2023, Retos, 50, 1155-1162

Control of recovery using the Total Quality Recovery (TQR) scale during four accumulation microcycles and its relationship to physiological factors

Control de la recuperación utilizando la escala de la calidad de recuperación total (TQR) durante cuatro microciclos de acumulación y su relación con factores fisiológicos

*Janeth Miranda-Mendoza, *Germán Hernández-Cruz, **Luis Felipe Reynoso-Sánchez, ***Roberto Andrés González-Fimbres, ****Bianca Angélica Cejas Hernández

*Autonomous University of Nuevo León (México), **Autonomous University of Occident (México), ***Sonora State University (México), ****Autonomous University of Ciudad Juárez, (México)

Abstract. Objectives. – The aim of the study was to analyze the behavior of the modified total quality recovery (TQR) scale during four microcycles of accumulation in volleyball players and its relationship with physiological markers as heart rate variability (HRV) and training impulse (TRIMP), as well as load perception by the session rating of perceived exertion (s-RPE), and perceived recovery-stress state using the RESTQ-Sport questionnaire. Equipment and methods. – Seven female players of a national volleyball team (age: 24.26 ± 3.37 years; weight: 71.63 ± 6.84 kg; height: 176.97 ± 8.04 cm; % fat: 32.64 ± 1.57%) were evaluated during a pre-competitive camp. HRV, TRIMP, TQR scale, and the s-RPE were assessed daily. While the RESTQ-Sport was applied at the beginning and at the end of the concentration camp. The Spearman correlation for all variables, as well as Friedman Test for HRV, TRIMP, TQR and S-RPE and Wilcoxon test for RESTQ-Sport were performed. Furthermore, the smallest worthwhile change (SWC) was applied to identify the magnitudes of change in the intra-subject data. Results. – The TQR scale showed significant correlations ($p < .05$) with HRV parameters (LnrMSSD and Stress Score), S-RPE and RESTQ-Sport dimensions. Conclusion. – The TQR scale shows to be sensitivity to microcycles of accumulation in female volleyball players. In addition, the study proves the TQR concurrent validity by correlating with different physiological and psychological parameters for monitoring load and recovery.
Keywords: assessment; recovery; sports performance; volleyball; internal training load

Resumen. Objetivos. – El objetivo del estudio fue analizar el comportamiento de la escala de recuperación de calidad total modificada (TQR) durante cuatro microciclos de acumulación en jugadores de voleibol y su relación con marcadores fisiológicos como la variabilidad de la frecuencia cardíaca (HRV) y el impulso de entrenamiento (TRIMP), así como la percepción de carga mediante el índice de la sesión de esfuerzo percibido (s-RPE), y el estado de recuperación-estrés percibido mediante el cuestionario RESTQ-Sport. Instrumentos y métodos. – Siete jugadoras de una selección nacional de voleibol (edad: 24,26 ± 3,37 años; peso: 71,63 ± 6,84 kg; altura: 176,97 ± 8,04 cm; % grasa: 32,64 ± 1,57%) fueron evaluadas durante un campamento precompetitivo. La HRV, TRIMP, la escala TQR y el s-RPE se evaluaron diariamente. Mientras que el RESTQ-Sport se aplicó al inicio y al final de la concentración. Se realizó la correlación de Spearman para todas las variables, así como el Test de Friedman para HRV, TRIMP, TQR y S-RPE y el test de Wilcoxon para RESTQ-Sport, se aplicó el mínimo cambio apreciable (SWC) para identificar las magnitudes de cambio en microciclor. Resultados. – TQR mostró correlaciones significativas ($p < .05$) con los parámetros HRV (LnrMSSD y Stress Score) y las dimensiones S-RPE y RESTQ-Sport. Conclusión. – La escala TQR muestra sensibilidad a microciclos de acumulación en jugadoras de voleibol. Además, el estudio demuestra la validez concurrente de TQR al correlacionar con diferentes parámetros fisiológicos y psicológicos para monitorear la carga y la recuperación.
Palabras clave: evaluación; recuperación; rendimiento deportivo; vóleibol; carga interna de entrenamiento

Fecha recepción: 09-06-23. Fecha de aceptación: 20-08-23
Germán Hernández Cruz
german.hernandezcrz@uanl.edu.mx

Introduction

National teams' training camps generally have relatively short durations due to time and space limitations. These events are characterized by elevated training loads executed in a narrow period of time (Clemente et al., 2020). Volleyball is no exception and, due to its high-intensity intermittent nature, coaches and physical trainers must use different strategies to avoid nonfunctional overreaching and injuries (Kellmann et al., 2018). Therefore, monitoring internal training load, fatigue, and recovery becomes crucial in this kind of conditions (Botonis et al., 2021). Literature suggests that a lack of control of these components can produce a disparity between training load and recovery, causing negative changes in physiological markers and an imbalance in the autonomic nervous system (ANS); in turn, it may affect sports performance (Miranda-Mendoza et al., 2020). This fact emphasizes the relevance of paying attention to recovery and internal training loads (Brink et al., 2010).

Despite the extensive research related to training load evaluation methods, a gold standard has not yet come out, since discrepancies between different types of sports and evaluation contexts have been observed, making difficult the standardization of measures (Impellizzeri et al., 2019). In the last decade, training load and recovery assessment has been promoted using subjective methods like questionnaires and scales that measure the perception of well-being, stress, and recovery (Heidari et al., 2019). Moreover, heart rate-based objective measures, like the training impulse (TRIMP), have also been used for practicality (Akubat et al., 2012) and their ability to reflect objective internal training load (Alexiou & Coutts, 2008).

