

Original article

Monitoring stress and recovery states: Structural and external stages of the short version of the RESTQ sport in elite swimmers before championships

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Abstract

Background: Psychological stress and recovery monitoring is a key issue for increasing athletes' health, well-being, and performance. This multi-study report examined changes and the dose–response relationships between recovery–stress psychological states, training load (TL), heart rate (HR), heart rate recovery (HRR), and heart rate variability (HRV) while providing evidence for the factorial validity of a short French version of the Recovery–Stress Questionnaire for Athletes (RESTQ-36-R-Sport).

Methods: Four hundred and seventy-three university athletes (Study 1), 72 full expert swimmers (Study 2), and 11 national to international swimmers (Study 3) participated in the study. Data were analyzed through confirmatory factor analyses (Study 1), repeated ANOVAs and correlational analyses (Study 2), *t* tests and correlational analyses (Study 3).

Results: Multiple-group confirmatory factor analyses showed that the RESTQ-36-R-Sport scores were partially invariant across gender, type of sport, and practice level (Study 1). A dose–response relationship was performed between TL and RESTQ-36-R-Sport scores during an ecological training program (Study 2). Finally, relationships were found between physiological (HRR) and psychological (RESTQ-36-R-Sport) states during an ecological tapering period leading to a national championship (Study 3).

Conclusion: As a whole, these findings provided evidence for the usefulness of the short version of the RESTQ-36-R-Sport for regular monitoring to prevent potential maladaptation due to intensive competitive sport practice.

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Keywords: Adaptation; Confirmatory factor analysis; Heart rate variability; Monitoring; Recovery; Stress

1. Introduction

Effective training loads (TLs) are among the key issues for coaches and athletes. Insufficient TL involves undertraining and leads to underperformance. On the contrary, excessive TL could lead to the accumulation of fatigue and its concomitants (i.e., non-functional overreaching or overtraining), and consequently impair athletes' well-being and performance.¹ Faced with this double dilemma, coaches strive to determine the precise dose–response relationship between stress provoked by TL and athletes' resources. Increasing our understanding of the recovery–stress balance is important not only because

optimal performance can only be achieved if athletes are able to balance training stress with their own recovery resources,² but also because the recovery–stress balance influences athletes' well-being and health.³ Consequently, monitoring the balance between recovery and stress still remains one of the most important theoretical questions^{4–6} and frequent requests coming from both coaches and athletes in the field.⁵

Numerous studies have attempted to identify reliable physiological, biological, or psychological markers of an adequate recovery–stress balance. However, a single consistent marker has not yet been identified.^{7,8} It is admitted that a prolonged and continuous decrease in performance^{9–11} and impaired mood states reported by psychological measures^{7,12} are among the main reliable indicators of prolonged fatigue associated with training. Furthermore, physiological monitoring (e.g.,

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blood analysis, specific medical/physiological diagnostics) may take days for feedback and are not so cost-effective.⁶ Hence, research suggested using psychometric self-report (available within minutes) to continuously monitor the athlete's subjective experience of recovery and stress during the training process.^{2,4,13}

Based on a biopsychological perspective of recovery and stress, the Recovery–Stress Questionnaire for Athletes (RESTQ-Sport)¹⁴ has been recognized as an interesting development on recovery in sport psychology.¹⁵ This self-report mainly embraces physical and psychosocial dimensions of both stress and recovery to indicate the extent to which someone is physically and/or mentally stressed, as well as whether that person is capable of using individual strategies for recovery and which strategies are used. The RESTQ-Sport appeared effective in monitoring individuals and teams during training camps or over an entire season as well as preparation phases and competition periods.^{3,4,12,16,17} However, criticism has been raised concerning the factorial structure of the RESTQ-Sport.¹⁵ Mainly, the individual items comprising the subscales were not verified for their utility (i.e., the method used for exploring the structural validity of the RESTQ-Sport scores was based on the subscales instead of an analysis empirically driven by the items) within the original study.^{14,15} In addition, according to the feedback from practitioners considering the need to repeat the administration of the questionnaire for effective monitoring, a shorter version of the 76-item original version currently used is necessary.³ A shorter version of the RESTQ-Sport could meet this request, but the effectiveness of a short version remains to be validated. Thus, the development of a valid and reliable inventory for measuring stress and recovery is an important step (a) to monitor continuously athletes during training and/or competition, and (b) to provide an easy assessment of the early indicators of overtraining and burnout in athletes.⁴ In this line, the authors of the original 76-item version recently developed a modified version of the scale, namely, the RESTQ-36-R-Sport, to satisfy the request of the sports practice for an economic, valid, and change sensitive psychometric instrument to quantify recovery and stress.¹⁸ The development and validation process (i.e., exploratory and confirmatory factor analyses) resulted in the emergence of a 12-factor 36-item version of the RESTQ-Sport (i.e., RESTQ-36-R-Sport). However, further reliability and validity evidence of the RESTQ-36-R-Sport scores is still warranted.

