TRAINING LOAD AND PLAYERS' READINESS MONITORING METHODS USED IN VOLLEYBALL: A SYSTEMATIC REVIEW

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Abstract:

Monitoring workloads during training and competition and players' readiness seems to be key to increasing performance, reducing injury incidence and avoiding overtraining. We systematically reviewed the methods used to measure workloads and athletes' readiness in volleyball to help coaches make the best decision when selecting monitoring methods. Databases Web of Science, Scopus, SPORTDiscus and PubMed were searched from inception to the 21st of February 2022. All peer-reviewed original research in English, Spanish, Portuguese and Italian, longitudinally monitoring loads and athlete readiness in indoor volleyball team settings of any level, gender and age were included. The quality of evidence was evaluated with a modified risk of bias assessment used in previous research by Castellano et al. (2014). This study has been registered in PROSPERO ID CRD42022316313. Out of 1774 records identified, 78 were screened of which 55 full texts were added for systematic review. For internal workload, the session rating of perceived exertion (sRPE) seems to be the "golden standard" used from 2010 to 2022 across all the studies. External workload has mainly been researched through quantified jumps. Even with technological advances and the introduction of microsensors in 2017, the use of video analysis is still present nowadays. Players' readiness studies mainly used the total quality recovery scale (TQR) and wellness questionnaires in most research. New technological advances offer coaches more extensive and real-time data on external load. However, the use of the sRPE, TQR/WB, CMJ would create a monitoring system sufficient for teams at developmental stages and of a reduced cost.

Keywords: *workload, monitoring methods, wellness, readiness, performance*

Introduction

Volleyball is a dynamic and unpredictable sport that stands out for the combination of high-intensity efforts with short periods of rest at low intensity. Among the skills that a volleyball player should possess, the following stand out: at a physical level, lower limb power, accelerations and decelerations over short distances (Sheppard & Newton, 2012), and at a technical level: setting, serving, blocking and attacking, which are highly influenced by the jumping action (Sheppard, Nolan & Newton, 2012).

Due to the high density of eccentric actions, together with the high number of impacts generated by landings and braking, an increase in fatigue and muscle damage is to be expected, which can lead to a decrease in athletic performance (Eliakim, et al., 2009; Souglis, Bogdanis, Giannopoulou, Papadopoulos & Apostolidis, 2015). Which, in addition to the competitive density of the sport itself and certain contextual factors, can lead to a suboptimal recovery state (Clemente, et al., 2017; Fessi, et al., 2016).

This highlights the importance of knowing the state of our athletes and their progression towards previously established objectives. Also, that knowledge helps in the decision-making of coaches and technical staff regarding possible modifications in planning (Jeffries, et al., 2022). To this end, it seems essential to know the effects of training and competition on athletes at physiological, psychological and biomechanical levels, among others. More specifically, it is necessary to analyze training effects from the point of view of the work performed (external load) and of the response of athletes' body to the performance of this work (internal load). Coaches need to know the effect of the loads applied (acute, chronic, positive and negative) and the contextual and individual factors of each player (Jeffries, et al., 2022).

The range of load quantification methods that have been used over the years is very extensive but we can observe that certain methods stand out in scientific literature over others. Among the internal load quantification methods, the subjective perception of effort in the session (sRPE) (Foster, et al., 2001) or, at the objective level, heart rate and training impulse (TRIMP). Among the most current external load quantification methods are GPS systems, microsensors, and accelerometers (Bourdon, et al., 2017). It is also worth mentioning those tools that allow us to know the state of athletes' readiness through questionnaires (wellness or wellbeing). Although not scientifically validated (Jeffries, et al., 2020), they are widely used by sports professionals in their decision-making and can be at the same level of use as the total quality recovery scale (TQR) or the recovery-stress questionnaire for athletes (REST-Q) scales.

Despite the large number of options available, a consensus on the methods that should be used for monitoring athletes (Scott, Duthie, Thornton & Dascombe, 2016) does not yet exist and, specifically in volleyball, there is a lack of clarity on the tools that should be used to monitor loads and players' readiness status. Although some recent reviews have been able to detect the tools used in volleyball (Pisa, Zecchin, Gomes, Norberto & Puggina, 2022), they have only focused on internal loads with professional and male players, which could still generate a total lack of clarity. Therefore, this study aims to systematically review the scientific literature to know the methods and tools used in volleyball for the control of training loads, match loads and readiness status in volleyball teams with the secondary objective of helping coaches and technical staff in the decision-making process when selecting the most appropriate monitoring and readiness tools for their teams.

Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 protocol was used for this systematic review (Page, et al., 2021).

Research strategy

A systematic search of four electronic databases was conducted: PubMed, Scopus, Web of Science, and SPORTDiscus. The combination of different terms in title, abstract or keywords was made as follows: (Volleyball AND ("monitor*" OR "control" OR "record*" OR "quantif*") AND ("load*" OR "internal load*" OR "external load*" OR "training load*" OR "match load*" OR "internal training load*" OR "external training load*" OR "workload" OR "training intens*" OR "training respon*" OR "subjective" OR "objective" OR "fatigue" OR "non-functional overreaching" OR "recovery" OR "readiness" OR "wellness" OR "wellness questionnaire" OR "wellbeing" OR "well being" OR "well-being" OR "mood" OR "stress" OR "sleep") NOT "beach volleyball"). The range for years was established from the earliest available record to the 21st of February 2022. To reduce the chances of studies being left out, reference lists of included articles and relevant reviews were scanned to ensure a wider reach of our search.

Inclusion and exclusion criteria

Eligibility criteria were established using the PICO model from the PRISMA 2020 report (Page, et al., 2021):

The manuscripts selected in this systematic review followed these criteria: (1) studies based on either internal load, external load, readiness for training/matches or any combination of the three; (2) studies collecting longitudinal data of workloads and/or player's readiness in training, matches or both events; (3) articles on indoor volleyball; (4) English, Italian, Portuguese or Spanish versions of the studies; (5) original research published in a peer-reviewed journal of players enrolled in a team setting of any age, level or gender; (6) studies from the database inception to 21st of February 2022.

Exclusion criteria were established as follows: (1) studies evaluating injury prevention or reduction; (2) studies on beach volleyball; (3) manuscripts checking validity and reliability or focusing on specific drills or testing specific individual physiological demands; (4) studies with exact measurements (5) experimental studies, conference abstracts or unpublished manuscripts.