Likewise, parasympathetic heart rate variability (HRV) indices, have been consolidated as indicators of the autonomic nervous system response to training (Buchheit, 2014). In particular, the natural logarithm of the square root of the sum of the mean of the differences of the squares of consecutive RR intervals (LnrMSSD) is the most popular, since it is related to vagal activity and recovery (Buchheit, 2014; Hernández-Cruz et al., 2022). Additionally, more recently, the stress score (SS) has been shown to be a sensitive parameter of changes in training load, suggesting that it may be an indicator of fatigue (Naranjo Orellana et al., 2015; Nieto-Jimenez et al., 2020).

Despite the above, due to the relatively high cost of measurement devices, the implementation of subjective tools such as perceived load and recovery scales to assess training loads have gained relevance (Halson, 2014). The session rating of perceived exertion (sRPE) is a scale used to control the perceived training load (Freitas et al., 2014; Hernández-Cruz et al., 2017). This scale has been suggested as a non-expensive and effective tool for controlling training load in an easier and less invasive way, being widely used to assess changes in team and individual sports, both in training and in competition (Foster et al., 2021; Halson, 2014).

Along the same line, the use of instruments such as the Recovery-Stress Questionnaire for Athletes (RESTQ-Sport) as an additional tool, allows a more precise assessment of athletes' stress and recovery through a multidimensional approach (Kellmann & Kallus, 2016). This approach is oriented toward general aspects of the athletes' life that are specific to their sports practice (Reynoso-Sánchez et al., 2021). However, the scale's high number of items can render repeated application in short periods of time to be inconvenient, which affects the willingness of the athletes to respond comprehensively (Kellmann & Kallus, 2016).

The Total Quality Recovery (TQR) scale could be a possible solution to the difficulties associated with the high time demands of RESTQ-Sport. This tool was designed to measure perceived recovery in athletes (Linkenttä & Hassmén, 1998). Like the Borg scale, the TQR was adapted by Laurent et al. (2011) for the subject to score from 0 to 10 on their recovery status, and it is considered a practical and reliable measure (Sansone et al., 2020, 2021).

Additionally, correlations with sRPE, internal load parameters (Heidari et al., 2019; McLaren et al., 2018; Sansone et al., 2020) and muscle damage markers such as Creatin Kinasa (Freitas et al., 2014) have been observed. However, more research is needed to prove the TQR behavior in other contexts and conditions. Also, we have not found studies comparing TQR to physiological parameters like HR-based or HRV, which can further establish its usefulness in assessing recovery.

According to the literature (Halson, 2014; Heidari et al., 2019), a strategy combining the daily monitoring training load and recovery process through physiological HR-based (*e.g.*, TRIMP and HRV) and self-reported psychological tools (*e.g.*, sRPE, RESTQ-Sport, and TQR) can be useful to monitor athletes' stress-recovery status in high-performance sports practice. Consequently, given the need to implement more effective and efficient strategies to control internal training load, the aim of this study was to analyze the behavior of the modified TQR scale in four cumulative microcycles and its relationship with physiological markers such as HRV, perception with the RPE, and the RESTQ-Sport.

Material and Methods

Subjects

A panel design study was conducted with female players from the Mexican senior volleyball team chosen by a non-probabilistic convenience sampling. Subjects were evaluated for 21 days pre-competition training camp. Initially, fourteen female players participated voluntarily in the study. Only seven players comprised the final sample (age: 24.26 ± 3.37 years; weight: 71.63 ± 6.84 kg; height: 176.97 ± 8.04 cm; % fat: 32.64 ± 1.57%). Subjects who did not complete all records and measurements during the evaluation period were excluded.

Procedure

To carry out the study, we contacted the team's coach, who obtained authorization from the National Federation. Subsequently, an informative meeting was held with the players who would be present during the concentration period, in which the objective of the project, the variables to be measured and the procedure to be followed were explained to them. At this meeting, they were given a letter to sign the informed consent for their participation in the study and were notified that they could withdraw from the research at any time they chose to do so without any repercussions. Subsequently, all players complied with a medical history to determine if they had any injury or pathology that could alter the results of the evaluations. The research was ethically conducted under the ethical recommendations for the treatment of subjects and the data obtained as stated in the declaration of Helsinki (World Medical Association, 2013). This study did not involve subjects under 18 years of age, animals, genetic samples, or drugs; no invasive techniques were applied to the study subjects. For this reason, there was no ethical approval by a committee considering that the research was an observational study that is classified as research without risk, according to the Regulations of the General Health Law on Research for the Health of Mexico, published in the official journal of the federation considering the latest reform in force as of 04/02/2014.

Measurements

Heart rate variability

This parameter was measured daily in the morning in a fasted state, from the beginning until the end of the study. The measurement was made in a controlled environment (lighting, acoustic disturbance levels). Consumption of stimulant substances that could alter HRV was controlled. Polar Team 2 chest straps devices were used employing the built-in RR interval (beat-to-beat) option. Subjects adopted a supine position, recording periods were 10 minutes long. Obtained data were later processed with Kubios software (version 2.0 University of Kuopio, Finland), and rMSSD was calculated and log-transformed. Calculations for Stress Score (SS) were made using the methodology proposed by Naranjo-Orellana et al. (2015).

Perceived internal training load (sRPE)

The methodology proposed by Foster et al. (2001) was used to calculate the session rating of perceived exertion (sRPE). 30 minutes after ending the training session players were individually asked about their intensity perception using the Borg scale of 1 to 10. The obtained value was then multiplied by the duration of the training session in minutes.

Training impulse (TRIMP)

Measurements were made using Polar Team 2 chest straps in the ppm (pulses per minute) mode to quantify TRIMP according to Edwards (1993). An automatic report of time in minutes spent in each heart rate zone was provided by the Polar Team 2 software, and time in each zone was multiplied by the corresponding weighting factor and added to obtain the TRIMP (Edwards, 1993).