A 3-level development and validation process with substantive, structural, and external stages provides a strong analytical framework for construct validation.¹⁹ The substantive stage of construct validation defines and delineates the construct under investigation. The structural stage pertains to establishing evidence of factorial validity and reliability relative to the construct of interest. The external stage examines whether the construct under investigation is related to other variables (e.g., TL, heart rate (HR)) in accordance with the theoretical expectations. Because questionnaire validation is an ongoing process, several reasons justified the exploration of the validity and reliability of the RESTQ-36-R-Sport scores for measuring recovery–stress states (RSS) of athletes. Firstly, the RESTQ-36-R-Sport has

recently been introduced in the literature, but its factorial validity still remains to be examined (Study 1).¹⁸ Secondly, a translated version (French) was used. Thirdly, because the RESTQ-36-R-Sport was designed to monitor the balance between stress and recovery, it was of primary importance to focus on the potential interrelationships between TL and psychological RSS during 3 training periods preceding competitions (Study 2) and between psychological RSS and physiological markers (i.e., HR, heart rate recovery (HRR), and heart rate variability (HRV)) before a national championship (Study 3).

2. Study 1

This study examined (a) the substantive stage of construct validity (i.e., ensuring the item content was covering the intended construct within the translation procedure) and (b) the structural stage with the construct validity and the reliability of the RESTQ-36-R-Sport scores among a sample of French athletes.

2.1. Materials and methods

2.1.1. Participants

Four hundred and seventy-three French university athletes (129 women and 344 men, age = 18.61 ± 0.99 years) responded voluntarily to the RESTQ-36-R-Sport during an academic session. All the participants signed informed consent to participate in this study conducted in accordance with the University of Bourgogne Franche-Comté Institutional Review Board. They trained 6.08 ± 3.93 h per week, and practiced their sport for 8.57 ± 4.24 years.

2.1.2. Instruments

Like the original version in 76 items,¹⁴ the version used in the present study consists of 36 items divided into 12 subscales with 3 items for each subscale.¹⁸ This self-report includes 3 general subscales concerning stress (general stress, social stress, and fatigue) and 3 general recovery subscales (somatic relaxation, general well-being, and sleep quality), as well as 6 specific subscales which aim at addressing the sport dimension of stress (3 subscales: disturbed breaks, emotional exhaustion, and fitness/injury) and recovery (3 subscales: fitness/being in shape, personal accomplishment, and self-efficacy) processes from physical, emotional, behavioral, and social perspectives.

The RESTQ-36-R-Sport was translated into French and then back-translated by 2 bilingual translators into English. Differences were resolved so that the original meaning of each item was considered to be present in the final French version. Subsequently, comprehensibility, acceptability, relevance, and completeness of all items were discussed with 8 swimmers not involved in this study. At this step, no changes were considered necessary. The participants indicated how often they participated in the various activities during the past 3 days/nights using a 7-point Likert-type scale ranging from 0 (*never*) to 6 (*always*).

