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ENDURANCE ASSESSMENT IN HANDBALL: A SYSTEMATIC REVIEW

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ABSTRACT

Introduction: recent research has shown that although training stimuli for high-intensity endurance training should be given more attention in the full handball training season planning, a high aerobic capacity appears to be important to maintain a high level of performance over the 60 minutes of playing time. In spite of there are many different tests to evaluate endurance in this way, these are used without clear logic, independently of age, level or gender. Reviewing in the current literature the endurance test carried out in the handball sport could be the first step to clarify this problem. Methods: articles published between 2002 and 2019 in PubMed, Web of Science and SPORT Discuss, in English or Spanish languages, observational and experimental studies that evaluated endurance outcomes in handball players of any age were selected. Results: 50 studies measured anaerobic efficiency and 63 studies measured aerobic efficiency, involved 3,649 handball players of different age categories. Conclusions: a great variety of studies have shown the importance to choose field-specific tests to assess anaerobic and aerobic efficiency, being shuttle RSA tests and Yo-Yo IR1 test the most reliable and used test in this sense.

Keywords: sports performance, testing, anaerobic threshold, physical endurance

EVALUACIÓN DE LA RESISTENCIA EN BALONMANO: UNA REVISIÓN SISTEMÁTICA

RESUMEN

Introducción: Aunque recientes estudios han mostrado que el entrenamiento de resistencia de alta intensidad debería tener más protagonismo en la planificación completa de una temporada de balonmano, una alta capacidad aeróbica también podría ser importante para mantener el nivel de rendimiento a lo largo de los 60 minutos de un partido. A pesar de que existen en la literatura diferentes test para evaluar la resistencia, suelen ser usados sin una clara lógica, independientemente de la edad, nivel o género. Una revisión de la literatura científica en cuanto a los test de resistencia utilizados en el balonmano podría ser un primer paso para solucionar esta problemática. Métodos: En las conocidas bases de datos Pubmed, Web of Science y Sport Discuss fueron seleccionados artículos publicados entre 2002 y 2019 escritos en inglés o en español, de carácter observacional o experimental que evaluaban la resistencia en jugadores de balonmano. Resultados: Cincuenta estudios evaluaron la eficiencia anaeróbica y 63 la eficiencia aeróbica, involucrando 3.649 jugadores de diferentes categorías. Conclusiones: A pesar de que una amplia variedad de test específicos para evaluar la eficacia aeróbica y anaeróbica en jugadores de balonmano son utilizados en la bibliografía científica, el test de sprint repetidos y el test Yo-Yo IR1 son los más frecuentes y los más fiables.

Palabras clave: rendimiento deportivo, evaluación, umbral anaeróbico, resistencia física

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INTRODUCTION

Requirements for team handball players have changed as the game of handball has evolved substantially. In 2002, rule changes have contributed to elevating the intensity of game-play and increasing the physical demands imposed on the players (Michalsik, Aagaard, & Madsen, 2013). Research about determinate factors has grown exponentially over the last years (H Wagner, Finkenzeller, Wurth, & von Duvillard, 2014). However, it has to be known that the evidence-based knowledge for trainers and sport scientists is limited (Manchado, Cortell-Tormo, & Tortosa-Martinez, 2018), and therefore more research about this topic is necessary. Determining the factors that influence performance in team-handball based on scientific studies should contribute to the increase in quality of training as well as to develop specific measuring methods and tests from scientific studies (H Wagner et al., 2014).

Recent research has shown that most of distance covering handball players during a match is spent performing low-intensity aerobic exercise actions interspersed by a short duration of very high-intensity anaerobic actions (Povoas et al., 2012). Mean intensity to exercise was 82 ± 9.3% of maximal heart rate (HRmax) in male handball players. A recent study showed that during a female elite team handball match, high aerobic demands (~80 % of maximum oxygen intake (VO2max)) interspersed by very brief time periods of substantial anaerobic energy production (~1 % of total effective playing time per match) on the players were observed (Michalsik et al., 2013). So, although training stimuli for high-intensity endurance training should be given more attention in the full training season planning, a high aerobic capacity appears to be important to maintain a high level of performance over the 60 minutes of playing time (Manchado et al., 2013).