Total Quality Recovery (TQR) Scale

The perception of recovery was evaluated individually before the start of every training session using the modified 10-point scale of the TQR (Laurent et al., 2011). Following the method proposed by Kenttä and Hassmén (1998), the players were asked to indicate the degree of recovery they perceived based on physical (muscle pain, fatigue) and mental (mood states) indicators.

The Recovery-Stress Questionnaire for Athletes (RESTQ-Sport)

Stress-recovery perception by volleyball players was measured with the Mexican version (Reynoso-Sánchez et al., 2021) of the Recovery-Stress Questionnaire for Athletes designed by Kellmann and Kallus (2016). The questionnaire consists of 76 items in a 7-point Likert-type scale that goes from 0, "never" to 6, "always." It is divided into 19 scales grouped into four dimensions: 1) general stress, 2) general recovery, 3) sports stress, and 4) sports recovery. The scores corresponding to the dimensions of the questionnaire and the stress-recovery balance (obtained by subtracting the total stress average from the total recovery average) were used to analyze the results. The questionnaire was applied at the beginning of the concentration (the day before microcycle one) and at the end of microcycle 4. A period of 18 days passed between both applications. The athletes were asked to consider the events and their perception of stress and recovery during the last three days/nights according to the recommendations proposed by the authors (Kellmann & Kallus, 2016). In our study, Cronbach's alpha coefficients for the first and final applications of the questionnaire were .73 and .81 respectively.

Statistical analysis

Descriptive statistics for all variables are presented as means (M) and standard deviations (SD). The variables measured on each day of the microcycle as training load and recovery parameters (LnrMSSD, SS, TRIMP, sRPE, and TQR) were calculated and pooled by microcycle. In the case of the RESTQ-Sport, the data was analyzed for each of the measurements made.

Data was not normally distributed. Non-parametric statistics was used for all the analyzes. All inferential analyzes were performed using IBM SPSS statistics version 25 (IBM Corp., Armonk, NY) significance was established a $p < .05$. The Spearman correlation was applied to analyze the relationship between variables. Also, variance analysis was performed using Friedman Test for HRV, TRIMP, TQR and S-RPE variables while Wilcoxon test was used for the comparison among the RESTQ-Sport measures.

In addition, the smallest worthwhile change (SWC) analysis was used according to Hopkins et al. (2009), to assess the magnitudes of changes in data behavior of the variables. The standardized effect size (ES) difference was calculated with confidence intervals of 90%. Modified ES interpretation criteria suggested by Cohen (Hopkins et al., 2009) were considered, > 0.2, small, > 0.6, moderate, > 1.2, large, > 2.0, very large, and > 4.0, extremely large correlation coefficients.

Results

The behavior of the internal load and recovery variables through the four microcycles is show in table 1.

Table 1.
Descriptive and variance analysis of the evaluated variables during the four microcycles and the RESTQ-Sport

Variable	M1	M2	M3	M4
HRV				
LnrMSSD	3.9 ± 0.37	3.8 ± 0.53	3.8 ± 0.68	3.4 ± 0.74
SS	11.5 ± 3.53	12.6 ± 4.63	12.2 ± 5.12	15.0 ± 7.62
ITL				
TRIMP	307.8 ± 68.31	283.3 ± 46.39	349.8 ± 107.23	290.4 ± 65.09
sRPE	522.5 ± 46.59	551.7 ± 147.79	685.5 ± 150.2	578.8 ± 152.9
TQR	3.8 ± 1.15	4.3 ± 0.76	4.8 ± 0.96	4.1 ± 1.26
RESTQ-Sport				
General Stress	1.22 ± .64	-	-	1.79 ± 1.16
General Recovery	4.29 ± .92	-	-	3.94 ± 1.06*
Sport Stress	1.60 ± .86	-	-	2.09 ± 1.47
Sport Recovery	4.79 ± 1.08	-	-	4.36 ± 1.15*
Recovery-Stress Balance	3.13 ± 1.53			2.21 ± 2.22*

Note. HRV= heart rate variability parameters; ITL= Internal training load parameters; LnrMSSD= mean of the Napierian logarithm of the square root of the mean of the sum of the squared differences of adjacent r-r intervals; SS= mean of the Stress Score; TRIMP= Training Impulse average; sRPE= mean session rating of perceived exertion; TQR= mean total quality recovery; RESTQ-Sport= Recovery-Stress Questionnaire for Athletes; M1: microcycle one; M2: microcycle two; M3: microcycle three; M4: microcycle four; Mean ± Standard deviation.

The Spearman correlation coefficients of the internal load, HRV, and the RESTQ-Sport dimensions are shown in Table 2, where significant correlations ($p < .05$) between most variables are shown.

Table 2.
Spearman correlation coefficients between HRV parameters, internal training load, and RESTQ-Sport dimensions

	LnrMSSD	SS	TRIMP	sRPE	TQR	D1	D2	D3
SS	−.91*	-						
TRIMP	−.58**	.48*	-					
sRPE	−.49**	.43*	.51**	-				
TQR	.69**	−.56**	−.35	−.39*	-			
D1	−.64*	.64*	.31	.60*	−.70**	-		
D2	.69**	−.59*	−.37	−.63*	0.50	−.70**	-	
D3	−.62*	.44	.55*	.46	−.80**	.66*	−.60*	-
D4	.76**	−.60*	−.33	−.70**	.66*	−.72**	.89**	−.70**

Note. LnrMSSD = mean of the Napierian logarithm of the square root of the mean of the sum of the squared differences of adjacent r-r intervals; SS = Stress score; TRIMP = Training Impulse; sRPE= session rating of perceived exertion; TQR = total quality recovery; RESTQ-Sport= Recovery-Stress Questionnaire for Athletes; D1= RESTQ-Sport general stress dimension; D2= RESTQ-Sport general recovery dimension. D3= RESTQ-Sport sport stress dimension. D4= RESTQ-Sport recovery dimension.
*Correlation coefficients p < .05. **Correlation coefficients p < .01.