2.1.3. Statistical analysis

The structural stage of the RESTQ-36-R-Sport was examined through a series of confirmatory factor analyses (CFAs)

with Lisrel 8.71 using maximum likelihood estimation.²⁰ First, the original 12-factor correlated model was tested to assess the tenability of the original factor structure. Second, 2 hierarchical models were tested and compared to the 12-factor correlated model (i.e., 4 second-order latent variables of General and Sport-Specific Stress and Recovery, or 2 second-order latent variables of Total Recovery and Total Stress were added to the 12-factor model). Finally, the best fitting model of the RESTQ-36-R-Sport was also tested for invariance across gender (men *vs.* women), sport type (individual *vs.* team sports) and practice level (elites *vs.* non-elites) using the methodology proposed by Gregorich²¹ (i.e., configural metric; strong and strict invariances were successively tested).

2.2. Results

2.2.1. Factor structure of the RESTQ-36-R-sport

Table 1 presents fit indices for the CFA models of the RESTQ-36-R-Sport. The goodness-of-fit indices of the original 12-factor correlated model reached cut-off criterion values. CFA results are shown in Tables 1 and 2. The goodness-of-fit indices of the hierarchical models also reached cut-off criterion values (Table 1). All second-order factor loadings (range = 0.54–0.95 and 0.51–0.83 for the 4- and 2-factor hierarchical models, respectively) were statistically significant. Nevertheless, the χ^2 difference test ($\Delta\chi^2 = 423.76$ and 672.03 , $\Delta df = 48$ and 53 , $p < 0.001$), the Akaike information criterion (AIC), and the expected cross-validation index (ECVI) values provided evidence for the relative superiority of the 12-factor correlated model in comparison to the hierarchical models.

2.2.2. Factorial invariance across gender, type of sport, or practice level

The 12-factor correlated model of the RESTQ-36-R-Sport demonstrated an adequate model fit among the separate samples of males and females, elites (international and national athletes) and non-elites (regional and departmental athletes) as well as athletes practicing individual and team sports (Table 3). The configural multiple-sample CFA model fitted the data adequately (i.e., identical number of latent constructs across samples). The metric multiple-sample model fitted the data adequately. The differences in comparative fit index (CFI) values between the configural and metric models were less than 0.01 (Table 3), providing evidence of metric invariance across samples (i.e., equal factor loadings across groups).²² The third model tested strong factorial invariance by additionally imposing equality constraints on corresponding item intercepts. These models encountered the problem of convergence and thus could not be computed.

2.2.3. Reliability

Several researchers prefer the use of the raw mean inter-item correlation instead of Cronbach's α as a statistical marker of internal consistency.^{23,24} For this, a rule of thumb is offered by Clark and Watson²⁵ who recommend that the average inter-item correlation fall in the range of 0.15–0.50. The average inter-item correlation for the RESTQ-36-R-Sport subscales ranged from 0.21 to 0.60 (Table 2). Therefore, in view of the small

amount of violations, inter-item correlation analysis provided evidence for the reliability of the RESTQ-36-R-Sport scores. To further assess the reliability of the RESTQ-36-R-Sport scores, composite reliability values were provided as well.²⁶ ρ values indicated that the reliability of most of the RESTQ-36-R-Sport subscales was acceptable, with ρ ranging from 0.61 to 0.94. Nevertheless, the ρ values for the social relaxation ($\rho = 0.56$) and disturbed breaks ($\rho = 0.57$) subscales suggested a relatively poor reliability for these 2 RESTQ-36-R-Sport subscales (Table 2). Finally, it is noteworthy that results of the present study provided evidence for the reliability of the second-order factor scores of the RESTQ-36-R-Sport ($0.84 < \rho < 0.94$).

2.3. Discussion

The primary goal of this research was to examine the factorial structure of the RESTQ-36-R-Sport. The construct validity of the RESTQ-36-R-Sport scores was supported by several arguments. CFAs revealed good fits between participants' item responses and the 12-factor 36-item model. Internal consistency coefficients as well as item analysis also showed that the RESTQ-36-R-Sport scores demonstrated acceptable reliability. As a whole, the results of the CFAs were consistent with the original factor structure of the RESTQ-Sport¹⁴ and its short form¹⁸ and revealed the multi-dimensional nature of this self-report questionnaire. Specifically, CFA results suggested that the 12 RESTQ-36-R-Sport factors are tapping unique, yet correlated, dimensions of RSS of athlete. A shorter questionnaire has the advantage of being more convenient in sport settings, especially for regular monitoring throughout the season. This scale could stimulate much needed research on recovery and fatigue.

