined reliability) compared with intra/intrarater reliability (15% of the studies) (Table 4). To effectively establish reliability, previous studies recommended determining both types of it i.e., relative and absolute reliability (Atkinson and Nevill, 1998; Weir, 2005; Impellizzeri and Marcara, 2009). To do so, a mixed statistical approach could be used, for instance, ICC which is indicative of the relative reliability of a test and SEM which is indicative of its absolute aspect (Atkinson and Nevill, 1998; Weir, 2005). Results of the current review showed that only few studies applied a mixed approach to examine both relative and absolute reliability of their sport-specific tests (40% of the studies that examined reliability). As this may constitute a limitation, upcoming investigations need to establish both types of reliability. On the other hand, a number of studies used other statistical approaches such as paired sample t-test (10% of the studies that addressed reliability). However, such an approach has been criticized in a previous review (Atkinson and Nevill, 1998) in the way that it does not provide any indication of random variation between tests. Additionally, Bland and Altman (1995) recommended paying attention to the interpretation of paired t-test results of reliability mainly because the detection of a significant difference is actually dependent on the amount of random variation between tests. Overall, to accurately establish sport-specific test’s reliability, it is recommended to calculate both relative and absolute reliability by adopting appropriate statistical approaches. In addition, the other reliability aspects (i.e., inter/intra-rater) need to be investigated in conjunction with test-retest reliability. In that manner, a clear and accurate overview about the sport-specific test’s reliability can be drawn. In fact, ensuring of test’s reliability at first will enable the researcher to move on to check aspects related to validity and sensitivity. Otherwise, the testing protocol will be judged as non-valid. In this regard, Atkinson and Nevill (1998) argued that a measurement tool will never be valid if it provides inconsistent outcomes from repeated measurements.

Validity and Sensitivity
Content validity was established in all the reviewed studies. This is obvious since one of the current study’s inclusion criteria is to deal with a sport-specific testing. Content validity was generally assumed (i.e., in 98% of the studies) by mainly referring to the specific literature and appraisal of the actual competition/comb requirements. However, only one study (Tabben et al., 2014) established this test’s quality through a mixing of previous consultation with combat sports practitioners, coaches, sports scientists, and a review of the literature and competition requirements. Criterion validity was addressed in approximately half of the reviewed studies. The major part of these studies (95%) considered concurrent validity. Concurrent validity was generally studied by associating the sport-specific testing’s outcome with a gold standard protocol (e.g., treadmill running test, cycle ergometer test). These gold standard tests are based on actions and thereafter involve muscle groups that are not combat sport specific, which may affect findings related to test’s property (e.g., results reflective of a poor concurrent validity when the test reflect the true sport-related effort or findings indicative of good concurrent validity when the test did not reflect the true sport-related effort). From the whole eligible studies considered in this review, only one study addressed predictive validity (Lidor et al., 2005). This is particularly surprising in view of the critical importance of such a testing’s property for coaches, strength and conditioning professionals, and combat sports athletes (Currell and Jeukendrup, 2008; Robertson et al., 2014). Therefore, future studies are encouraged to establish this important sport-specific testing’s aspect.

Compared with criterion validity, construct validity received less attention in the literature (31% of the studies). Of note, only the discriminative side of construct validity was addressed by mainly comparing combat sports practitioners with a different competitive level and/or background (e.g., international vs. national level, elite vs. sub-elite) (Franchini et al., 1998, 2005, 2011b; Smith et al., 2000; Sterkowicz and Franchini, 2001; Tsolakis and Vagenas, 2010; Chaabene et al., 2012c; Chaabene et al., 2017b; Weichenberger et al., 2012; Del Vecchio et al., 2014; Chen et al., 2015; Tavra et al., 2016). To do so, the main statistical approach used were ROC analysis (Chaabene et al., 2012c; Chaabene et al., 2017b), independent sample t-test (Tosolakis and Vagenas, 2010; Weichenberger et al., 2012; Del Vecchio et al., 2014; Chen et al., 2015; Tavra et al., 2016), two-way repeated measures ANOVA (Franchini et al., 1998, 2011b; Smith et al., 2000; Sterkowicz and Franchini, 2001), and ANCOVA (Franchini et al., 2005). Nevertheless, as ROC analysis seems to be the more appropriate statistical approach to study discriminative ability of a test (Chaabene et al., 2012c; Chaabene et al., 2017b; Castagna et al., 2014), future investigations are recommended to use this
approach. Regarding convergent validity, it was not studied in any of the reviewed studies. This seems to be due to the fact that creating a new sport-specific test is mainly due to a gap in the literature so there is no previous protocol to compare with the new one (Steiner and Norman, 2005). It is noteworthy that 8% of the studies (Weichenberger et al., 2012; Del Vecchio et al., 2014; Chaabene et al., 2017b) addressed, at least, one aspect of the three sport-specific properties (i.e., content, criterion, and construct validity). This observation may constitute another gap in the literature because, to be considered valid and applicable, a sport-specific test should cover the whole validity aspects (i.e., content, criterion, and construct validity). Therefore, a particular focus in the future investigations should be given to examining all validity properties of sport-specific performance testing in Olympic combat sports.