Table 3 shows the changes in the SWC analysis. This analysis identified probable and highly probable changes between the microcycles in variables such as LnrMSSD, SS, sRPE, TQR, and the dimensions of the RESTQ-Sport questionnaire.

Table 3.
Probability of change in HRV variables, internal training load, and RESTQ-Sport dimensions between microcycles

Variable	ES (90% CI)	Qualitative inferences	Change %
	VFC LnrMSSD		
M1 vs. M2	-0.37 (-1.30, 0.56)	Unclear	15/23/63
M1 vs. M3	-0.53 (-1.81, 0.76)	Unclear	16/16/66
M1 vs. M4	-2.00 (-3.65, -0.35)	Very likely	2/2/96
M2 vs. M3	-0.13 (-1.23, 0.97)	Unclear	30/25/45
M2 vs. M4	-1.34 (-2.72, -0.04)	Likely	4/5/92
M3 vs. M4	-0.78 (-1.75, 0.19)	Likely	5/10/85
	SS		
M1 vs. M2	0.34 (-0.50, 1.17)	Unclear	61/25/14
M1 vs. M3	0.18 (-0.74, 1.11)	Unclear	49/28/24
M1 vs. M4	0.67 (-0.45, 1.78)	Unclear	77/14/9
M2 vs. M3	-0.02 (-0.78, 0.83)	Unclear	35/34/31
M2 vs. M4	0.38 (-0.55, 1.30)	Unclear	63/23/14
M3 vs. M4	0.39 (-0.58, 1.36)	Unclear	63/22/15
	CIE TRIMP		
M1 vs. M2	-0.43 (-1.23, 0.37)	Unclear	9/21/69
M1 vs. M3	0.73 (-0.01, 1.48)	Likely	89/9/2
M1 vs. M4	-0.10 (-0.85, 0.65)	Unclear	25/35/40
M2 vs. M3	1.28 (-0.51, 2.05)	Very likely	99/1/0
M2 vs. M4	0.23 (-0.71, 1.17)	Unclear	52/26/21
M3 vs. M4	-1.09 (-1.93, 0.25)	Very likely	1/3/96
	sRPE		
M1 vs. M2	0.50 (-0.75, 1.75)	Unclear	66/17/17
M1 vs. M3	2.29 (1.42, 3.17)	Most likely	100/0/0
M1 vs. M4	0.92 (-0.59, 2.43)	Unclear	80/10/10
M2 vs. M3	0.99 (0.28, 1.69)	Very Likely	96/3/1
M2 vs. M4	0.16 (-0.71, 1.04)	Unclear	47/29/24
M3 vs. M4	-1.36 (-2.61, 0.10)	Likely	2/4/94
	TQR		
M1 vs. M2	0.44 (-0.27, 1.14)	Unclear	72/21/7
M1 vs. M3	0.65 (0.05, 1.35)	Likely	86/11/3
M1 vs. M4	0.22 (-0.66, 1.11)	Unclear	46/29/24
M2 vs. M3	0.36 (-0.49, 1.21)	Unclear	52/28/20
M2 vs. M4	-0.35 (-1.63, 0.93)	Unclear	22/19/58
M3 vs. M4	-0.69 (-1.94, 0.56)	Unclear	11/13/75
	RESTQ-Sport General Stress		
M1 vs. M4	0.47 (-0.52, 1.45)	Unclear	68/19/12
	General Recovery		
M1 vs. M4	-0.36 (-1.28, 0.57)	Unclear	15/23/62
	Sport Stress		
M1 vs. M4	0.34 (-0.46, 1.14)	Unclear	62/25/12
	Sport Recovery		
M1 vs. M4	-0.32 (-1.17, 0.53)	Unclear	15/25/60
	Recovery-Stress Balance		
M1 vs. M4	-0.52 (-1.58, 0.53)	Unclear	12/17/71

Note. The magnitude of changes between microcycles 1 and 4 are expressed as percentage of change (%), and the confidence intervals are at 90% (± 90% CI); ES, effect size; LnrMSSD= Napierian logarithm of the square root of the mean of the sum of the squared differences of adjacent RR intervals; SS= Stress Score; TRIMP= Training Impulse; sRPE= session rating of perceived exertion; TQR = total quality recovery scale; M1= microcycle one; M2= microcycle two; M3= microcycle three; M4= microcycle four.

Discussion

The aim of this study was to analyze the behavior of the modified TQR scale in four cumulative microcycles and its relationship with physiological markers such as HRV, and TRIMP, as well as perception with the RPE, and the

2023, Retos, 50, 1155-1162

RESTQ-Sport.

The study's main findings show a relationship between TQR and the internal training load and recovery parameters. The positive linear correlation between the TQR and the LnrMSSD is notable; the lower the recovery perceived by the scale, the lower the parasympathetic activity. This finding is interesting because both variables evaluate the athletes' recovery and promise to be sensitive to training loads, providing evidence of the methodological and practical usefulness of the TQR. Previous studies have used HRV and TQR parameters in male volleyball players, recommending it as sensitive for the evaluation of recovery (Cardoso et al., 2021). However, the relationship between these variables has only been tasted in one study with lacrosse players (using the TQR scale from 6 to 20) without finding a relationship with the RMSSD of HRV (Hauer et al., 2020). The authors of that study mentioned that the lack of correlation could be due to the parameters used in their research and the study design. The use of the LnrMSSD is suggested to reduce the variability of the measurements to better interpret the results (Buchheit, 2014). This is a possible reason for the differences in the results of our study and the one mentioned. Although there is little research on these parameters, we consider that our results could be relevant by considering the TQR as a simple scale that could accompany physiological evaluations.

