Mini-Review/Systematic Review

Heart rate pro ile and heart rate variability in volleyball athletes: a systematic review with meta-analyses

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Abstract - Background: Physiological parameters can be objectively measured for controlling and quantifying physical activity levels. **Aims:** This study aimed to systematically review the literature on volleyball athletes' profile regarding heart rate (HR) and HR variability (HRV). **Methods:** PubMed, Scopus, Embase and SportDiscus databases were searched to find studies presenting resting HR, maximal HR, mean HR and time domain HRV during training sessions and matches. **Results:** Volleyball athletes' profile was HRrest 66 ± 2.5 bpm (minimum 41 ± 10 bpm; maximum 82.4 ± 2.1 bpm), HRmax was 184 ± 1.3 bpm (minimum 170 ± 8.0 bpm; maximum 192 ± 3.0 bpm), HRtraining data was in average 150 ± 12 bpm (minimum 124.8 ± 6.2 bpm; maximum 171.5 ± 11.0 bpm) and mean HRmatch was 154 ± 5.5 bpm (minimum 105.3 ± 12.8 bpm; maximum 182.3 ± 5.2 bpm). The RR interval data resulting in a mean value of 1096 ± 4 ms (minimum 1027.6 ± 168.9 ms; maximum 1097.0 ± 59.5 ms) and the rMSSD index presented a mean value of 44 ± 14 ms (minimum 42.2 ± 19.8 ms; maximum 93.2 ± 65.8 ms). SDNN data were extracted, however, no meta-analysis was performed. **Conclusion:** Resting HR were high for the athletes' fitness level, maximal HR and RR intervals were very similar to athletes from other sports. Mean HR data do not seem to represent the real physical demand in matches and training. HRV time domain index showed low values and could be related to training loads or fatigue situations.

Keywords: heart rate, sport, review, athlete, autonomic nervous system, staff development.

Introduction

Physiological parameters can be objectively measured for controlling and quantifying physical activity levels of several sports[1]. Heart rate (HR) is used as an exercise intensity indicator in sports of aerobic character, but it also can be used in intermittent sports such as volleyball or beach volleyball[2], which present fluctuations in HR[2], interspersing periods of high intensity with periods of low intensity[3].

During explosive actions in volleyball, athletes are more physically demanded and physiological parameters such as HR undergo major alterations, resulting in higher levels of fatigue and also greater cardiovascular adaptations[2,4]. Muscular fatigue from planning and execution of motor skills require actions of the central nervous system[5], which is linked to baroreceptor activity and can be understood through heart rate variability (HRV)[6]. HRV reflects neural control of the heart via sympathetic and parasympathetic innervations[6].

Through HR and HRV data, it is possible to monitor alterations in the autonomic nervous system (SNA) and cardiovascular fitness[6,7], which can represent the athlete's training status[8]. In addition, there is no other parameter capable of evaluating non-invasively, time-efficient, with low cost and in a continuous way a variable capable of bringing so much information about physiological responses to training and its repercussions[9].

The use of HR and HRV has been discussed in intermittent sports, but seem to bring important information about training loads, fatigue and adaptations to training. These assessments have an extremely important role, respecting the athlete's individuality, avoiding overtraining syndrome and leading athletes to present good adaptations[10]. Day-to-day fluctuations are among the most important components in the scientific discussions on HR and HRV for athletes[8].

For this reason, understanding the behavior of HR and HRV parameters in volleyball athletes helps coaches and physical trainers to compare with the parameters found in their athletes and assist in better interpretations about these indexes. Resting HR (HRrest), maximum HR (HRmax), HR of training and matches serve as a way to monitor the possible alterations and to understand their effects in an individualized way about athletes[11]. Therefore, the purpose of the present study was to systematically review the literature about the volleyball athletes' profile regarding their HR and HRV.

Methods

This study is characterized as a systematic review with meta-analysis of observational and intervention studies. This report was prepared according to the Meta-analysis of Observational Studies in Epidemiology: A Proposal for Reporting- MOOSE[12].

Eligibility criteria

This review included observational and intervention studies evaluating HR and/or HRV in young, adult, middle-aged, and elderly volleyball athletes (from 15 years and over).