A careful approach to the selection of test protocols and testing phases should be adopted by handball and conditioning coaches (Ziv & Lidor, 2009). In some studies, testing was conducted with cycle ergometer test. This type of tests may underestimate VO_2max values because handball players are not used to cycling, and therefore, local muscular fatigue may be responsible for general fatigue before the subject reaches his or her cardiovascular system limits (Ziv & Lidor, 2009). A previous study examined VO_2max using a portable metabolic system, a high-intensity intermittent endurance test and a field-graded exercise test (M Buchheit et al., 2009). The authors suggested that field-graded exercise test could underestimate the real values of aerobic capacity because different factors such as motivation or methodology could interfere in the results.

To the best of our knowledge, there are many different tests to evaluate endurance in this way. These are used without clear logic, independently of age, level or gender. Reviewing in the current literature the endurance test carried out in the handball sport could be the first step to clarify this problem. So, next step could be developed specific measuring methods and tests from scientific studies. Thus, the aim of this article was to summarise current scientific knowledge about endurance assessment in handball players of different ages and categories.

METHOD

Search strategy

This systematic review was undertaken in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Liberati et al., 2009). Articles published before 10 April 2019 were retrieved by using searches of PubMed, Web of Science and SPORT Discuss. The search terms used in the search utilising multiple combination of AND/OR phrases were, utilising both MeSH and free-text terms: handball, team-handball, physical-examination, fitness, endurance, sprint, agility, physical education, training, fatigue, athletic performance, match, test, adaptations physiological, heart rate.

Selection and review process

Titles and abstracts were reviewed to determinate if the studies met the following inclusion criteria, by two authors (ACC and MCC) independently: 1) articles published between January 2002 and April 2019 of the English or Spanish languages literature; 2) focus on handball players of any age were included; 3) measured endurance outcomes with test or battery. If they met the inclusion criteria or if the title and abstract did not provide enough information, full articles of these studies were obtained to apply the criterion to full-text by the same two authors. Discrepancies between the two reviewers about studies selection were resolved by consensus with a third author (JBS). Information was extracted from each including original article on: characteristics of handball players (age category and size sample) and characteristics of test (test and measured variables).

Risk of bias

Given that there is no consensus regarding reliable and valid instruments for the assessment of methodological quality of observational studies (Mallen, Peat, & Croft, 2006), no rating of studies was conducted. For experimental studies, the Physiotherapy Evidence Database (PEDro) scale was used to quantify the quality of the included studies on a scale from 0 to 10 point, which ≥6 points representing a cut-off score for high-quality studies (Maher, Sherrington, Herbert, Moseley, & Elkins, 2003).

Two authors applied the scales (MCC and ACC) independently. Inter-rater reliability was analysed using the following equation for the kappa statistic: κ =

[Pr(a) Pr(e)] / [1 Pr(e)], where Pr(a) is the relative observed agreement among raters, and Pr(e) is the hypothetical probability of chance agreement, using the observed data to calculate the probabilities of each observer randomly assigning each category. No studies were eliminated and no additional subgroup analysis was undertaken on the basis of methodological quality.

RESULTS

Study selection

The initial electronic database search resulted in a total of 448 citations of PubMed, 560 of Web of Science and 273 of SPORT Discuss (Figure 1). After deleting duplicates (n=466), 812 articles were analysed in title and abstract, applied the inclusion criteria. Four hundred and six were excluded and 406 potentially relevant studies were selected for the full-text review. Eighty-four original studies were identified in our systematic search from which data were extracted. Studies were divided according to the measured variable. Forty-eight studies measured anaerobic efficiency (Table 1), 72 studies measured aerobic efficiency (Table 2).

TABLE 1
Test to evaluate anaerobic efficiency.