As a complement to the study findings, our results regarding the LnrMSSD show a stable behavior in the first three microcycles, decreasing in the fourth microcycle with an effect size considered large. This variable has been reported in different sports modalities as an indicator of recovery and fatigue since it is currently used to know the behavior of parasympathetic activity because of its sensitivity to changes in sports performance (Chen et al., 2021; González-Fimbres et al., 2021). This finding could suggest that the reduction in parasympathetic activity was reflected in physiological parameters in the fourth microcycle, which is important to consider since, to date, there is no standard measure to evaluate fatigue and recovery since recovery depends on different physiological and psychological factors (Halson, 2014). According to the general law of adaptation (Selye, 1950) and the concept of allostatic load (McEwen, 2000), when the organism receives a stressor such as training, the systems try to maintain a balance. If the system does not have a recovery that allows it, it will collapse with failures at the psychophysiological level. This situation could indicate that in our study, parasympathetic activity was able to maintain the balance of the nervous system during the first three microcycles, declining in the fourth, unlike the TQR, which maintained a perception of insufficient recovery during the four microcycles. This finding highlights the importance of controlling the load through a combination of physiological and perception parameters that allow identifying possible indicators of non-functional overtraining in advance (Heidari et al., 2019).

In agreement with the above, the inverse linear correlation between the TQR and the SS reinforces the reliability of the TQR since SS has been considered a physiological parameter that reflects sympathetic activity and is sensitive to load accumulation (Miranda-Mendoza et al., 2020). Thus, understanding that the higher the stress score, the lower the perception of recovery of the subjects in our study, with SS being an indicator that can be affected by different factors, such as the global psychophysiological state of the participants and the impact of the training load (Task Force, 1996). We can infer that the perception of recovery indicated by the volleyball players in our study through the TQR can serve as a promising tool for evaluating recovery if it is taken with a responsible knowledge of bodily sensations.

Another important and striking finding was the lack of significance in the negative correlation found between the TQR and the Edwards TRIMP since it was not a result that agreed with our hypotheses; however, it has been found that methods based on heart rate during sports activity are not usually sensitive to the neuromuscular fatigue that tends to accumulate in sports such as volleyball (Ortega-Becerra et al., 2016). This finding is widely reflected in perception methods (Clemente et al., 2019), as in the case of our study, which reinforce the importance of not making isolated measurements with a single evaluation method and accompanying them with other tools that can give a complete picture of athletes' responses to training stimuli.

It is also relevant to point out that we have not found studies that present similar results. This report shows how these two parameters (TQR/SS) are related for the first time. However, in the background of the application of the TQR, intending to evaluate training loads during a precompetitive period in volleyball athletes, Freitas et al. (2014) found a relationship between the TQR and the biological marker creatine kinase (CK), pointing out that when the intensity of the load increased, the CK values increased and on the contrary, the values of the perception of recovery decreased. With these results, they inferred that both CK and TQR are sensitive to variations in training load and suggest that TQR considers the perception of sensations that athletes tend to experience after being exposed to intense stimuli that affect the neuromuscular component. Exposure to high-intensity work increases membrane permeability releasing CK into plasma which reflects muscle damage (Brancaccio et al., 2010). According to the aforementioned, SS and CK are variables that have scientific support relating them as indicators of physiological and biological fatigue, respectively. Thus, our results provide evidence that empirically supports the use of TQR as a method to assess recovery in volleyball.

On the other hand, the contrast to the TQR with perception markers, it was previously used with good results, reporting inverse correlations with the sRPE in longitudinal studies with basketball players (Sansone et al., 2020). These studies found variations in the state of recovery related to increases in load, both in daily evaluations and by microcycle and mesocycles, reflecting the sensitivity of the perception methods in detecting changes in training load and incapacity to recover, not only on a day-to-day basis but also during cumulative training. This finding demands important consideration since overload is part of the training process and must be controlled to avoid non-functional overtraining (Kalkhoven et al., 2021). These results support what was found in our study since the microcycles were considered accumulative. Although there were not many load variations, the chronic effect could be one of the reasons for the inability to have good recovery values.

In addition, the negative association of the TQR with the dimensions of general stress and sports stress of the RESTQ-Sport is a result that increases the reliability of the scale, which is relevant since the questionnaire mentioned above has shown reliability and has been widely used in different sports (Kellmann & Kallus, 2016; Reynoso-Sánchez et al., 2021). However, its application is limited by the number of items and the time to answer it, so its application every third day, as suggested by the original instructions, is not practical. This reason is why this type of instrument can be complemented with more practical scales that do not require much time to answer, recommending the use of the TQR for daily control.

Regarding the behavior of the TQR during the concentration, it did not show a significant difference in any of the microcycles; however, it is important to highlight that the TQR scores were classified as insufficient recovery in the four microcycles (Sansone et al., 2020, 2021). In response to this behavior, we suggest that the lower values in microcycle 1 may be due to different factors, mainly because in the first week of concentration, the players were not well adapted to the sports village, and in some cases, it was difficult to adapt to the training schedule. Concerning microcycles two, three, and four, a small increase in the perception of recovery was observed with no significance, considering that the scores were still low. This finding could be because the players' strategies and ability to recover were not enough to maintain reasonable recovery values (greater than 7) since some players unofficially reported discomfort sleeping due to the size of the beds, which becomes relevant when managing the spaces for athlete concentrations.