Studies assessing HR at rest, at maximal situations, during training sessions and during matches with HR data presented in beats per minute (bpm) were included. Studies evaluating time domain HRV indexes in standard deviation of the normal-to-normal interval (SDNN) represents overall variability, without differentiating between changes arising from sympathetic and parasympathetic systems[13], and the square root of the mean squared successive differences between adjacent RR intervals (rMSSD), representative of parasympathetic system alterations[13], were also included, with data analyzed in milliseconds (ms). The SDNN and rMSSD indexes for monitoring athletes of different modalities have been showing to be sensitive to alterations in training loads and physical requirements[37,38].

Search strategies

The following databases were consulted in September 2017 with update in September 2020, without date limit: PUBMED, Scopus, Embase and SportDiscus, without language restrictions. The following terms were used for searching all databases: "volley" or "volleyball" or "athlete volley" or "athletes' volleyball" and "heart rate".

Study selection and data extraction

Two researchers (L.K.; L.H.) independently evaluated the titles and abstracts of all articles found by the search strategy. The reviewers were not blinded to authors, institutions or manuscript journals. Studies that met the eligibility criteria or whose titles and abstracts did not provide sufficient information were selected for full reading.

For full reading, only the articles published in English, Spanish and Portuguese remained. The studies included in the full reading phase that presented interventions were considered as the initial data. The corresponding author was contacted as needed to obtain the data not included or not clear in the published full-text report.

The same two researchers independently extracted the data considering the methodological characteristics of the studies and outcomes of interest, using a standardized form. In case of disagreement between the two researchers, it was solved by consensus and, if necessary, by a third researcher (A.S.C.).

Data analysis

Using mean, standard deviation (SD) and sample size values of each outcome, a single-arm meta-analysis was performed for continuous variables, adopting the random effect.

For the meta-analysis of HRV data, only the results from studies that presented the same time domain analysis were used. This methodological care was taken considering the comparison of HRV data collected and expressed in different time domains is not recommended[13]. The other studies were presented qualitatively.

Data statistical heterogeneity presented in the included studies was assessed by Cochrane Q and I^2 tests. Values above 50% were considered indicative of high heterogeneity[14]. Furthermore, publication bias was assessed using funnel plots for each outcome (of each trial's effect size against the standard error). Funnel plot asymmetry was evaluated using Begg and Egger tests[15] and a significant publication bias was considered if the p value was < 0.05. Trim and fill computations were used to estimate the effect of publication bias on the interpretation of results. All analyses were conducted using Comprehensive Meta-Analysis software version 3.3.070 (CMA, Englewood, NJ).

Results

From the initial search, 448 studies were found and after removing the duplicates, 240 articles remained for reading of titles and the abstracts. After this phase, 136 studies were excluded and 65 articles remained for full reading. Thirteen studies were excluded because they were published in inaccessible language and therefore, 45 manuscripts remained for full reading. Four studies were not found in full, remaining 41 articles for this phase. Of these, 32 met the eligibility criteria and were included in this review (Figure 1).

The characteristics of the studies included with HRmax data are shown in Table 1, HRrest data are shown in Table 2, HRmatch data in Table 3, HRtraining data in Table 4, and HRV data are shown in Table 5, all in alphabetical order of authors' names.

The studies included in this review presented HR and HRV data of volleyball athletes under different conditions, and the present study sought to gather this information in order to draw a profile of volleyball athletes regarding their characteristics of HR and HRV variables. Of the 32 articles included in this review, 14 presented

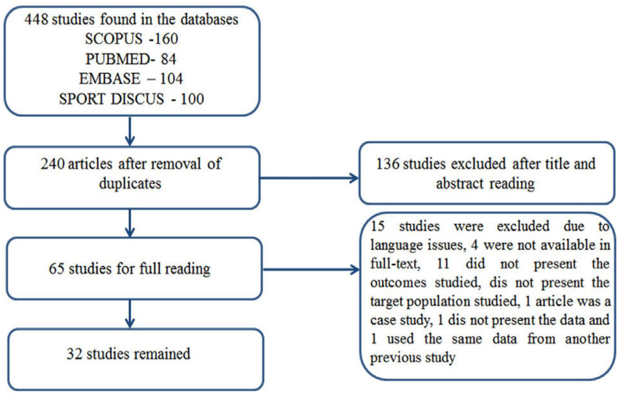

Figure 1 - Flowchart of search and analysis of articles in the different review phases.

HRrest data, 15 presented HRmax data, five studies provided information regarding HRmatch, and four presented HRtraining data. Regarding HRV data, five studies presented RR interval means, two presented SDNN index and four presented rMSSD index.