Test Name	Outcome Measure	References
Astrand Rhyming Test	Blood Lactate (mmol·L^{-1}) Heart Rate (bpm)	Shalaby, Liu, Saad, and Elaraby (2012)
Wingate 30-sec Test	Maximal Power (W) (W·kg^{-1}) Maximal Power (W) (W·kg^{-1}) Minimal Power (W) (W·kg^{-1}) Total Work (J: J·kg^{-1}) Time approaching Maximal Power (s) Time sustaining Maximal Power (s) Index of Power decrease (%) Fatigue Index (%) Blood Lactate (mmol·L^{-1})	Bencke et al. (2002) Nikolaidis and Ingebrigtsen (2013a) Nikolaidis and Ingebrigtsen (2013b) Nikolaidis, Ingebrigtsen, Povoas, Moss, and Torres-Luque (2015) Nikolaidis et al. (2016) Luszczyk, Laskowski, Ziemann, Grzywacz, and Szczesna-Kaczmarek (2009) Boraczyhski and Urniaz (2008) Jadach and Ciepliński (2008) Jafarzadeh and Nasiri (2012) Vargas, Dick, de Santi, Duarte, and da Cunha Júnior (2008) Kale (2016)
Bosco 30-sec Test	Average Power (W·kg^{-1})	Nikolaidis and Ingebrigtsen (2013b) Nikolaidis, Ingebrigtsen, Povoas, Moss, and Torres-Luque (2015) Nikolaidis et al. (2016)
Margaria Test	U	Saša, Popoviċ, Iliċ, and Mekiċ (2014)
800-m Test	U	Eugen, Zenovia, and Constantin (2014)
2x400-m Test	U	Eugen, Zenovia, and Constantin (2014)
400-m Test	Time (s) Blood Lactate (mmol·L^{-1}) Heart Rate (bpm) Running Speed (m·s^{-1}) Running Speed AnT (m·s^{-1})	Xhemaili (2012) Kruger, Pilat, Uckert, Frech, and Mooren (2014)
300-m Running Test	Time (s)	Vicente-Rodriguez, Dorado, Perez-Gomez, Gonzalez-Henriquez, and Calbet (2004)
300-yard Shuttle Run Test	Blood Lactate (mmol·L^{-1}) Time (s)	Sporis et al. (2014)

Four-Stage Submaximal Discontinuous Progressive Running Test	Blood Lactate (mmol·L-1) Submaximal Velocity (km·h-1) Heart Rate (bpm)	Gorostiaga, Granados, Ibanez, and Izquierdo (2005) Gorostiaga, Grandados, Ibanez, Gonzalez-Badillo, and Izauierdo (2006) Granados, Izquierdo, Ibanez, Bonnabau, and Gorostiaga (2007) Granados, Izquierdo, Ibanez, Ruesta, and Gorostiaga (2008) Granados, Izquierdo, Ibanez, Ruesta, and Gorostiaga (2013)
Maximal Intermittent Test-to-Exhaustion	Endurance Index	Buchheit et al. (2009)
5x30-m Test	Time (s)	Eugen, Zenovia, and Constantin (2014) Ţugurlan, Benedek, and Leuciuc (2011) CuriŢIanu and NeamŢU (2014)
8x30-m Test	Best Sprint Time (s) Time Total (s) Fatigue Index (%)	Romaratezabala, Nakamura, Castillo, Gorostegi-Anduaga, and Yanci (2018)
RSA 6x10-m Test	Time (s)	Ingebrigtsen and Jeffreys (2012)
RSA 6x30-m Test	Time (s)	Ingebrigtsen and Jeffreys (2012) Alonso-Fernandez, Lima-Correa, Gutierrez-Sanchez, and Abadia-Garcia de Vicuna (2017) Hermassi, Schwesig, et al. (2017) Schwesig et al. (2017)
RSA 6x12.5-m Test	Best Sprint Time (s) Average Sprint Time (s) Sprint Decrement (%)	Della Iacono, Ardigo, et al. (2016) Della Iacono, Ardigo, et al. (2016)
RSA 6x20-m Test	Best Sprint Time (s) Average Sprint Time (s) Sprint Decrement (%)	Germano et al. (2017) Hammami, Gaamouri, Aloui, Shephard, and Chelly (2018) Chaabene et al. (2019) Hammami, Gaamouri, Aloui, Shephard, and Chelly (2018)
RSA 6x2x15-m Test	Best Sprint Time (s) Average Sprint Time (s) Sprint Decrement (%)	Buchheit et al. (2009) Okuno et al. (2013) Hermassi et al. (2014) Hermassi et al. (2016) Hermassi, Chelly, et al. (2017) Hermassi, Hoffmeyer, et al. (2018) Cherif, Said, et al. (2012) Cherif, Mohamed, Najlaoui, and Gomri (2012) Hermassi, Schwesig, et al. (2017) Hermassi, Schwesig, et al. (2017)

Running Anaerobic Sprint Test	Average Running speed (m·s^{-1}) Fatigue Index (%)	Carvalho et al. (2018)
Repeated Change of Direction Performance (6x20m sprints)	Best Sprint Time (s) Average Sprint Time (s) Sprint Decrement (%)	Aloui et al. (2018)
Repeated Agility Run	Best Sprint Time (s) Average Sprint Time (s)	Andersen, Fimland, Cumming, Vraalsen, and Saeterbakken (2018)
RS T Test	Best Sprint Time (s) Average Sprint Time (s) Time Total (s) Fatigue Index (%)	Hammami, Gaamouri, Aloui, Shephard, and Chelly (2019)
RSSJA Test	Best Sprint Time (s) Average Sprint Time (s) Sprit Time (%)	Moss and Twist (2015) Mhenni et al. (2017)
Gamed-Based Performance Test	Heart Rate (bpm) Blood Lactate (mmol·L^{-1})	Hermassi, Hoffmeyer, et al. (2018) Schwesig et al. (2017)

** Note. AnT: anaerobic threshold; RSA: Repeat Sprint Ability; RSSJA: Repeat Shuttle Sprint and Jump Ability*

TABLE 2
Test to evaluate aerobic capacity.