Study selection

Database search results were added to reference manager Mendeley (Elsevier, London, UK) where duplicate articles were removed. Titles and abstracts screening of remaining records was performed by the first author RV. Then, full texts were analyzed against inclusion criteria by RV and, in case of uncertainty, MPMA and AUE were consulted for discussion and reaching a final consensus.

Data collection

The first author examined and extracted information from the selected studies to be included in the systematic review into a specifically created spreadsheet. When possible, the following data were extracted from each article following the "Population, Intervention, Comparison, Outcome" (PICO) framework: (1) sample size, gender, age, playing level and country; (2) study duration, study period, study observation (only training, only matches or both); (3) instruments used (e.g. sRPE, questionnaires, video analysis), characteristics of instruments (scales, devices, thresholds); (4) study goals, study variables, main results, outcome and conclusions; (5) statistical analysis; (6) study design.

Risk-of-bias assessment

Studies were evaluated qualitatively using modified assessment criteria from Castellano, Alvarez-Pastor & Bradley, (2014) (Table 1). The main modifications were as follows: item eight was removed from the original tool as irrelevant to the current review, and answers in item 7 were converted into "YES" or "NO", so all the questions could be affirmative or negative to avoid question scores. Finally, rewording of the remaining eight items was applied to better adapt the tool to this systematic review criteria. A maximum of eight positive responses could be achieved depending on how the criteria were met. The risk-of-bias assessment was used to weigh a study's contribution to the results. Articles with a positive response of five or above were considered to carry full weight, whereas for those with four or fewer "Yes" contributions to the results were halved. RV applied the tool to each of the included studies; in the case of discrepancies, they were solved by a discussion with the remaining authors.

Data synthesis

The synthesis of data was made descriptively with the information presented in text and detailed tables. The goal of this systematic review was to observe the most used methods for monitoring workloads and players' readiness in volleyball. Since a recompilation of the results of the studies was not sought, meta-analysis was not taken into consideration. The main goal of a meta-analysis is to statistically analyze results from a relatively homogeneous group of studies, to integrate their results. The selected studies were deemed heterogeneous in variables, methods, interventions, reporting, outcome measures and study designs. Also, meta-analysis can only analyze studies with specific statistical information, therefore discarding qualitative studies.

Results

Selected studies

Initially, 1774 records were retrieved from the different databases (PubMed = 307, SPORTDiscus = 423, Web of Science = 443, Scopus = 601). A total of 677 were removed as duplicates. After screening the remaining titles and abstracts, 78 articles were selected for the full-text analysis. The rationale for rejecting full texts was as follows: language (Çelebi & Aksu, 2018; Maksimenko, Maksimenko, Zhilina & Bayeva, 2019; Sattler, 2021), not considered monitoring or athletes' readiness research (Bara Filho, de Andrade, Nogueira & Nakamura, 2013; Garcia-de-Alcaraz, Valadés & Palao, 2017; Mroczek, et al., 2014; Podstawski, Boraczynski, Nowosielska-Swadzba & Zwolinska, 2014; Zhou, 2021), not on volleyball (Hamlin, Wilkes, Elliot, Lizamore & Kathiravel, 2019), injuries and/or rehabilitation studies (Hurd, Hunter-Giordano, Axe & Snyder-Mackler, 2009; Sole, Kavanaugh & Stone, 2017; Visnes & Bahr, 2013), not following up continuously or longitudinally (Hank, Zahalka & Maly, 2015; Horta, Bara Filho, Miranda, Coimbra & Werneck, 2017; Hurd, et al., 2009; Moreira, et al., 2013; Mortatti, Pinto, Lambertucci, Hirabara & Moreira, 2018; Noce, et al., 2008; Pires & Ugrinowitsch, 2016; Pires & Ugrinowitsch, 2021; Reynoso-Sánchez, et al., 2016) and no full-text available due to journal's embargo (Gielen, Mehuys, Berckmans, Meeusen & Aerts, 2022; Ungureanu, Brustio, Boccia, Rainoldi & Lupo, 2021; Xue, 2017). After further exploration of references, two records were recouped (Freitas, Miloski, & Bara Filho, 2015; Lacerda, et al., 2015) and added to the final 55 studies included in the systematic review. (See Table 2 for reference of the included studies.) A flow chart of the process is presented in Figure 1.

Studies were published between 2010 and 2022. Out of the 55 studies included in this review, 10 studies covered the 2010-2015 period, 33 period of 2016-2020 and 12 two years 2021-2022. Regarding gender, 33 studies included only male participants, 19 female, and three both. In terms of level, 32

Table 1. Risk of bias assessment criteria

	Criteria	Answer	
1	The study is published in a peer-reviewed journal	No	Yes
2	The study is published in an indexed journal	No	Yes
3	The study objective(s) is/are clearly set out	No	Yes
4	Either the number of recordings is specified or the distribution of player/recordings used is known	No	Yes
5	The duration of player recordings (how many weeks/training sessions, how many matches, etc.)	No	Yes
6	A distinction is made according to player position, training session type and/or match	No	Yes
7	The reliability/validity of the instrument is not stated or is mentioned	No	Yes
8	The results are clearly presented	No	Yes