A total of 477 athletes (325 men and 152 women) were evaluated in the 32 studies included. Athletes' mean age of both sexes was 22 ± 3.1 years (minimum 16 ± 0.5 years and maximum 27 ± 4.5), their average body mass was 76 ± 1.5 kg (minimum 64 ± 6.3 kg and maximum 92 ± 11 kg. Body mass index (BMI) data were presented in nine studies and the mean value found was 23 ± 0.3 kg/m^2 for both sexes (minimum 21 ± 0.9 kg/m^2 and maximum 25 ± 5.5 kg/m^2).

Studies that showed the characteristics of training volume and professional experience evidenced that the athletes included in the analysis had at least two years of experience and minimum training volume of three weekly training sessions with 2h of duration, and could reach a maximum of 20 h per week.

HRrest data were evaluated in 212 athletes, 158 men and 69 women. The results of this analysis showed a mean value of 66 ± 2.5 bpm (minimum 41 ± 10 bpm and maximum 82.4 ± 2.1 bpm). The heterogeneity in this analysis was 98.6% and the analysis of publication bias showed no significant bias (p = 0.474).

HRmax values were representative of 227 athletes, 190 men and 57 women. Mean value of HRmax was 184 ± 1.3 bpm (minimum 170 ± 8.0 bpm and maximum 192 ± 3.0 bpm). The heterogeneity in this analysis was 94.4% and the analysis of publication bias showed no significant bias (p = 0.058).

HRtraining mean value was 150 ± 12 bpm (minimum 125 ± 6.0 bpm and maximum 172 ± 11 bpm), and

Table 1 - Studies included in the analysis of HRrest data.

References	Subjects	Training and experience	Position	Collection instruments	Main results
Arazi et al., 2012[26]	n = 8 W	Training: 5 h per week Experience: 6.12 ± 2.29 years	Not reported.	Polar monitor S610i	62.3 ± 3.2 bpm
Azboy et al., 2009[23]	n = 10 M	Training: 2 weekly sessions Experience: 3 years	Not reported.	ECG DII	82.4 ± 2.1 bpm
Broatch et al., 2018[43]	n = 6 W	Experience: 5± 2 years international level	Seated for 15 min	UB-542 Wrist Blood Pressure Monitor, A&D	66 ± 3.4 bpm
Cuesta-Vargas et al., 2009[1]	n = 10 M	Training: >15 h per week Experience: at least 10 years	Not reported.	Polar monitor S610i	80.7± 7.3 bpm
D'Ascenzi et al., 2013[16]	n = 10 W	Training: 16 per week	Supine rest	MC030 monitor	41.6 ± 10.3 bpm
Fardy et al., 1976[44]	n = 6 W	Training: 6 h per week	Seated rest	Auscultation for 15s	80.8 ± 13.9 bpm
Gademan et al., 2011[45]	n = 17 M and 12W	Training: 3 sessions per week	Not reported.	Polar Electro monitor	61.3 ± 6.1 bpm (M) 67.6 ± 2.6 bpm (W)
Hertogh et al., 2005[46]	n = 7M	Training: 9 h per week	Not reported.	Polar Accurex Plus and Polar Electro monitor	75.0 ± 10 bpm
Karacabey et al., 2005[47]	n = 40 M	Training: 6 h per week Experience: at least 5 years	Not reported.	Polar monitor	55.5 ± 4.7 bpm
Laconi et al., 1998[48]	n = 6M and 4 W	Training: 12h per week	Not reported.	Telemetry device model K2	78.7 ± 7.0 bpm
Mazon et al., 2013[18]	n = 32 M	Not reported.	Supine rest	ML 866 Eletrocardiogram	58.6 ± 6.7 bpm
Podstawisk et al., 2014[19]	n = 8 M	Experience: 7.2 years	Supine rest	Polar S 810 Sport Monitor	60.2 ± 9.6 bpm
Saryg et al., 2015[22]	n = 21 M	Training: 12 h per week	Not reported	VNS-Rhythm Device	70.5 ± 1.9 bpm
Spence et al., 1980[3]	n = 15 W	Not reported.	Supine rest	ECG Quinton Instruments	59.2 ± 5.4 bpm

Note - M: men; W: women; "n": number of athletes; h: hour; HR: heart rate; HRrest: resting heart rate; ECG: electrocardiogram; s: seconds.

Table 2 - Studies included in the analysis of HRmax data.