Test name	Outcome measure	Reference
3000-m Running Test	Times (min: s)	Haugen, Tonnessen, and Seiler (2014) Haugen, Tonnessen, and Seiler (2016)
PWC170 Test	VO_2max (ml·kg^{-1})	Boraczyhski and Urniaz (2008)
Ruffier Test	U	Eugen et al. (2014)
Bruce Protocol	VO_2max (ml·kg^{-1}·min^{-1})	Vargas et al. (2008)
Astrand Rhyming	VO_2max (ml·kg^{-1}·min^{-1})	Shalaby et al. (2012)
Incremental Maximal Exercise Test	VO_2max (ml·kg^{-1}·min^{-1}) Heart Rate (bpm) Maximal Running speed (km·h^{-1}) Blood lactate (mmol·L^{-1}) VE max (L·min^{1}) Fitness Index (ml·L^{-1}·kg^{-1})	Sporis, Vuleta, Vuleta, and Milanovic (2010) Mazurek et al. (2018) Manchado et al. (2013) Michalsik, Madsen, and Aagaard (2014) Michalsik and Aagaard (2015) Kale (2016) Wagner et al. (2017) Wagner, Sperl, Bell, and von Duvillard (2019) Pontaga and Zidens (2018)
30-15 IFT	V_{IFT} (km/h) Time running at 100% V_{IFT} (s) Time running at 90% V_{IFT} (s) Time running at 95% V_{IFT} (s) Intermittent Endurance Index VO_2max (ml·kg^{-1})	Buchheit et al. (2009) Perandini et al. (2009) Karpan, Škof, Bon, and Šibila (2015) Viano-Santasmarinas et al. (2018)
Cooper Test	Distance (m) Time (s) VO_2max (ml·kg^{-1}·min^{-1})	Ţugurlan et al. (2011) Djordjevic et al. (2011) CuriŢIanu and NeamŢU (2014) Jadach and Ciepliński (2008)

20m-Shuttle Run Test	Time (min) Running Speed (km·h^{-1}) VO_2max (ml·kg^{-1}·min^{-1}) Repetition (n)	Vicente-Rodriguez et al. (2004) Chaouachi et al. (2009) Galal El-Din, Zapartidis, and Ibrahim (2011) Zapartidis, Nikolaidou, Vareltzis, and Kororos (2011) Zapartidis, Kororos, Christodoulidis, Skoufas, and Bayios (2011) Rousanoglou, Noutsos, and Bayios (2014) Mohamed et al. (2009) Maurelli, Bernard, Dubois, Ahmaidi, and Prioux (2018) Maurelli, Bernard, Dubois, Ahmaidi, and Prioux (2019) Carvalho et al. (2018) Alonso-Fernandez et al. (2017) Hammami et al. (2019) Fernandez-Romero et al. (2017)
Yo-Yo Intermittent Recovery 1	Distance (m) Running Speed (km·h^{-1}) Maximal Heart Rate (bpm) Blood lactate (mmol·L^{-1}) VO_2max (ml·kg^{-1}·min^{-1})	Matthys et al. (2013) Michalsik et al. (2014) Moss, McWhannell, Michalsik, and Twist (2015) Cherif, Said, et al. (2012) Cherif, Mohamed, et al. (2012) Della Iacono, Eliakim, and Meckel (2015) Della Iacono, Ardigo, et al. (2016) Souhail, Castagna, Mohamed, Younes, and Chamari (2010) Hermassi et al. (2015) Hermassi et al. (2016) Hermassi, Schwesig, et al. (2017) Hermassi, Chelly, et al. (2017) Hermassi, Schwesig, et al. (2018) Schwesig et al. (2017) Penna et al. (2018) Van Den Tillaar, Waade, and Roaas (2015) Romaratezabala et al (2018)