Another explanation for the low recovery scores is the main characteristic of the microcycles in this research, which sought to concentrate high loads in a short period before a competition. This characteristic is common in national team concentrations since there is usually little time to prepare for competition. This explanation could have even more credibility considering that studies report that the accumulation of training load is related to the decrease in well-being parameters (Clemente et al., 2019). In addition to the fact that, after prolonged periods of accumulation of fatigue, this can be reflected in a decrease in the recovery levels perceived by the TQR (Kenttä & Hassmén, 1998), an idea that is reinforced by the behavior of the RESTQ-Sport dimensions as explained above, showing a significant association with the TQR, coinciding with what was stated in the study performed with volleyball players by Freitas et al. (2014). This finding demonstrates the sensitivity of the questionnaire to identify changes in the behavior of the stress-recovery balance of athletes (Kellmann & Kallus, 2016). Several research has been demonstrated the RESTQ-Sport as a reliable method to measure the changes generated by the increase in the training load in team sports such as male volleyball (Berriel et al., 2020; Freitas et al., 2014; Reynoso-Sanchéz et al., 2016) and handball players (Reynoso-Sánchez et al., 2017), female soccer (Morales et al., 2019) and basketball players (Nunes et al., 2014), as well as in individual sports like a study which followed the recovery-stress balance using the RESTQ-Sport in male and female decathletes and pole vaulters (Reynoso-Sánchez et al., 2020). This behavior is reflected in the perception of less recovery in the final measure regarding the initial measure of the RESTQ-Sport.

Limitations and future research

The main limitation of the study was the small sample which does not allow the results to be generalized. Another limitation was not having an analysis of the external load that would allow a better interpretation of the internal load. However, authors suggest that future research must investigate the behavior of the TQR and internal training load and recovery variables in different sport disciplines to determine a better understanding of the TQR behavior as tool for monitoring training adaptation.

Conclusion

The simple scale of the TQR shows sensitivity to cumulative microcycles in women volleyball players and correlates positively with the LnRMSSD, while with the SS it correlates negatively. Regarding perception parameters, such as the sRPE, it shows an inverse correlation, concluding that it is important to consider both the physiological and the perception parameters since, many times, the latter can provide information on possible non-functional training before this is expressed in physiological parameters.

Acknowledgements

The researchers acknowledge to the Mexican Volleyball Federation, the staff and players of the National Team for their support and facilities to carried out the study.

Disclosure of interest

The authors declare that they have no competing interests.

References

Akubat, I., Patel, E., Barrett, S., & Abt, G. (2012). Methods of monitoring the training and match load and their relationship to changes in fitness in professional youth soccer players. *Journal of Sports Sciences*, *30*(14), 1473–1480. https://doi.org/10.1080/02640414.2012.712711

Alexiou, H., & Coutts, A. J. (2008). A comparison of methods used for quantifying internal training load in women soccer players. *International Journal of Sports Physiology and Performance*, *3*(3), 320–330. https://doi.org/10.1123/ijspp.3.3.320

Berriel, G. P., Costa, R. R., da Silva, E. S., Schons, P., de Vargas, G. D., Peyré-Tartaruga, L. A., & Kruel, L. F. M. (2020). Stress and recovery perception, creatine kinase levels, and performance parameters of male volleyball athletes in a preseason for a championship. *Sports Medicine - Open*, *6*(1), 26. https://doi.org/10.1186/s40798-020-00255-w

Botonis, P. G., Smilios, I., & Toubekis, A. G. (2021). Supercompensation in elite water polo: Heart rate variability and perceived recovery. *Sports Medicine International Open*, *5*(02), E53–E58. https://doi.org/10.1055/a-1494-9254

Brancaccio, P., Lippi, G., & Maffulli, N. (2010). Biochemical markers of muscular damage. *Clinical Chemistry and Laboratory Medicine*, *48*(6), 757–767. https://doi.org/10.1515/CCLM.2010.179

Brink, M. S., Nederhof, E., Visscher, C., Schmikli, S. L., & Lemmink, K. A. P. M. (2010). Monitoring load, recovery, and performance in young elite soccer players. *Journal of Strength and Conditioning Research*, *24*(3), 597–603. https://doi.org/10.1519/JSC.0b013e3181c4d38b

Buchheit, M. (2014). Monitoring training status with HR measures: do all roads lead to Rome? *Frontiers in Physiology*, *5*, e73. https://doi.org/10.3389/fphys.2014.00073

Cardoso, A. S., Berriel, G. P., Schons, P., Costa, R. R., & Kruel, L. F. M. (2021). Recovery behavior after matches for returning to training in volleyball athletes. *Archivos de Medicina del Deporte*, *38*(5), 343–349. https://doi.org/10.18176/ARCHMEDDEPORTE.00061

Chen, Y.-S., Pagaduan, J. C., Bezerra, P., Crowley-McHattan, Z. J., Kuo, C.-D., & Clemente, F. M. (2021). Agreement of ultra-short-term heart rate variability recordings during overseas training camps in under-20 national futsal players. *Frontiers in Psychology*, *12*, e621399. https://doi.org/10.3389/fpsyg.2021.621399

Clemente, F. M., Mendes, B., Palao, J. M., Silvério, A., Carriço, S., Calvete, F., & Nakamura, F. Y. (2019). Seasonal player wellness and its longitudinal association with internal training load: study in elite volleyball. *The Journal of Sports Medicine and Physical Fitness*, *59*(3), 345–351. https://doi.org/10.23736/S0022-4707.18.08312-3

Clemente, F. M., Silva, A. F., Sarmento, H., Ramirez-Campillo, R., Chiu, Y.-W., Lu, Y.-X., Bezerra, P., & Chen, Y.-S. (2020). Psychobiological changes during national futsal team training camps and their relationship with training load. *International Journal of Environmental Research and Public Health*, *17*(6), e1843. https://doi.org/10.3390/ijerph17061843

Edwards, S. (1997). *The Heart Rate Monitor Guidebook to Heart Zone Training*. Heart Zones Publishing.