Another important property related to sport-specific testing is the sensitivity (Currell and Jeukendrup, 2008; Impellizzeri and Marcara, 2009). Findings of the current review showed that only 4 studies examined this aspect (Chaabène et al., 2012c; Chaabene et al., 2017b; Tabben et al., 2014; da Silva Santos and Franchini, 2016). Additionally, despite its importance from a practical point of view, the minimal detectable change was investigated in only 3 studies (Chaabène et al., 2012a; Chaabene et al., 2017b; Tabben et al., 2014). Therefore, more research dealing with these two determinant aspects are required.

Utility and Limitations

In reviewing studies that aimed to validate sport-specific tests, thorough details about the applicability (i.e., whether it is easy to administer and scored) and the limits of the test in question were expected. However, most of the selected studies (64%) either partially detailed or ignored this valuable aspect. Details related to sport-specific test background were either partially or even ignored in 28% of the studies (Franchini et al., 1998, 2005; Smith et al., 2000; Tsolakis and Vagenas, 2010; Obminski et al., 2011; Santos et al., 2011; Sertić et al., 2011; Shiyan, 2011; Oliveira et al., 2015; Sogabe et al., 2015; Tavra et al., 2016). Therefore, future investigations should pay attention to these central sport-specific tests' aspects.

LIMITATIONS

Because of the variety of statistical approaches used to assess sport-specific measurements properties, it was not possible to perform any meta-analysis (Robertson et al., 2014). Additionally, compared with other sporting activities such as team sports, scientific contributions on combat sports in indexed journals are limited, with studies mainly published in non-indexed journals (i.e., gray literature) or remain even unpublished. Therefore, the stringent search approach adopted in this review has neglected information available to coaches in specific technical magazines and websites.

CONCLUSIONS AND FUTURE RECOMMENDATIONS

Establishing valid sport-specific tests that assess the actual physical fitness and/or physiological attributes of Olympic combat sports practitioners still one of the major concerns for sports sciences scholars. After reviewing 39 studies in different Olympic combat sports disciplines (e.g., karate, taekwondo, amateur boxing, judo, wrestling, and fencing), several methodological gaps have been pointed-out. These limits may prevent sport-specific testing from being widely used. These limitations are mainly related to the small sample size, backgrounds of participants, being elite level in most of the studies, sex (mainly males), lack of details about the inclusion/exclusion criteria in most of the studies, lack of familiarization session prior to testing, and paucity of details about stability of testing conditions. Additionally, both types of reliability (e.g., relative and absolute) have rarely been addressed in the reviewed studies and the available results showed reliability levels ranging from poor to excellent. Moreover, despite its critical importance, predictive validity was reported in only one study. Similarly, compared with criterion validity, construct validity received less attention by researchers. Studies addressing, at least, one aspect of the three main validity properties are limited. All these concerns may limit the applicability, generality, and accuracy of outcomes of sport-specific testing in Olympic combat sports. Additional research should adopt more strict validation procedures by addressing reliability, validity, and sensitivity in the application and description of sport-specific performance tests in Olympic combat sports. Additionally, predictive validity should receive more attention in future research.

AUTHOR CONTRIBUTIONS

HC: Worked on study design, data collection, data analysis, and manuscript preparation. YN: Worked on data collection, data analysis, and manuscript preparation. RB: Assisted on data collection and analysis and worked on manuscript preparation. LC: Assisted in study design and worked on manuscript preparation. EF: Worked on manuscript preparation. OP: Worked on manuscript preparation. HH: Worked on manuscript preparation. UG: Data analysis and manuscript preparation.

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