Yo-Yo Intermittent Recovery 2	Distance (m) Running Speed (km·h^{-1})	Kvorning, Hansen, and Jensen (2017) Marković, Vučković, Sekulić, and Gadžić (2015) Saavedra et al. (2018)
Yo-Yo Endurance Test 2	Distance (m) Maximal Heart Rate (bpm)	Massuca, Branco, Miarka, and Fragoso (2015) Milanez, Ramos, Leprêtre, Leme, and Nakamura (2014)
Course Navette	VO_2max (ml·kg^{-1}·min^{-1})	Manchado, Cortell-Tormo, and Tortosa-Martinez (2018) Camacho-Cardenosa et al. (2018)
Multistage Aerobic Efficiency Test	VO_2max (ml·kg^{-1}·min^{-1}) Maximal Heart Rate (bpm) Maximal Ventilation (L·min^{-1}) Blood lactate (mmol·L^{-1}) AnT (min)	Jadach and Ciepliński (2008)
Gamed Based Performance Test	VO_2max (ml·kg^{-1}·min^{-1}) Heart Rate (bpm) Blood lactate (mmol·L^{-1}) Running Time (s)	Wagner et al. (2017) Wagner, Sperl, Bell, and von Duvillard (2019)

Note. PWC_{170}: Physical Work Capacity to 170 ppm; VO_2max: maximum oxygen uptake; U: unable to determine; IFT: Intermittent Field Test; VE: peak respiratory minute volume; V_{IFT}: velocity reached at the end of the 30-15_{IFT} test.

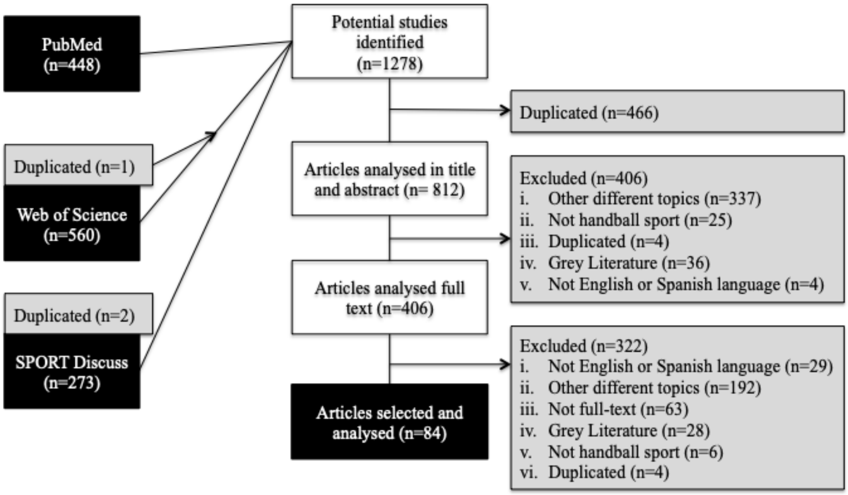

FIGURE 1: Flowchart of search strategy.

Study population

Regarding with endurance, the included studies involved 3,640 handball players of different age categories: 1,994 senior players, 135 players U20, 268 players U18, 906 players U16 and 337 players U14.

Measurement of endurance performance

Anaerobic efficiency: seventeen different tests were used to measure anaerobic efficiency. A modification of Astrand Ryhming test - for anaerobic exercise 100w increment, 30-sec stage protocol by adding 50 watios each- (n=1) and Wingate 30-sec test (n=12) were used on cycloergometer to evaluate blood lactate (mmol·L-1), HR (bpm), maximal, average and minimal power (W), fatigue index (%), maximum anaerobic efficiency (W·kg-1), time approaching/sustaining maximal power (s), total work (J) and power decrease index (%). Average relative power lower limbs (W·kg-1) were evaluated with Bosco test 30-sec (n=3) in a jump vertical protocol.

Margaria test (n=1), 800-m test (n=1), 2x400-m test (n=1), 5x30-m test (n=3), 8x30-m test (n=1); 400-m test (n=2), 300-m running test (n=2), 300-yard shuttle run test (n=1), four-stage submaximal discontinuous progressive running test (n=5) and maximal intermittent test-to-exhaustion (n=1) are running test that were used to evaluate anaerobic efficiency through time (s), blood lactate (mmol·L-1), HR (bpm) and running speed (m·s-1); running speed at the anaerobic threshold (m·s-1), submaximal velocity (km·h-1) and endurance index for short intermittent runs.