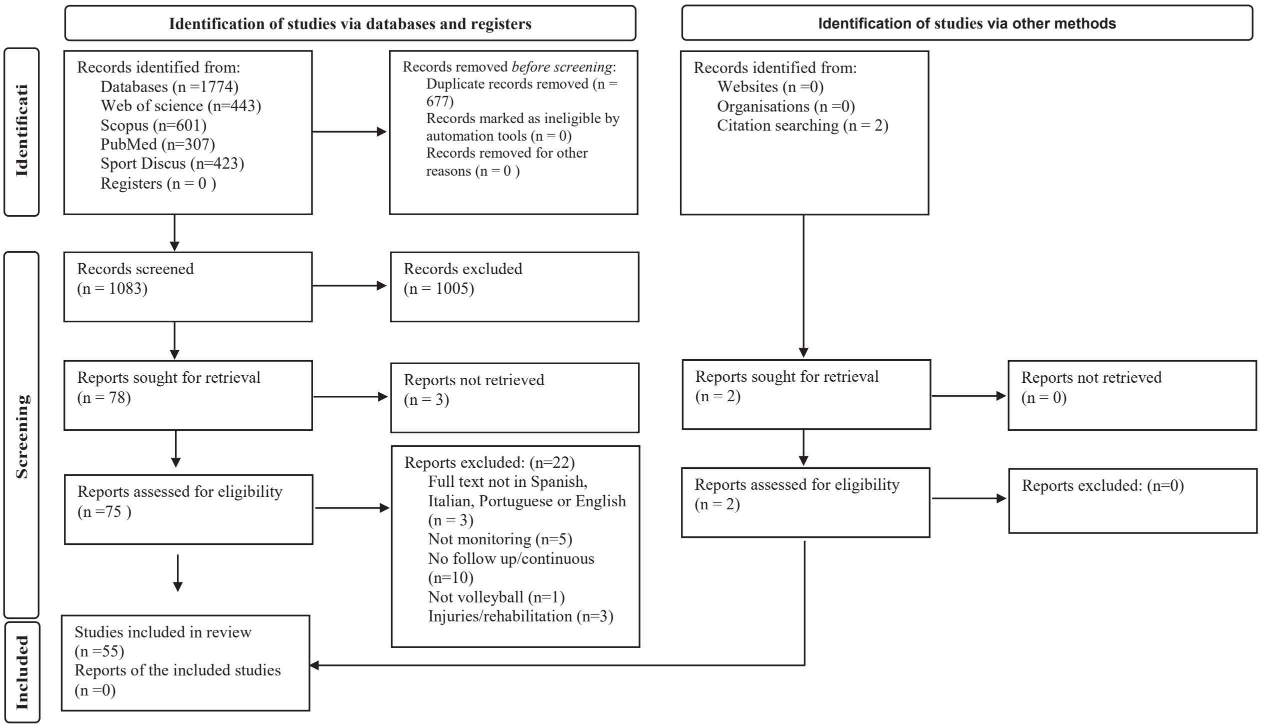

Fig. 1. Studies selection process flow chart recommended in the PRISMA, 2020. Outlining the path followed to select articles included in the systematic review

Table 2. Participants' characteristics (number, gender, level) and results of methodological quality assessment of a study

Study	Year	N	Gender	Level	Quality questions								
					Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Total
Andrade et al.	2021	15	Male	Professional Brazil	Y	Y	Y	Y	Y	Y	N	Y	7
Aoki et al.	2017	18	Male	U16 & U19	Y	Y	Y	N	N	Y	Y	Y	6
Bahr & Bahr	2014	44	Both	Junior volleyball Norway	Y	Y	Y	Y	Y	Y	N	Y	7
Brandão et al.	2018	14	Male	Professional	Y	N	Y	Y	Y	Y	Y	Y	7
Cardoso et al.	2021	9	male	professional brazil	Y	Y	Y	Y	Y	Y	N	Y	7
Carroll et al.	2019	11	Female	NCAA D1	Y	Y	Y	Y	Y	Y	N	Y	7
Castello et al.	2018	10	Female	NCAA D1	Y	N	Y	Y	N	N	Y	Y	5
Clemente et al.	2019	13	Male	Professional Portugal	Y	Y	Y	Y	Y	Y	Y	Y	8
Clemente et al.	2020	13	Male	Professional Portugal	Y	Y	Y	Y	Y	Y	N	Y	7
Coyne et al.	2021	63	Female	Olympic level	Y	Y	Y	Y	Y	Y	Y	Y	8
de Andrade et al.	2014	15	Male	National level Brazil	Y	Y	Y	Y	Y	Y	N	Y	7
De Leeuw et al.	2021	10	Male	Elite	Y	Y	Y	Y	Y	Y	Y	Y	8
Debien et al.	2018	15	Male	Professional Brazil	Y	Y	Y	Y	Y	Y	N	Y	7
Duarte et al.	2019	14	Male	Professional Brazil	Y	Y	Y	Y	Y	Y	N	Y	7
Duarte et al.	2019	15	Male	Professional Brazil	Y	Y	Y	Y	Y	Y	N	Y	7
Edmonds, Schmidt & Siedlik	2021	14	Female	NCAA D1	Y	Y	Y	Y	Y	Y	Y	Y	8
Freitas et al.	2014	16	Male	Professional Brazil	Y	Y	Y	Y	Y	Y	Y	Y	8
Freitas et al.	2015	7	Male	Under 16 Brazil	Y	Y	Y	Y	Y	Y	Y	Y	8
Freitas, Miloski & Bara Filho	2015	12	Male	National League	Y	Y	Y	Y	Y	Y	N	Y	7
García-de-Alcaraz et al.	2020	11	Male	Professional Spain	Y	Y	Y	Y	Y	Y	N	Y	7
Háp et al.	2011	8	Male	Professional Czech Republic	Y	Y	Y	Y	Y	Y	N	Y	7
Haraldsdottir et al.	2021	17	Female	NCAA D1	Y	Y	Y	N	Y	N	N	Y	5

Table 2. (Continued)