Foster, C., Boullosa, D., McGuigan, M., Fusco, A., Cortis, C., Arney, B. E., Orton, B., Dodge, C., Jaime, S., Radtke, K., van Erp, T., de Koning, J. J., Bok, D., Rodriguez-Marroyo, J. A., & Porcari, J. P. (2021). 25 years of session rating of perceived exertion: Historical perspective and development. *International Journal of Sports Physiology and Performance*, *16*(5), 612–621. https://doi.org/10.1123/ijspp.2020-0599

Foster, C., Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L. A., Parker, S., Doleshal, P., & Dodge, C. (2001). A new approach to monitoring exercise training. *Journal of Strength and Conditioning Research*, *15*(1), 109–115. https://doi.org/10.1519/00124278-200102000-00019

Freitas, V. H., Nakamura, F. Y., Miloski, B., Samulski, D., & Bara-Filho, M. G. (2014). Sensitivity of physiological and psychological markers to training load intensification in volleyball players. *Journal of Sports Science & Medicine*, *13*(3), 571–579.

González-Fimbres, R. A., Hernández-Cruz, G., & Flatt, A. A. (2021). Ultrashort versus criterion heart rate variability among international-level girls' field hockey players. *International Journal of Sports Physiology and Performance*, *16*(7), 985–992. https://doi.org/10.1123/ijspp.2020-0362

Halson, S. L. (2014). Monitoring training load to understand fatigue in athletes. *Sports Medicine*, *44*(S2), 139–147. https://doi.org/10.1007/s40279-014-0253-z

Hauer, R., Tessitore, A., Knaus, R., & Tschan, H. (2020). Lacrosse athletes load and recovery monitoring: Comparison between objective and subjective methods. *International Journal of Environmental Research and Public Health*, *17*(9), e3329. https://doi.org/10.3390/ijerph17093329

Heidari, J., Beckmann, J., Bertollo, M., Brink, M., Kallus, K. W., Robazza, C., & Kellmann, M. (2019). Multidimensional monitoring of recovery status and implications for performance. *International Journal of Sports Physiology and Performance*, *14*(1), 2–8. https://doi.org/10.1123/ijspp.2017-0669

Hernández-Cruz, G., Estrada-Meneses, E. F., Ramos-Jiménez, A., Rangel-Colmenero, B. R., Reynoso-Sánchez, L. F., Miranda-Mendoza, J., & Quezada-Chacón, J. T. (2022). Relación entre el tipo de ejercicio físico y la fatiga cuantificada mediante VFC, CK y el lactato en sangre. *Retos, 44*, 176–182. https://doi.org/10.47197/retos.v44i0.89479

Hernández-Cruz, G., Quezada-Chacón, J. T., González-Fimbres, R., Miranda-Mendoza, J., Naranjo-Orellana, J., & Rangel-Colmenero, B. R. (2017). Effect of consecutive matches on heart rate variability in elite volleyball players. *Revista de Psicología Del Deporte*, *26*(Suppl. 2), 9–14.

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in Sports Medicine and Exercise Science. *Medicine & Science in Sports & Exercise*, *41*(1), 3–12. https://doi.org/10.1249/MSS.0b013e31818cb278

Impellizzeri, F. M., Marcora, S. M., & Coutts, A. J. (2019). Internal and external training load: 15 years on. *International Journal of Sports Physiology and Performance*, *14*(2), 270–273. https://doi.org/10.1123/ijspp.2018-0935

Kalkhoven, J. T., Watsford, M. L., Coutts, A. J., Edwards, W. B., & Impellizzeri, F. M. (2021). Training load and injury: Causal pathways and future directions. *Sports Medicine*, *51*(6), 1137–1150. https://doi.org/10.1007/s40279-020-01413-6

Kellmann, M., Bertollo, M., Bosquet, L., Brink, M., Coutts,

A. J., Duffield, R., Erlacher, D., Halson, S. L., Hecksteden, A., Heidari, J., Kallus, K. W., Meeusen, R., Mujika, I., Robazza, C., Skorski, S., Venter, R., & Beckmann, J. (2018). Recovery and performance in sport: Consensus statement. *International Journal of Sports Physiology and Performance*, *13*(2), 240–245. https://doi.org/10.1123/ijspp.2017-0759

Kellmann, M., & Kallus, W. (2016). The Recovery-Stress Questionnaire for Athletes. In K. W. Kallus & M. Kellmann (Eds.), *The Recovery-Stress Questionnaires: User Manual* (pp. 86–131). Pearson.