References	Subjects	Training and experience	Protocol	Collection instruments	Main results
Arazi et al., 2012[26]	n = 8 W	Training: 5 h per week Experience: 6.12 ± 2.29 years	Maximal treadmill protocol	Polar monitor S610i	170.0 ± 8.0 bpm
Azboy et al., 2009[23]	n = 10 M	Training: 2 sessions per week Experience: 3 years	Maximal cycle ergometer protocol	ECG DII	184.1 ± 7.1 bpm
Concu & Marcelo, 1993[49]	n = 6 M	Training: 6 h per week	Maximal cycle ergometer protocol	Not reported.	180.0 ± 4.0 bpm
CuestaVargas et al., 2009[1]	n = 10 M	Training: > 15 h per week week Experience: at least 10 years	Maximal treadmill protocol	Polar monitor S610i	190.3 ± 5.3 bpm
Nascimento et al., 2013[50]	n = 9 W	Experience: >2 years	Highest value in In the TW20 meters test	Polar Vantage NV	183.6 ± 10.7 bpm
Karaca et al., 2018[51]	n = 12 W	Training: 10h per week Experience: 6.8 ± 1.7 years	Highest value in the IR1 test	Telemetric gauge System (Activio AB, Stockholm, Sweden)	177 ± 17.2 bpm
Kasabalis et al., 2005[52]	n = 20 sênior and 16 junior (M)	Experience: Senior: 4.82 ± 1.06 years Junior: 9.80 ± 2.98 years	Maximal treadmill protocol	Polar Sport Tester Vantage NYTM	190.2 ± 5.5 bpm (Senior) 184.6 ± 6.1 bpm (Junior)
Manna et al., 2011[11]	n = 30 M	Training: 20 h per week Experience: 12 to 17 years	Maximal treadmill protocol	Oxycon Champion Metabolic analyzer	188.8 ± 2.2 bpm
Manna et al., 2012[27]	n = 30 M	Training: 20 h	Maximal treadmill protocol	Oxycon Champion Metabolic analyzer	192.4 ± 9.0 bpm
Parnat et al., [3] 1975[53]	n = 12 M	Not reported.	Maximal cycle ergometer protocol	Cardiotachograph.	183.2 ± 2.4 bpm
Pense et al., 2012[54]	n = 6 M	Experience: national level athletes	Highest value in the 20 m Modified Shuttle-Run Test	Transmitter and watch (brand not reported)	180.0 ± 13.8 bpm
Pereira et al., 2008[55]	n = 10 M	Experience: 5.4 years	Highest value in the CMJ performed until fatigue (fatigued when they no longer could touch the target)	Polar Sport Tester; Polar Electro Oy	194.0 ± 9.0 bpm
Puhl et al., 1982[56]	n = 8 M and 14 W	Not reported.	Maximal treadmill protocol	Not reported.	178.0 ± 6.0 bpm (M) 179.0 ± 8.0 bpm (H)
Simões et al., 2009[57]	n = 11 W	Experience: 4 years	Maximal treadmill protocol	Polar Vantage NV	190.6 ± 7.0 bpm
Spence et al., 1980[3]	n = 15 W	Not reported.	Maximal treadmill protocol	ECG Quinton Instrum ents	180.1 ± 5.1 bpm

Note - M: men; W: women; "n": number of athletes; h: hour; HR: heart rate; HRmax: maximum heart rate; CMJ: countermovement jumps; TW20: test performed over a distance of 20 meters with five changes of direction in the form of "W"; IR1: Yoyo intermittent recovery test; Senior: 18-25 years; Junior: 15-16 years.

Table 3 - Studies included in the analysis of HRtraining data.

Reference	Subjects	Training and experience	Approach	Collection instruments	Main results
Fardy et al., 1976[44]	n = 6 W	Training: 6 h per week	All training sessions	Auscultation for 15s	133.8 ± 16.9 bpm
Kasabalis et al., 2005[52]	n = 20 Senior (M) and 16 Junior (M)	Experience: Senior: 4.82 ± 1.06 years Junior: 9.80 ± 2.98 years	Simulation of competitive conditions during training	Polar Sport Tester Vantage NYTM	171.5 ± 11.0 bpm (Senior) 167.2 ± 14.4 bpm (Junior)
Petrov et al., 2014[21]	n = 10 H	Experience: 9 years and 8 months	Simulation of competitive conditions during training	Telemetric system TEMEO	152.0 ± 18.9 bpm
Sienkiewicz-Dianzenza et al., 2015[58]	n =12 M	Experience: 4.9 years	Six sets of eight vertical jumps (with 15 s of rest)	Not reported	124.8 ± 6.2 bpm

Note - M: men; W: Women; “n”: number of athletes; HR: heart rate during training; Senior: 18-25 years; Junior: 15-16 years.