Study	Year	N	Gender	Level	Quality questions								
					Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Total
Hernández-Cruz et al.	2017	12	Male	Professional Mexico	Y	Y	Y	N	Y	Y	Y	Y	7
Herring & Fukuda	2022	14	Female	NCAA Div 1	Y	Y	Y	Y	Y	Y	Y	Y	8
Horta et al.	2017	15	Male	Professional Brazil	Y	Y	Y	Y	Y	Y	Y	Y	8
Horta et al.	2019	12	male	elite	Y	Y	Y	Y	Y	Y	Y	Y	8
Horta et al.	2019	12	Male	Professional Brazil	Y	Y	Y	Y	N	Y	N	Y	6
Horta et al.	2020	9	Male	Professional Brazil	Y	Y	Y	Y	Y	Y	Y	Y	8
Kraft et al.	2020	56	Female	NCAA D2	Y	Y	Y	Y	Y	Y	Y	Y	8
Kupperman et al.	2021	11	Female	NCAA Div 1	Y	Y	Y	Y	N	Y	N	Y	6
Lacerda et al.	2015	8	male	professional	Y	Y	Y	Y	Y	Y	N	Y	7
Libs et al.	2019	3	Female	NCAA D1	Y	Y	Y	Y	Y	Y	N	Y	7
Lima et al.	2019	5	Male	Professional Portugal	Y	Y	Y	Y	Y	Y	Y	Y	8
Lima et al.	2020	8	Male	Professional Portugal	Y	Y	Y	Y	Y	Y	Y	Y	8
Lima et al.	2021	10	Male	Portuguese 1st division	Y	Y	Y	Y	Y	Y	Y	Y	8
Malisoux et al.	2013	269	both	Elite juniors	Y	Y	Y	Y	Y	Y	N	Y	7
Mendes et al.	2018	13	Male	Professional Portugal	Y	Y	Y	N	Y	Y	N	Y	6
Moreira et al.	2010	20	male	Juniors	Y	Y	Y	Y	Y	Y	N	Y	7
Piatti et al.	2021	12	Male	Elite	Y	Y	Y	Y	Y	Y	Y	Y	8
Rabbani et al.	2021	13	Female	Iran national team	Y	Y	Y	Y	Y	Y	N	Y	7
Rabello et al.	2019	18	Male	Top Dutch division	Y	Y	Y	Y	Y	Y	Y	Y	8
Rodríguez-Marroyo et al.	2014	12	Female	Spanish Primera National	Y	Y	Y	N	Y	Y	N	Y	6
Roy et al.	2019	15	Female	University Canada	Y	N	Y	N	Y	N	Y	Y	5
Roy et al.	2020	15	Female	University Canada	Y	N	Y	N	Y	N	Y	Y	5
Sanders et al.	2018	1	Female	NCAA D1	Y	Y	Y	Y	Y	Y	Y	Y	8
Skazalski et al.	2018	14	Male	Professional Qatar	Y	Y	Y	Y	Y	Y	Y	Y	8
Tavares et al.	2018	13	Male	U19 Portugal	Y	Y	Y	Y	Y	Y	Y	Y	8
Taylor et al.	2019	14	Female	NCAA D1	Y	Y	Y	Y	Y	Y	N	Y	7
Taylor et al.	2022	16	female	NCAA D1	Y	Y	Y	Y	Y	Y	Y	Y	8
Timoteo et al.	2017	12	Male	Professional Brazil	Y	Y	Y	Y	Y	Y	N	Y	7
Timoteo et al.	2021	14	Male	Professional Brazil	Y	Y	Y	Y	Y	Y	N	Y	7
Ungureanu et al.	2021	10	Female	Professional Italy	Y	Y	Y	Y	Y	Y	Y	Y	8
van der Does et al.	2017	86	Both	University Netherlands	Y	Y	Y	Y	Y	Y	Y	Y	8
Vlantes & Readdy	2017	11	Female	NCAA D1	Y	Y	Y	Y	Y	Y	Y	Y	8
Wolfe et al.	2019	19	Female	NCAA D1	Y	Y	Y	Y	N	Y	N	Y	6
								Average					7,2

NCAA: National Collegiate Athletic Association
Q1-Q8: Y= yes; N= no

articles focused on the professional and elite level, 14 on the university competition level and nine on juniors and recreational players.

Quality of the studies

The quality of the included studies was considered medium-high as an average of seven positive responses ("YES") were obtained and no study received less than five. This means all studies got the same weight for the results. A more explanatory description of quality is illustrated in Table 2.

Monitoring methods

Studies showed a tendency to use a combination of different methods (36 articles). However, it is important to point out that, from the remaining 19 studies using a single metric, the majority of them were able to retrieve more than one derivative from one method (e.g., microsensors obtaining jump count, jump height, jumps per position, jump frequency), hence multiple metrics were obtained. From these articles, seven studies only used internal measures (Castello, Reed, Lund & Mack, 2018;

de Andrade, et al., 2014; Freitas, Miloski, et al., 2015; Háp, et al., 2011; Horta, Coimbra, Miranda, Werneck & Bara Filho, 2017; Horta, Bara Filho, Coimbra, Werneck & Miranda, 2019; Malisoux, Frisch, Urhausen, Seil & Theisen, 2013), eight exclusively external (Bahr & Bahr, 2014; Herring & Fukuda, 2022; Lima, Palao, Castro & Clemente, 2019; Piatti, et al., 2021; Skazalski, Whiteley & Bahr, 2018; Taylor, Kantor, Hockenjos, Barnes & Dischiavi, 2019; Taylor, Barnes, Gombatto, Greenwood & Ford, 2022; Wolfe, et al., 2019) and the remaining four investigated readiness (Carroll, Wagle, Sole & Stone, 2019; Haraldsdottir, Sanfilippo, McKay & Watson, 2021; Hernández-Cruz, et al., 2017; van der Does, Sanne Brink, Ardi Otter, Visscher & Plechelmus Marie Lemmink, 2017). From studies combining measures, 22 mixed internal workload and readiness (Andrade, Fernandes, Miranda, Reis Coimbra & Bara Filho, 2021; Cardoso, Berriel, Schons, Costa & Kruel, 2021; Carroll, et al., 2019; Clemente, et al., 2019; de Andrade, et al., 2014; Duarte, Alves, et al., 2019; Edmonds, Schmidt & Siedlik, 2021; Freitas, Nakamura, Miloski, Samulski & Bara Filho, 2014; Freitas, Nakamura, et al., 2015; Herring & Fukuda, 2022; Lima, et al., 2021; Lima, et al., 2019; Malisoux, et al., 2013; Rabbani, Agha-Alinejad, Gharakhanlou, Rabbani & Flatt, 2021; Rabello, Zwerver, Stewart, van den Akker-Scheek & Brink, 2019; Skazalski, et al., 2018; Tavares, Simões, Matos, Smith & Driller, 2018; Taylor et al., 2022; Timoteo, et al., 2021; Ungureanu, Lupo, Boccia & Brustio, 2021), four internal and external loads with readiness (all 3 together) (Cardoso, et al., 2021; de Leeuw, van der Zwaard, van Baar & Knobbe, 2022; Kupperman, Curtis, Saliba & Hertel, 2021; Ungureanu, Lupo, et al., 2021), five internal and external loads (Libs, Boos, Shipley, Peacock & Sanders, 2019; Lima, et al., 2021; Lima, Silva, Afonso, Castro & Clemente, 2020; Rabello, et al., 2019; Vlantes & Readdy, 2017), three used two different internal load measures (Duarte, Coimbra, et al., 2019; Rodríguez-Marroyo, Medina, García-López, García-Tormo & Foster, 2014; Roy, Caya, Charron, Comtois & Sercia, 2020) and other two different external load measures (Garcia-de-Alcaraz, Ramírez-Campillo, Rivera-Rodríguez & Romero Moraleda, 2020; Sanders, Boos, Shipley, Scheadler & Peacock, 2018). Following a timeline, we can observe 12 studies combining methods from 2010 to 2018 and then an exponential increase between 2019 to 2021 with 23 studies in this period.