Other intermittent running test were used to evaluate best and average sprint time (s), sprint decrement (%), average running speed (m·s-1) and time (s): RSA 6x2x15-m test (n=7), RSA 6x10-m test (n=1), RSA 6x12.5-m test (n=2), RSA 6x20-m test (n=4), RSA 6x30-m test (n=4), Repeat Sprint T Test (RS T Test) (n=2), Running Anaerobic Sprint Test (n=1) and Repeat Agility Run (n=1). Blood lactate (mmol·L-1), HRmax (bpm), best and average sprint (s) and sprint decrement (%) were evaluated in two specific handball test: Gamed-Based Performance test (n=2) and Repeated Shuttle Sprint and Jump Ability (RSSJA) test (n=2).

Aerobic efficiency: was evaluated with 13 different tests. Physical work capacity to 170 ppm (PWC170) test (n=1), 3000m- Running Test (n=2), Ruffier test (n=1), Bruce protocol (n=1), a modification of Astrand Ryhming test - for aerobic exercise 50w increment, 3-min stage protocol by adding 25 watios each- (n=1), 1-min Incremental Maximal exercise test (n=2), Incremental Treadmill Running test (n=7), 30-15 Intermittent field test (IMT; n=4), Cooper test (n=4), multistage aerobic efficiency test (n=1), 20-m shuttle run test (n=13), Yo-Yo intermittent recovery 1 (n=16), Yo-Yo endurance test 2 (n=6) and Course Navette Test (n=2) were used to measure VO_2max (ml·min-1, L·min-1 or ml·kg-1·min-1), HRmax (bpm), running speed (km·h-1), blood lactate (mmol·L-1) and fitness index (ml·L-1·kg-1), velocity reach and the end of the 30-15 IFT (VIFT; km·h-1); time running at 90, 95 and 100% VIFT (s), intermittent endurance index, distance (m), time (s or min), anaerobic threshold (min) or level (position achieve using a four point scale in a yo-yo endurance test 2). Gamed-Based Performance test, a specific handball test, has been used in two studies to VO_2max (ml·kg-1·min-1).

Risk of bias

Median quality score for intervention studies was 4.39 point (standard deviation 0.66), which can be interpreted as low methodological quality. Eight studies reached the pre-determined cut-off score of ≥6 points (see Table 3).

TABLE 3
Mythological quality of included experimental studies.

Study	1	2	3	4	5	6	7	8	9	10	11	Score	Evidence
Abade et al. (2014)	y	n	n	n	n	n	n	y	y	n	y	3	C
Alonso-Fernandez et al. (2017)	y	y	n	y	n	n	n	y	n	y	y	5	B
Aloui et al. (2018)	n	y	n	y	n	n	n	y	n	y	y	5	B
Andersen et al. (2018)	n	y	y	y	y	n	n	y	n	y	y	7	B
Boraczyhski and Urniaz (2008)	n	n	n	n	n	n	n	y	y	n	y	3	C
Boraczyński and Urniaż (2008)	n	n	n	n	n	n	n	y	y	n	y	3	C
Buchheit et al. (2009)	y	y	n	y	n	n	n	y	y	y	y	6	C
Carvalho et al. (2018)	y	y	y	y	y	n	y	y	n	y	y	8	A2
Chaabene et al. (2019)	n	n	n	y	n	n	n	y	n	y	y	4	C
Cherif, Said, et al. (2012)	y	n	n	n	n	n	n	y	y	y	y	4	B
Emeish (2015)	n	n	n	n	n	n	n	y	y	y	y	4	B
Germano et al. (2017)	y	n	n	n	n	n	n	y	y	n	y	3	C
Gorostiaga et al. (2006)	y	n	n	n	n	n	n	y	y	n	y	3	C
Granados et al. (2008)	y	n	n	n	n	n	n	y	y	n	y	3	C
Hammami et al. (2018)	n	y	n	y	n	n	n	y	n	y	y	5	B
Hammami et al. (2019)	n	y	n	y	n	n	n	y	n	y	y	5	B
Hermassi et al. (2014)	y	n	n	y	n	n	n	y	y	y	y	5	B
Hermassi et al. (2016)	y	y	n	y	n	n	n	y	y	y	y	6	B
Hermassi, Chelly, et al. (2017)	y	y	n	y	n	n	n	y	y	y	y	6	B
Della Iacono et al. (2015)	y	y	n	y	n	n	n	y	y	y	y	6	B
Della Iacono, Ardigo, et al. (2016)	y	y	n	y	n	n	n	y	y	y	y	6	C
Della Iacono, Eliakim, et al. (2016)	y	n	n	y	n	n	n	y	y	y	y	5	C
Jafarzadeh and Nasiri (2012)	n	y	n	y	n	n	n	y	y	y	y	6	B
Kale (2016)	n	n	n	y	n	n	n	y	y	y	y	5	B
Kvorning et al. (2017)	y	n	n	n	n	n	n	y	y	n	y	3	C
Penna et al. (2018)	n	n	n	n	n	n	n	y	n	y	y	3	C
Manchad et al. (2018)	n	n	n	y	n	n	n	y	n	y	y	4	C
Maurelli et al. (2018)	y	n	n	n	n	n	n	y	n	y	y	3	C
Maurelli et al. (2019)	n	n	n	n	n	n	n	y	n	y	y	3	C
Mazurek et al. (2018)	n	y	n	y	n	n	n	y	n	y	y	5	B
Milanez et al. (2014)	y	n	n	n	n	n	n	y	y	n	y	3	C
Moss and Twist (2015)	y	y	n	n	n	n	n	y	y	n	y	4	C
Okuno et al. (2013)	y	n	n	n	n	n	n	y	y	n	y	3	C
Ţugurlan et al. (2011)	y	n	n	n	n	n	n	y	y	n	y	3	C
Van Den Tillaar et al. (2015)	y	n	n	n	n	n	n	y	y	n	y	3	C
Viano-Santasmarinas et al. (2018)	y	y	n	y	y	n	n	y	n	y	y	5	B