Table 4 - Studies included in the analysis of HRmatch data.

Reference	Subjects	Training and experience	Approach	Collection instruments	Main results
Gabett et al., 2008[59]	n = 12 M and 13 W	Experience: National and international level athletes	Competitive matches	Not reported.	160.0 ± 22.4 bpm
Gonzalez et al., 2005[2]	n = 30 M	Experience: 13.40 years	Competitive matches	Polar Vantage NV-TM pulsometers monitor	156.0 ± 12.5 bpm
Karaca et al., 2018[51]	n = 12 W	Training: 10h per week Experience: 6.8 ± 1.7 years	During technical time-outs (8^{th} and 16^{th} points)	Telemetric gauge System (Activio AB, Stock-holm, Sweden)	105.3 ± 12.8 bpm
Kasabalis et al., 2005[52]	n = 20 Senior (M) and 16 Junior (M)	Experience: Senior: 4.82 ± 1.06 years Junior: 9.80 ± 2.98 years	Competitive matches	Polar Sport Tester Vantage NYTM	182.3 ± 5.2 bpm (Senior) 170.9 ± 12.7 bpm (Junior)
Laconi et al., 1998[48]	n = 6M and 4 W	Training: 12h per week	All attacking periods	Telemetry device model K2	149.0 ± 15.0 bpm

Note - M: men; W: women; “n”: number of athletes; HR: heart rate; HRmatch: heart rate during match; Senior: 18-25 years; Junior: 15-16 years.

Table 5 - Studies included in the analysis of HRV data.

Reference	Subjects	Training and experience	Position and period of analysis	Collection instruments	Main results
D'Ascenzi et al., 2013[16]	n = 10 W	Training: 16 h per week	Supine (10 min at rest)	MC030 Monitor	Mean RR = 1092.2 ± 106.2 ms rMSSD = 93.2 ± 65.8 ms
Hernandez Cruz et al., 2014[20]	n = 12 M	Training: 15 to 18h per week	Supine (15 min at rest)	Polar Electro	SDNN = 98.6 ± 62.5 ms rMSSD = 43.4 ± 34.6 ms
Menezes et al., 2009[17]	n = 7M	Training: 9 h per week	Not reported (10 min at rest)	ECG (Contec - 8000D – Telemetry – ECG - EUA)	Mean RR = 1097.0 ± 59.5 m
Mazon et al., 2013[18]	n = 32 M	Not reported.	Supine (20 min at rest)	ECG ML866	Mean RR = 1036.0 ± 122,0 ms
Petrov et al., 2014[21]	n = 10 M	Experience: 9 years and 8 months	Not reported (5 min at rest)	Telemetric system TEMEO	SDNN = 87.5 ± 21.1 ms rMSSD = 42.2 ± 19.8 ms
Podstawisk et al., 2014[19]	n = 8 M	Experience: 7.2 years	Supine (15 min at rest)	Polar S 810 Sport Monitor	Mean RR = 1027.6 ± 168.9 ms rMSSD = 70.6 ± 532.9 ms
Saryg et al., 2015[22]	n = 21 M	Training: 12 h per week	Not reported	VNS-Rhythm Device	SDNN = 47.9 ± 5.9 ms rMSSD = 43.4 ± 8.5 ms

Note - M: men; W: women; "n": number of athletes; h: hours; HR: heart rate; HRV: heart rate variability; SDNN: HRV time-domain index; rMSSD: HRV time-domain index; mean RR: mean of intervals between RR waves corresponding to electromyographic signals; ECG: electrocardiogram.

this analysis consisted of 64 athletes composed of 46 men and 18 women. The heterogeneity was 98.5% and the analysis of publication bias showed no significant bias ($p = 0.642$).

HRmatch mean value was 154 ± 5.5 bpm (minimum 105 ± 13 bpm and maximum 182 ± 5.2 bpm), and this result was obtained from 93 athletes, composed of 64 men and 29 women. The heterogeneity in this analysis was 64.9% and the analysis of publication bias showed no significant bias ($p = 0.799$).