A full descriptive illustration of monitoring measures in chronological order, to observe the evolution of methods through time, is available in Table 3 and Figure 2.

Internal load

Internal load was tracked in 41 studies (74.5%) (Andrade, et al., 2021; Aoki, et al., 2017; Brandão, et al., 2019; Cardoso, et al., 2021; Castello, et al., 2018; Clemente, et al., 2019, 2020; Coyne, Coutts, Newton & Haff, 2021; de Andrade, et al., 2014; de Leeuw, et al., 2022; Debien, et al., 2018; Duarte, Alves, et al., 2019; Duarte, Coimbra, et al., 2019; Edmonds, et al., 2021; Freitas, et al., 2014; Freitas, Miloski, et al., 2015; Freitas, Nakamura, et al., 2015; Háp, et al., 2011; Horta, Coimbra, et al., 2017; Horta, Bara Filho, Coimbra, Miranda, & Werneck, 2019; Horta, Bara Filho, Coimbra, Werneck, et al., 2019; Horta, et al., 2020; Kraft, et al., 2020; Kupperman, et al., 2021; Lacerda, et al., 2015; Libs, et al., 2019; Lima, et al., 2021; Lima, et al., 2020; Malisoux, et al., 2013; Mendes, et al., 2018; Moreira, de Freitas, Nakamura & Aoki, 2010; Rabbani, et al., 2021; Rabello, et al., 2019; Rodríguez-Marroyo, et al., 2014; Roy, et al., 2019, 2020; Tavares, et al., 2018; Timoteo, et al., 2017, 2021; Ungureanu, Lupo, et al., 2021; Vlantes & Readdy, 2017), 38 of them (92.7%) operated with

Table 3. Characteristics of study duration and methods used to monitor load in each article

Study	Monitoring method	Year
Moreira et al.	sRPE[a] / RPE[b] / sRPE derivatives + Other readiness	2010
Háp et al.	Other internal	2011
Malisoux et al.	sRPE / RPE / sRPE derivatives	2013
Bahr & Bahr	Video analysis (Jump/Swing count/load)	2014
Freitas et al.	sRPE / RPE / sRPE derivatives + other internal + CMJ[c]/SJ[d]/Rsi[e] + TQR[f] + REST-Q[g]	2014
Rodríguez-Marroyo et al.	sRPE / RPE / sRPE derivatives + HR[h]	2014
de Andrade et al.	sRPE / RPE / sRPE derivatives	2014
Lacerda et al.	sRPE / RPE / sRPE derivatives + TQR	2015
Freitas et al.	sRPE / RPE / sRPE derivatives + CMJ/SJ/Rsi + REST-Q	2015
Freitas, Miloski & Bara Filho	sRPE / RPE / sRPE derivatives	2015
Vlantes & Readdy	sRPE / RPE / sRPE derivatives + Microsensor (Jump/swing count/load) (Jump/swing count/load)	2017
Timoteo et al.	sRPE / RPE / sRPE derivatives + TQR + WB	2017

Table 3. Characteristics of study duration and method used to monitor load in each article (continuation)

Study	Monitoring method	Year
Horta et al.	sRPE / RPE / sRPE derivatives	2017
Aoki et al.	sRPE / RPE / sRPE derivatives + other readiness	2017
Hernández-Cruz et al.	HRV[i]	2017
van der Does et al.	REST-Q	2017
Sanders et al.	Microsensor (Jump/swing count/load)	2018
Skazalski et al.	Microsensor (Jump/swing count/load)	2018
Brandão et al.	sRPE / RPE / sRPE derivatives + WB + TQR	2018
Tavares et al.	sRPE / RPE / sRPE derivatives + CMJ/SJ/Rsi + WB + other readiness	2018
Mendes et al.	sRPE / RPE / sRPE derivatives + WB	2018
Debien et al.	sRPE / RPE / sRPE derivatives + TQR	2018
Castello et al.	sRPE / RPE / sRPE derivatives	2018
Rabello et al.	sRPE / RPE / sRPE derivatives + Microsensor (Jump/swing count/load) + Video analysis (Jump/Swing count/load)	2019
Libs et al.	HR + Microsensor (Jump/swing count/load)	2019
Lima et al.	Microsensor (Jump/swing count/load)	2019
Wolfe et al.	Video analysis (Jump/Swing count/load) + Other external	2019
Taylor et al.	Video analysis (Jump/Swing count/load)	2019
Duarte et al.	sRPE / RPE / sRPE derivatives + TQR + WB	2019
Clemente et al.	sRPE / RPE / sRPE derivatives + WB	2019
Roy et al.	sRPE / RPE / sRPE derivatives + WB	2019
Duarte et al.	sRPE / RPE / sRPE derivatives + HR	2019
Horta et al.	sRPE / RPE / sRPE derivatives + other internal + REST-Q	2019
Horta et al.	sRPE / RPE / sRPE derivatives	2019
Carroll et al.	CMJ/SJ/Rsi	2019
Lima et al.	sRPE / RPE / sRPE derivatives + Microsensor (Jump/swing count/load)	2020
García-de-Alcaraz et al.	Video analysis (Jump/Swing count/load)	2020
Clemente et al.	sRPE / RPE / sRPE derivatives + WB	2020
Horta et al.	sRPE / RPE / sRPE derivatives + TQR + other readiness	2020
Kraft et al.	sRPE / RPE / sRPE derivatives + HR + other readiness	2020
Roy et al.	sRPE / RPE / sRPE derivatives + Other Internal	2020
Lima et al.	sRPE / RPE / sRPE derivatives + Microsensor (Jump/swing count/load) + Video analysis (Jump/Swing count/load) + other external	2021
Kupperman et al.	sRPE / RPE / sRPE derivatives + Microsensor (Jump/swing count/load) + WB + other external	2021
Piatti et al.	Microsensor (Jump/swing count/load)	2021
Ungureanu et al.,	sRPE / RPE / sRPE derivatives + HR + WB + Video analysis (Jump/Swing count/load)	2021
Rabbani et al.	sRPE / RPE / sRPE derivatives + HR + HRV + CMJ/SJ/Rsi + WB	2021
De Leeuw et al.	sRPE / RPE / sRPE derivatives + other external + WB	2021
Edmonds, Schmidt & Siedlik	HR + HRV + WB	2021
Haraldsdottir et al.	WB	2021
Andrade et al.	sRPE / RPE / sRPE derivatives + TQR	2021
Timoteo et al.	sRPE / RPE / sRPE derivatives + TQR	2021
Cardoso et al.,	sRPE / RPE / sRPE derivatives + HRV + TQR + other readiness	2021
Coyne et al.	sRPE / RPE / sRPE derivatives + other readiness	2021
Herring & Fukuda	Microsensor (Jump/swing count/load)	2022
Taylor et al.	Microsensor (Jump/swing count/load)	2022