Note1: eligibility criteria were specified; 2: subjects were randomly allocated to groups or to a treatment order; 3: allocation was concealed; 4: the groups were similar at baseline; 5: there was blinding of all subjects; 6: there was blinding of all therapists; 7: there was blinding of all assessors; 8: measures of at least one key outcome were obtained from more than 85% of the subjects who were initially allocated to groups; 9: intention-to- treat analysis was performed on all subjects who received the treatment or control condition as allocated; 10: the results of between-group statistical comparisons are reported for at least one key outcome; 11: the study provides both point measures and measures of variability for at least one key outcome; total score: each satisfied item (except the first) contributes 1 point to the total score, yielding a PEDro scale score that can range from 0 to 10. CBO: the level of evidence was B and C; n: criterion not fulfilled; y: criterion fulfilled.

DISCUSSION

The purpose of this systematic review was to summarise current scientific knowledge about endurance assessment in handball players of different ages and categories. Seventy-one studies were included in this systematic review that measured anaerobic or aerobic efficiency in 3,649 handball players. U16 and senior players, male and female, were the most common samples used by the researches. So, there are no batteries of standard test for adult or young players to assess endurance in handball players. It is important to mention that the quality of the included intervention studies of present systematic review is rather low (Table 3). Similarly, previous systematic review highlighted the low methodology quality of literature for different intervention in athletes from different sports (Prieske, Muehlbauer, & Granacher, 2016; Stuber, Bruno, Sajko, & Hayden, 2014). In order to scientifically contribute to this results field, further high quality studies are needed to determinate most reliable assess.

Anaerobic efficiency

Sprint (specially short-duration, i.e., <10 seconds) and high-intensity intermittent efforts are very common in team-sports such as handball, basketball and soccer. It well-known that the anaerobic ATP production during short-duration sprinting is provided by considerable contributions from phosphocreatine (PCr) degradation, but by the fact that PCr stores are limited during this type of effort, anaerobic glycolysis is supported (Spencer, Bishop, Dawson, & Goodman, 2005). Studies reviewed in this systematic review have used cycle ergometers (specially in Wingate test), treadmills (specially four-stage submaximal discontinuous progressive test) or over-ground running as the mode of exercise. Because mode of exercise may have an influence on performance, different studies (Fitzsimons, Dawson, Ward, & Wilkinson, 1993; Spencer et al., 2005) suggested that the mode of exercise should be specific to the sports, i.e., over-ground running for team sports such as handball.