In the meta-analysis of RR interval data, previous studies were included because they presented the same analysis period (10 min), resulting in a mean value of 1096 ± 46 ms[16,17] while other studies evaluating mean RR intervals lasting for 15 and 20 min with mean of 1036 ± 122 ms and 1028 ± 169 ms[18,19].

Regarding rMSSD data, the studies that adopted the analysis period of 15 min, composed the meta-analysis, resulting in a mean of 44 ± 14 ms[19,20] while another study that evaluated this variable, but adopted 10 min of analysis, and found a mean of 93 ± 66 ms[16]. Petrov et al.[21] with an analysis period of 5 min, presented a mean of 42 ± 20 ms. Saryg et al.[22] did not mention the analysis period adopted and found a mean of 43 ± 9.0 ms.

SDNN data were also extracted for the present review, however, no meta-analysis was performed, considering that the analysis periods of the two studies that collected this variable were not the same. A previous study used the analysis period of 15 min and presented a mean of 99 ± 63 ms[20], and another study with an analysis period of 5 min found a mean of 88 ± 21 ms[21]. On the other hand, Saryg et al.[22] presented a mean of 48 ± 6.0 ms, without mentioning the duration of the analysis.

Discussion

The present study aimed to conduct a systematic review with meta-analysis aiming to understand which values characterize volleyball athletes in relation to HR variables (HRrest, HRmax, HRmatch, and HRV indices). Studies[1,9] have been demonstrate that HR monitoring has gained a lot of interest in recent decades, because generates non-invasive and time-efficient responses of the autonomic nervous system behavior and fitness level.

Mean HRrest was 66 ± 2.5 bpm. Studies show large variations in the HR rest values, with the lowest values found of 41 ± 10 bpm[16] and the highest values of 82 ± 2.1 bpm[23]. D'Ascenzi et al.[16] assessed HRrest during the final matches of a championship, which may justify the better physical fitness showed in this study in relation to the other studies that performed the assessments in pre-competitive periods.

Mean HRrest for the general population is between 60 and 80 bpm, sedentary middle-aged individuals may have values greater than 100 bpm and aerobic endurance athletes may have minimum values between 28 and 40 bpm[24]. The mean values of volleyball athletes found in this study were not different from the values found in the general population and are similar to the values presented by 2484 male soccer athletes who presented mean HRrest of 59 ± 11 bpm[25].

Mean HRmax values found was 184 ± 1.3 bpm, evaluated in 227 athletes. The study of Arazi et al.[26] presented the lowest values (170 ± 8.0 bpm), whereas the highest values were presented in the study of Manna et al.[27] (192 ± 3.0 bpm). Arazi et al[26] evaluated HRmax with jumps performed to exhaustion, and Manna et al.[27] evaluated in a maximal treadmill laboratory test to exhaustion. This difference can be justified by the difference in assessment methods. Saudi Arabian soccer athletes presented HRmax of 139 ± 7 bpm[28], which was considered low when analyzed at maximal conditions. In contrast, 114 Division I athletes from the Spanish soccer league presented mean HRmax values of 187 ± 8 bpm[29]. Studies with basketball athletes show that can present HRmax of 165 ± 9 bpm[30] and 171 ± 13 bpm[31]. Thus, volleyball athletes' mean HRmax was similar to the values of soccer players and higher than those presented by basketball athletes.

Mean HRtraining was 150 ± 12 bpm, and mean HRmatch value was 154 ± 5.5 bpm. Such findings show that athletes undergo greater physical demands during matches when compared to training sessions. It can be explained by the fact that during matches situations, in addition to the increased physical demand, the success of the result may depend on psychophysiological variables, such as effort perception and the motivation to maintain the required effort levels[32,33].

Due to volleyball characteristics, is an intermittent sport involving short and high intensity efforts with recovery periods at low to moderate intensities, it presents data of HRmatch and HRtraining whose values are considered relatively low when compared to other sports[34]. Thus, for intermittent sports such as volleyball, instead of adopting mean HR as a reference, using each athlete's periods in HR zones established from HRmax is a more efficient method for assessing the requirements during training and matches[10]. The highest effort concentration in volleyball is maintained at intensities between 50 and 80% of HRmax[10]. High-intensity and short-duration efforts in this modality may not directly correspond to the HR increase, showing that mean HR values for matches and training do not really seem to represent the intensity of training and matches for this sport[35,36].