Note. [a]sRPE: session rating of perceived effort; [b]RPE: rating of perceived effort; [c]CMJ: counter movement jump; [d]SJ: squat jum [e]RSi: reactive strength index; [f]TQR: total quality recovery scale; [g]REST-Q: recovery-stress questionnaire; [h]HR: heart rate; [i]HRV: heart rate variability.

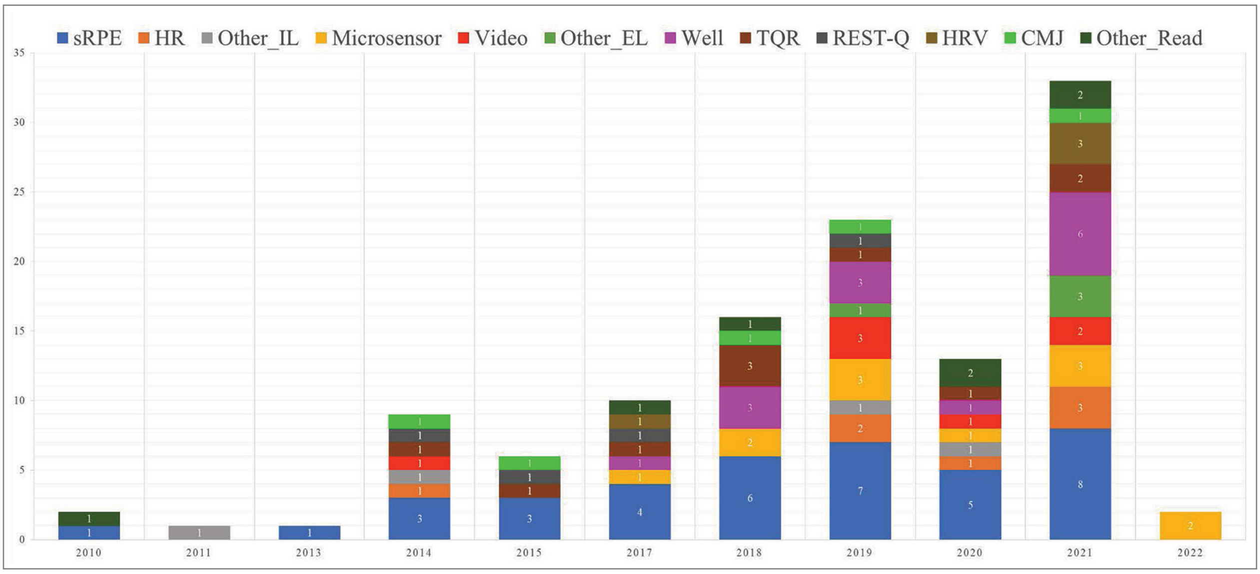

Fig. 2. Chronological evolution of the use of different measurement instruments found in the selected studies included in this systematic review

the sRPE/RPE as a measure for internal training and competition loads (Andrade, et al., 2021; Aoki, et al., 2017; Brandão, et al., 2019; Cardoso, et al., 2021; Castello, et al., 2018; Clemente, et al., 2019, 2020; Coyne, et al., 2021; de Andrade, et al., 2014; de Leeuw, et al., 2022; Debien, et al., 2018; Duarte, Coimbra, et al., 2019; Duarte, Alves, et al., 2019; Freitas, et al., 2014; Freitas, Miloski, et al., 2015; Freitas, Nakamura, et al., 2015; Horta, Coimbra, et al., 2017; Horta, Bara Filho, Coimbra, Miranda, et al., 2019; Horta, Bara Filho, Coimbra, Werneck, et al., 2019; Horta, et al., 2020; Kraft, et al., 2020; Kupperman, et al., 2021; Lacerda, et al., 2015; Lima, et al., 2021; Lima et al., 2020; Malisoux, et al., 2013; Mendes, et al., 2018; Moreira, et al., 2010; Rabbani, et al., 2021; Rabello, et al., 2019; Rodríguez-Marroyo, et al., 2014; Roy, et al., 2019, 2020; Tavares, et al., 2018; Timoteo, et al., 2017, 2021; Ungureanu, Lupo, et al., 2021; Vlantes & Readdy, 2017). All the studies recording sRPE applied the Category Ratio Scale 10 (CR-10) (Foster, et al., 2001). Multiple studies (18) took advantage of the versatility of the sRPE using derivatives. The sum of daily workloads into a weekly internal training load (WITL), monotony, strain and acute to chronic workload ratio (ACWR) were the most employed (Andrade, et al., 2021; Clemente, et al., 2019, 2020; de Leeuw, et al., 2022; Debien, et al., 2018; Duarte, Coimbra, et al., 2019; Freitas, et al., 2014; Freitas, Miloski, et al., 2015; Horta, Coimbra, et al., 2017; Horta, Bara Filho, Coimbra, Werneck, et al., 2019; Horta, Bara Filho, Coimbra, Miranda, et al., 2019; Horta, et al., 2020; Lacerda, et al., 2015; Malisoux, et al., 2013; Rabbani, et al., 2021; Rodríguez-Marroyo, et al., 2014; Timoteo, et al., 2021). Objective internal measures were less used among the selected studies, with seven records using HR (Duarte, Alves, et al., 2019; Edmonds, et al., 2021; Kraft, et al., 2020; Libs, et al., 2019; Rabbani, et al., 2021; Rodríguez-Marroyo, et al., 2014; Ungureanu, Lupo, et al., 2021) and three other methods such as: saliva and blood markers (Háp, et al., 2011; Horta, Bara Filho, Coimbra, Miranda, et al., 2019; Roy, et al., 2020). See Table 3.