Conttä, G., & Hassmén, P. (1998). Overtraining and recovery. *Sports Medicine*, *26*(1), 1–16. https://doi.org/10.2165/00007256-199826010-00001

Laurent, C. M., Green, J. M., Bishop, P. A., Sjo¨kvist, J., Sjo¨kvist, S., Schumacker, R. E., Richardson, M. T., & Curtner-Smith, M. (2011). A practical approach to monitoring recovery: Development of a perceived recovery status scale. *The Journal of Strength and Conditioning Research*, *25*(3), 620–628. http://doi.org/10.1519/JSC.0b013e3181c69ec6

McEwen, B. (2000). Allostasis and allostatic load implications for neuropsychopharmacology. *Neuropsychopharmacology*, *22*(2), 108–124. https://doi.org/10.1016/S0893-133X(99)00129-3

McLaren, S. J., Macpherson, T. W., Coutts, A. J., Hurst, C., Spears, I. R., & Weston, M. (2018). The relationships between internal and external measures of training load and intensity in team sports: A meta-analysis. *Sports Medicine*, *48*(3), 641–658. https://doi.org/10.1007/s40279-017-0830-z

Miranda-Mendoza, J., Reynoso-Sánchez, L. F., Hoyos-Flores, J. R., Quezada-Chacón, J. T., Naranjo, J., Rangel-Colmenero, B., & Hernández-Cruz, G. (2020). Stress score and LnrMSSD as internal load parameters during competition. *Revista Internacional de Medicina y Ciencias de la Actividad Física y del Deporte*, *20*(77), 21–35. https://doi.org/10.15366/rimcafd2020.77.002

Morales, J., Roman, V., Yáñez, A., Solana-Tramunt, M., Álamo, J., & Fíguls, A. (2019). Physiological and psychological changes at the end of the soccer season in elite female athletes. *Journal of Human Kinetics*, *66*(1), 99–109. https://doi.org/10.2478/hukin-2018-0051

Naranjo Orellana, J., de la Cruz, B., Sarabia, E., de Hoyo, M., & Domínguez-Cobo, S. (2015). Two New Indexes for the Assessment of Autonomic Balance in Elite Soccer Players. *International Journal of Sports Physiology and Performance*, *10*(4), 452–457. https://doi.org/10.1123/ijspp.2014-0235

Nieto-Jimenez, C., Ruso-Álvarez, J., Pardos-Mainer, E., & Naranjo Orellana, J. (2020). La variabilidad de la frecuencia cardiaca en el control del entrenamiento en un corredor de Ironman. Estudio de caso. *Retos, 37*, 339–343. https://doi.org/10.47197/retos.v37i37.73873

Nunes, J. A., Moreira, A., Crewther, B. T., Nosaka, K., Viveiros, L., & Aoki, M. S. (2014). Monitoring training load, recovery-stress state, immune-endocrine responses, and physical performance in elite female basketball players during a periodized training program. *Journal of Strength and Conditioning Research*, *28*(10), 2973–2980. https://doi.org/10.1519/JSC.0000000000000499

Ortega-Becerra, M., Asián-Clemente, J., & López-Adarve, C. (2016). El uso de los impulsos de entrenamiento (TRIMPS) para cuantificar la carga de entrenamiento en situaciones reducidas en balonmano. *E-Balonmano.Com: Revista de Ciencias del Deporte*, *12*(1), 53–64.

Reynoso-Sanchéz, L. F., Hernández-Cruz, G., López-Walle, J., Rangel-Colmenero Blanca, Quezada-Chacón, J.-T., & Jaenes-Sanchez, J. C. (2016). Balance de estrés-recuperación en jugadores universitarios de voleibol durante una temporada. *Retos*, *30*, 193–197. https://doi.org/10.47197/retos.v0i30.50244

Reynoso-Sánchez, L. F., Hernández-Cruz, G., Morales-Beltrán, R., Miranda-Mendoza, J., & Muñoz-Helú, H. (2020). Comportamiento del balance estrés-recuperación en atletismo: Diferencias entre pruebas combinadas y salto con pértiga. In J. M. López-Walle, J. L. Tristán Rodríguez, R. de Fátima Ferrera, & A. R. Ceballos García (Eds.), *Psicología del deporte y ciencias aplicadas* (pp. 139–172). Fondo Editorial de Nuevo León.

Reynoso-Sánchez, L. F., Hoyos-Flores, J. R., García-Dávila, M., Rosas Taraco, A. G., Jaenes Sánchez, J. C., López-Walle, J., & Hernández-Cruz, G. (2017). Cortisol y estrés-recuperación durante un periodo competitivo en jugadores de balonmano. *Revista de Psicología Del Deporte*, *26*(Suppl. 2), 125–131.

Reynoso-Sánchez, L. F., Pérez-Verduzco, G., Celestino-Sánchez, M. Á., López-Walle, J. M., Zamarripa, J., Rangel-Colmenero, B. R., Muñoz-Helú, H., & Hernández-Cruz, G. (2021). Competitive recovery–stress and mood states in Mexican youth athletes. *Frontiers in Psychology*, *11*, e627828. https://doi.org/10.3389/fpsyg.2020.627828

Sansone, P., Gasperi, L., Tessitore, A., & Gomez, M. (2021). Training load, recovery and game performance in semi-professional male basketball: Influence of individual characteristics and contextual factors. *Biology of Sport*, *38*(2), 207–217. https://doi.org/10.5114/biolsport.2020.98451

Sansone, P., Tschan, H., Foster, C., & Tessitore, A. (2020). Monitoring training load and perceived recovery in female basketball: Implications for training design. *Journal of Strength and Conditioning Research*, *34*(10), 2929–2936. https://doi.org/10.1519/JSC.0000000000002971

Selye, H. (1950). Stress and the general adaptation syndrome. *BMJ*, *1*(4667), 1383–1392. https://doi.org/10.1136/bmj.1.4667.1383

Task Force of The European Society of Cardiology and the North American Society of pacing and Electrophysiology. (1996). Heart rate variability. Standars of Measurement, physiological interpretation, and clinical use. *Circulation*, *93*(5), 1043–1065. https://doi.org/10.1161/01.CIR.93.5.1043

World Medical Association. (2013). World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. *JAMA*, *310*(20), 2191–2194. https://doi.org/10.1001/jama.2013.281053