The physical demand generated by training and matches, besides leading to HR changes and adaptations, can also change HRV indices, as complex motor skills require planning and involve operations at central and peripheral levels[5]. Time domain of HRV analysis has proved to be of fundamental importance for athletes and coaches who need an easy method for detraining or overtraining analyses, capable of providing important information on fatigue and adaptation[37,38].

Athletes with higher physical capacity have higher values of HRV indices when compared to untrained[8,13]. In our analysis, mean RR intervals found for volleyball athletes was 1096 ± 46 ms. Similar values were found in aerobically trained individuals[6], soccer athletes with mean RR intervals of 1046 ± 191 ms[25], and basketball athletes with mean RR intervals of 1070 ± 127 ms, which shows the high physical capacity presented by these athletes[39].

The rMSSD index presented a mean value of 44 ± 14 ms in our analysis, which is a low value for high performance athletes when compared to other studies[6,39]. Spanish soccer players showed values between 98.6 ± 80.9 ms and 116 ± 53 ms after 8 weeks of training[40], basketball athletes showed 104.1 ± 49.9 ms[39], 100.7 ± 38 ms (under 20 years) and 64 ± 49.8 ms (under 18 years)[41]. These studies showed higher values than the mean presented by volleyball athletes.

A study showed a strong negative correlation between rMSSD and training loads ($r = -0.85$), i.e., the increase in training loads was associated with decreased in this HRV index[33]. Therefore, low values of rMSSD indexes may be related to the physical demands imposed by matches and training. In a previous study, the evaluations were performed at rest and after the matches and show that HRV changed after matches[20] while another study was performed seven days before the pre-competitive period, but athletes performed very demanding training routines proceeding such periods[19]. The study of D'Ascenzi et al.[16] also evaluated this variable, but with 10 min of analysis, and found an average of 93 ± 66 ms, and Saryg et al.[22], who presented a mean of 43 ± 9 ms, which was similar to that found in the present meta-analysis.

SDNN data were extracted for the present review, however, no meta-analysis was performed, considering that the analysis times of the two studies that collected this variable were not the same. The study of Hernandez-Cruz et al.[20] used analysis period of 15 min and presented a mean of 99 ± 63 ms. On the other hand, the study of Saryg et al.[22] presented an average of 48 ± 6 ms, without mentioning the analysis period. The values of Hernandez-Cruz et al.[20] are similar to those found in trained individuals, whereas the data of Saryg et al.[22] are below those found in untrained individuals[6].

HRV has proven to be sensitive to changes in training loads, and it is correlated with performance indices, being able to identify fatigue conditions in athletes, assisting coaches and performance coaches in choosing the best strategies for recovery and training[37,38]. The rMSSD index has been the most used index to access daily changes in the autonomic nervous system (ANS) proving to be reliable, and it can be captured in short-term analysis (10 s to

1 min), having a great reliability when compared to other HRV indices[37,42]. With advancing technologies capable of monitoring HRV in environments outside the laboratory, this variable has been increasingly used, thus, understanding how these indices behave in athletes can help in the interpretation of information in practice.

It is noticed that a high heterogeneity was found in HR analyzes. In order to find possible causes of heterogeneity, a subgroup analysis was performed, verifying studies with male and female athletes separately. However, the results were similar and the heterogeneity could not be explained by this grouping factor. A possible cause may be related to the different methods used to record HR and HRV and the different training volumes presented by the studies, which ranged from 6 h to 20 h per week. In addition, the fact that previous studies from the 1970s had different physical training patterns when compared to the present day, in which training and game intensity requirements have increased, it could partially explain such high heterogeneity. However, these characteristics have not been tested and can be considered a limitation of the present study.

Conclusion

Volleyball athletes' profile, based on the studies included in this meta-analysis. Regarding HR data a high value for this variable considering their physical fitness level, resembling data obtained from trained individuals and athletes from other sports. HRtraining data was on average 150 ± 12 bpm and mean HRmatch was 154 ± 5.5 bpm, but the mean HR data does not seem to be representative of the actual physical demand performed by athletes during matches and training due to the characteristics of the sport evaluated. In HRV analysis, the mean RR intervals presented by athletes were very similar to elite soccer athletes and trained individuals, whereas the rMSSD index presented values below those found for trained individuals, and reductions in this index appear to be related to the increased training loads or fatigue situations.

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