Regarding the usage of the above measures through the years, the sRPE, RPE and its derivatives, have been used evenly from 2010 to 2022. However, HR was mostly used (in six out of seven studies) from 2019 to 2021. See Figure 2.

Athletes' readiness

Analyses of data collected from wellness or well-being questionnaires (WB) (Hooper & Mackinnon, 1995; McLean, Coutts, Kelly, McGuigan & Cormack, 2010) were the most observed methods for the assessment of athletes' readiness in 14 studies (Brandão, et al., 2019; Clemente et al., 2019, 2020; de Leeuw, et al., 2022; Duarte, Coimbra, et al., 2019; Edmonds, et al., 2021; Haraldsdottir, et al., 2021; Kupperman, et al., 2021; Mendes, et al., 2018; Rabbani, et al., 2021; Roy, et al., 2019; Tavares, et al., 2018; Timoteo, et al., 2017; Ungureanu, Lupo, et al., 2021), followed by the Total Quality Recovery Scale (TQR), used in 10 studies (Andrade, et al., 2021; Brandão, et al., 2019; Cardoso, et al., 2021; Debien, et al., 2018; Duarte, Coimbra, et al., 2019; Freitas, et al., 2014; Horta, et al., 2020; Lacerda, et al., 2015; Timoteo, et al., 2017, 2021). Other questionnaires such as the Recovery Stress Questionnaire for Sports (REST-Q-sports) were used in four studies (Freitas, et al., 2014; Freitas, Nakamura, et al., 2015; Horta, Bara Filho, Coimbra, Miranda, et al., 2019; van der Does, et al., 2017), the Profile of Mood States (POMS) in two studies (Aoki, et al., 2017; Horta, et al., 2020) and lastly the Daily Analyses of Life Demands of Athletes (DALDA) in one study (Moreira, et al., 2010). Other different scales were also found in our review, with one study each: the Rating of Perceived Recovery (RPR) (Kraft, et al., 2020), the Visual Analogue Scale (VAS) for mental fatigue (Coyne, et al., 2021) and the Perceived Recovery State (PRS) (Cardoso, et al., 2021). Objective measures were also collected, via Heart Rate Variability (HRV) (Cardoso, et al., 2021; Edmonds, et al., 2021; Hernández-Cruz, et al., 2017; Rabbani, et al., 2021) and countermovement jump (CMJ) (Carroll, et al., 2019; Freitas, et al., 2014; Freitas, Nakamura, et al., 2015; Rabbani, et al., 2021; Tavares, et al., 2018) in four and five studies, respectively. See Table 3.

If a chronological order of use in studies is implemented for readiness measures, the first method detected is DALDA in a 2010 study, followed by the REST-Q sport, TQR and CMJ from 2014 to 2019-2021 and lastly WB and HRV from 2017 to 2021. See Figure 2.

External load

The most studied variables to monitor external workload were vertical displacement variables, specifically, jump count and/or jump load. In 12 studies microsensors were used to measure workload (predominantly VERT Classic and Catapult Sports' Optimeye 5S) (Herring & Fukuda, 2022; Kupperman, et al., 2021; Libs, et al., 2019; Lima, et al., 2019, 2021, Lima et al., 2020; Piatti, et al., 2021; Rabello, et al., 2019; Sanders, et al., 2018; Skazalski, et al., 2018; Taylor, et al., 2022; Vlantes & Readdy, 2017), but also: jump height, establishing height thresholds, detect jump type and measure jump intensity from the devices' integrated gyroscope, magnetometer and tri-axial accelerometer. Other metrics such as player load, vertical accelerations, high impacts, high impacts % and explosive efforts could also be obtained from their software.

Video analysis was also used in seven studies (Bahr & Bahr, 2014; Garcia-de-Alcaraz, et al., 2020; Lima, et al., 2021; Rabello, et al., 2019; Taylor, et al., 2019; Ungureanu, Lupo, et al., 2021; Wolfe, et al., 2019) for jump count/load, the detection of the type of jumps/landings, jumps by position, the calculation of distances covered by players, technical actions quantification (sets, spikes, serves, blocks, digs, receptions, defences). Other methods were also observed for external workload monitoring, including swing count (Wolfe, et al., 2019), Changes of direction, accelerations, decelerations, and high-intensity efforts (Kupperman, et al., 2021), data volley variables (defences, receptions, digs…) (Lima, et al., 2021) and sets, repetitions and loads in the gym and/or court sessions (de Leeuw, et al., 2022). See Table 3.

Finally, if we look at the evolution of external methods through the years, the first method to be observed in volleyball studies on external load was the video analysis of jump load in 2014. In 2017 microsensors started to appear, and from there, all the methods are evenly used from 2019 onwards. See Figure 2.

Discussion and conclusions

This systematic review seeks to address the lack of consensus on the selection of training and competition load monitoring tools (Fox, Stanton, Sargent, Wintour & Scanlan, 2018) as well as on the methods for assessing the readiness of volleyball players. The findings of this review are intended to provide valuable information for sports professionals to facilitate their informed decision making about their training plans (Jeffries, et al., 2022). To achieve this purpose, we presented the most commonly used methods found in scientific literature and their trend of use over time with the intention to provide an updated record of tools that can be employed by any volleyball team.

In this review, three clearly defined types of tools have been identified and described in the current literature (Jeffries, et al., 2022). These tools are divided into those that monitor internal loads, those that focus on external loads, and those used to assess players' readiness.

In volleyball, it is common to use multiple monitoring tools (Clemente, et al., 2019; Mendes, et al., 2018). To make more accurate planning decisions, it is recommended to combine tools that measure internal loads, external loads, and players' readiness (Burgess, 2017; De Beéck, et al., 2019; Fox, et al., 2018; S. Ryan, Kempton & Coutts, 2021; Saw, Main & Gastin, 2016).

The sRPE is a popular tool for internal monitoring due to its simplicity and ability to provide detailed information. For assessing players' readiness, the TQR scale, wellness questionnaires and the CMJ are prominent options. For external loads, it is important to measure a variety of actions, ideally using microsensors in all three axes of motion.

Objective measurement, through technological advances in devices, shows a steady increase in the literature since 2017. Especially in technology focused on quantifying workloads during on-court sessions. Among the most prominent contributions of technology is the ability to provide real-time information (Garcia-de-Alcaraz, et al., 2020; Lima, et al., 2021; Ungureanu, Lupo, et al., 2021) and to quantify load in all spatial axes (Kupperman, et al., 2021).