Field performance test that involve several sprints interspersed with brief recovery periods elicit physiological responses similar to intensive handball match (Souhail Hermassi et al., 2017). These sports are characterized by multiple short sprints, accelerations, and decelerations with changes of direction, which are collectively called repeated-sprint ability (RSA) (Spencer et al., 2005). Thus, assessment of RSA might be a useful indicator for successful in these sports (Okuno et al., 2013). Many different exercise protocols have been used in the studies of this review. Large differences between some exercise protocols and the repeated-sprint activity of handball sports may question validity and specific relevance of many of them. In this systematic review, RSA 6x(2x15-m) test was th(Negra et al., 2017)e most used protocols. Some studies that have investigated the movement patterns of field-based team sports showed the mean distance of sprints between 10-20m; so, the distances performed in this protocol of RSA could be suitable. However, further research is required to document the time-motion analysis of repeated-sprint ability during handball activity (Spencer et al., 2005). By the other hand, RSA test have been used with repeated straight sprints, with no changes of direction (i.e. 6x30-m) or shuttle sprint, with change direction (i.e. 6x(2x15-m), may show very different qualities. Previous studies described relationship between two different types of repeated sprint test. The straight RSA test does not seem relevant for the testing of handball players; match-analyses shown that during the play a great deal of intermittent, high-intensity and short change of direction runs were performed by handball players (Ruscello et al., 2013). Thus, shuttle RSA test such as RSA 6x(2x15-m) test or RSA 6(2x12.5-m) test should be chose by coaches and sports scientists (Souhail Hermassi et al., 2017).

RSSJA test 6x(2x12.5-m) sprints departing on 25 s, with a countermovement jump performed during recovery between sprints) was designed to simulate the repeated explosive efforts with changes of direction commonly performed in team sports like team handball (Mhenni et al., 2017). Although, (Martin Buchheit, Spencer, & Ahmaidi, 2010) showed the reliable and valid of RSSJA test to assess repeated explosive effort sequences in team sports such as; only two have used it to evaluate anaerobic efficiency in handball players. Thus, more investigations could be necessary to confirm and determinate the valid and reliable test in different categories and levels.

Aerobic efficiency

Although training stimuli for high-intensity endurance training should be given more attention in the full training season planning, a high aerobic capacity appears to be important to maintain a high level of performance over the 60 minutes of playing time (Manchado et al., 2013). Traditionally, the assessment of aerobic endurance has been carried out with submaximal or maximal continuous running tests performed in field and laboratory conditions, such us Cooper test or Bruce protocol. Although the information provided with those tests could be considered of interest to evaluate endurance level, those procedures are not the most handball-sports specific tests (S Hermassi, Chelly, Fathloun, & Shephard, 2010). A field test cannot be considered sport specific until a direct association between some aspects of match performance and the field test has been determined (Castagna, Impellizzeri, Rampinini, D'Ottavio, & Manzi, 2008; Krustrup et al., 2003). Yo-Yo IR1, which was the most used test used in the investigated studies in this review, mimics efforts observed in team handball actual game play (Perš, Bon, Kovačič, Šibila, & Dežman, 2002); so may be considered a field test relevant in team handball and consequently a useful tool for the evaluation of physical performance in intermittent sports (Bangsbo, Iaia, & Krustrup, 2008).

Specific Movements Handball Test

As have already been mentioned, most of used tests are general or specific tests, which are performed stepwise under standardized conditions. However, (Wagner et al., 2016) developed and validated a team-handball game-based performance (GBPT) that including similar movements and intensities as in competition match: short accelerations with numerous stops and change of directions, throws, passes, jumps, pass interceptions, light and hard body checking, and some fast breaks between 10 and 30 m. Of this way, it is possible to measure specific aerobic performance, throwing performance, speed and agility under conditions that are similar to competition. Although, GBPT test showed valid and reliable test to analyse team-handball performance under conditions similar to competition, only one study administered this test to compare specific physiological and biomechanical performance in elite, sub-elite and non-elite male team handball players (Wagner, Fuchs, & von Duvillard, 2017). Thus, more investigations more investigations could be necessary to confirm and determinate the valid and reliable test in different categories and levels.

Strength and limitations

To our knowledge, this study represents the first review about endurance assessment in handball, synthesizing previous studies between 2002 and 2019 in a unique document. In contrast, the first limitation of this systematic review is regarding with the type of analyse study. Given that there is no consensus regarding reliable and valid instruments for the assessment of methodological quality of observational studies 9, the review of it representing substantial limitation. Furthermore, methodological quality of 22 experimental studies was relatively low. Thus, there is a need for more high-quality studies to identify reliable and valid tests. Secondly, a wide terminology is used to define outcomes and tests in this field. Of this way, a consensus in this aspect could be necessary.

CONCLUSIONS

The results of this review showed like anaerobic and aerobic efficiency have been assessed in handball fields. A great variety of studies shown the importance to choose field-specific tests to assess anaerobic and aerobic efficiency, being shuttle RSA tests and Yo-Yo IR1 test the most reliable test in this sense. Both are, also, the most tests used in the investigated studies in this review. Due to the fact that the included intervention studies were predominantly low in methodological quality, further high quality studies are needed to develop standard test batteries for adult or young player to assessment these parameters in handball player.

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