However, subjective methods through questionnaires have continued to be used. In some cases, there is an explicit confrontation between the objective and subjective sources. For example, although objective methods exist to measure internal load, such as heart rate for the calculation of TRIMP (Bara Filho, et al., 2013; Duarte, Alves, et al., 2019; González, et al., 2005; Kraft, et al., 2020; Libs, et al., 2019; Rodríguez-Marroyo, et al., 2014), a preference for the use of sRPE has been observed.

Technological advances in the search for greater objectivity in measurement are intrinsic to scientific research and sports training.

The use of subjective tools such as the sRPE and wellness questionnaires has also been found to affect self-awareness and, in addition, to promote the development of self-regulation (Vavassori, Moreno & Ureña, 2023).

Therefore, from a perspective based on subjective insight, there is a phenomenological approach (Sousa, 2014; Vavassori, et al., 2023; Zahavi, 2020) that could provide value in terms of self-regulation.

Studies on self-regulation have highlighted its relevance in sports development, performance and readiness (Balk & Englert, 2020; Harrison, et al., 2022). In addition, its importance has been evidenced in issues related to well-being (Crawford, Tripp, Gierc & Scott, 2021), which includes the aspects assessed in the wellness questionnaires analyzed in this review. However, it was not that there was hidden knowledge about the value of self-regulation. Rather, there was a comfort and/or accessibility that was not refuted by the technology. Hence the importance of giving added value to qualitative instruments.

Possibly, the extensive use of sRPE in volleyball (Pisa, et al., 2022), may also be due to the existing relationship between various tools regardless of their objective or subjective nature.

Although the focus in volleyball has been on quantifying jumps for years, it is relevant to note that less than 50% of a players' total load on the court comes from jumps, as significant load occurs during horizontal movements (Vlantes & Readdy, 2017). Volleyball is characterized by a series of small movements, accelerations, decelerations and changes of direction that generate high stress on players, and thanks to technological advances, these can be detected through microsensors (Kupperman, et al., 2021).

On the other hand, obtaining real-time information allows for faster and highly individualized training decisions. Individualization in the monitoring and planning of sessions is crucial, since, for example, the volume and intensity of jumps vary significantly depending on the role of each player (Skazalski, et al., 2018; Vlantes & Readdy, 2017). This highlights the importance of establishing player-specific load thresholds (Brito, Hertzog & Nassis, 2016; Kellmann, et al., 2018). However, we should not underestimate another potential benefit of the immediate feedback offered by some technologies, such as the stimulation of self-motivation. Motivation theories distinguish between mastery-focused motivation and ego-focused motivation (Ryan & Deci, 2000). In the case of volleyball student-athletes using objective tools, it has been observed that their motivation is mainly focused on outperforming their teammates (Vavassori, et al., 2023). Therefore, we should not dismiss the motivational contributions they can derive from technology and objective methods.

Although these two perspectives (objective and subjective) are interconnected, as information from the objective world can influence human consciousness and decisions, technological advances transform the subjective into objective information for information systems (Xu, et al., 2023). Therefore, although the relationship between these two dimensions is complex, the information is simultaneously subjective and objective (Bates, 2006).

In summary, using the sRPE (and its derivatives), TQR/WB, CMJ would create a monitoring system sufficient for teams in developmental stages and at a reduced cost. Furthermore, it is worth insisting on taking advantage of the added value in terms of self-regulation and motivation provided by the use of qualitative instruments. However, the combination of these tools with microsensors would result in a complete and real-time monitoring system for decision-making of the volleyball team staff.

Limitations and strengths

Because of the reduced number of research regarding monitoring in the sport of volleyball compared to other team sports (soccer, rugby, Australian football), limitations may arise in the current review. Many studies identified used a limited number of participants. Although volleyball teams usually have 12-14 players, and collecting data from more than one team might not be feasible, small sample conclusions should be taken with caution. Also, there might have been some selection bias as in team sports, the composition of the teams is already set and players are not selected randomly. Another possible selection bias could have arisen from the decision to use only one author for the initial selection of studies. Even though PRISMA allows the use of a single author for this stage, some studies might have been wrongly included or excluded during the process.

Comparison between studies is not advised, as findings in studies with different statistical analyses may be complicated. Meta-analysis is suggested in the future to solve this issue. However, to minimize this effect, article quality was assessed to reduce bias and include higher standard research in the results. We may have incurred in risk of bias by not executing a dual and independent screening. Nevertheless, we are confident that the conclusions of this review have not been affected by these methodological limitations.

Important to notice that, due to different playing levels, ages and genders, training control methods should be adapted to each team, situation, level, goals and limiting factors.

Despite these constraints, we feel the information provided in this systematic review may contribute to increasing team performance, avoiding non-functional overreaching and hence, mitigating injury occurrence by selecting monitoring methods supported by science and used by professionals in elite and development teams in volleyball. It may also help coaches in selecting the best available method to monitor the load and readiness of their teams.

Future directions

In this review, two studies quantified load on 3 axes measuring vertical and horizontal displacement with wearable microsensors, concluding vertical displacement loads cover less than half of the training and match loads. Consequently, horizontal movements create greater workloads (Kupperman, et al., 2021; Vlantes & Readdy, 2017). Thus, more research is needed as most studies in the past focused solely on jumps.

All sessions of a training week (gym, individual training, rehab) either in the preseason or competitive period should be investigated further. Since the current research has limited the information to on-court sessions only, we feel an immense quantity of load is discarded. Furthermore, some studies did not include match loads in the weekly load calculation, creating false load information. Keep in mind that match load usually is the highest load of the week (Brito, et al., 2016; Fessi & Moalla, 2018; Murphy, Duffield, Kellett & Reid, 2016).

From our search, there was no study observing training loads and readiness distribution during the off-season. Collecting information during this period might assist in anticipating the planning of workloads for the preseason, normally the period with the highest volume of the year (Andrade, et al., 2021; Aoki, et al., 2017; Horta, Bara Filho, Coimbra, Miranda, et al., 2019). By doing so, coaches should be able to avoid excessive spikes in load by having access to workload data from the transition period. Studies in the future may shed light on what methods are used to monitor players when are away from team settings.

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