A series of multiple-sample CFAs tested the invariance of parameter estimates across gender, practice level (international and national *vs.* regional and departmental athletes) or type of sport (individual *vs.* team sports). All the 36 factor loadings were not significantly different across gender, practice level, and type of sport (i.e., metric invariance), which highlight that RESTQ-36-R-Sport items measure the same attribute across independent samples of athletes. However, it is noteworthy that results of multiple-sample CFAs did not provide evidence for the cross-sample equality in the RESTQ-36-R-Sport intercepts (strong invariance) and residual variances (strict invariance). Therefore, future research should test the factorial invariance of the RESTQ-36-R-Sport again to see if it was a result specific to the current sample.

In the present study, the hierarchical models produced fit values that were only marginally lower than that of the first-order model (12-factor 36-item model). Given that the fit of a second-order model cannot be better than the fit of an equivalent first-order structure,²⁷ it is suggested that the hierarchical model of the RESTQ-36-R-Sport should be adopted by researchers interested in a general measure of the recovery–stress state of athletes. For those examining relationships between specific recovery and stress dimensions and other concepts or outcomes, the 12-factor model of the RESTQ-36-R-Sport

Table 1
Standardized factor loadings (SFL) and standardized error variances (SEV) for the 12-factor correlated and hierarchical models of the French RESTQ-36-R-Sport (Study 1).

Items	Model				
	12-factor correlated model		Hierarchical models		
	SFL	SEV	SFL	SEV	
General stress					
7	Je me sentais triste (I felt down)	0.79 ^a	0.37	0.79 ^b /0.78 ^c	0.38/0.39
9	***	0.87	0.24	0.88/0.90	0.23/0.20
13	***	0.62	0.61	0.62/0.60	0.62/0.64
Social stress					
6	J'étais énervé par les autres (I was annoyed by others)	0.86	0.26	0.87/0.87	0.24/0.25
11	***	0.77	0.40	0.77/0.78	0.40/0.40
18	***	0.68	0.54	0.67/0.67	0.56/0.55
Fatigue					
4	J'étais fatigué par le travail (I was tired from work)	0.71	0.49	0.75/0.73	0.44/0.47
10	***	0.76	0.42	0.77/0.77	0.41/0.41
15	***	0.73	0.47	0.69/0.70	0.53/0.51
Social relaxation					
1	J'ai ri (I laughed)	0.13	0.98	0.11/0.11	0.99/0.99
3	***	0.88	0.22	0.93/0.93	0.13/0.14
8	***	0.55	0.70	0.52/0.52	0.73/0.73
General well-being					
2	J'étais joyeux (I felt content)	0.78	0.39	0.76/0.74	0.43/0.45
14	***	0.75	0.43	0.77/0.78	0.40/0.38
17	***	0.79	0.37	0.80/0.80	0.37/0.36
Sleep quality					
5	Je m'endormais satisfait et détendu (I fell asleep satisfied and relaxed)	0.76	0.42	0.75/0.74	0.43/0.45
12	***	0.71	0.50	0.70/0.72	0.50/0.48
16	***	0.77	0.41	0.77/0.78	0.40/0.39
Disturbed breaks					
23	J'avais l'impression qu'il n'y avait pas assez de pauses (I had the impression there were too few breaks)	0.68	0.53	0.63/0.60	0.60/0.65
29	***	0.50	0.75	0.51/0.52	0.74/0.73
33	***	0.48	0.77	0.52/0.56	0.73/0.69
Emotional exhaustion					
21	Je me suis senti surmené à cause de mon sport (I felt burned out by my sport)	0.52	0.73	0.58/0.51	0.67/0.74
30	***	0.56	0.68	0.53/0.55	0.72/0.69
35	***	0.67	0.55	0.62/0.69	0.62/0.52
Injury					
19	J'avais mal partout (Parts of my body were aching)	0.76	0.42	0.73/0.75	0.47/0.44
22	***	0.49	0.76	0.48/0.47	0.77/0.78
27	***	0.73	0.47	0.77/0.76	0.41/0.43
Being in shape					
20	J'ai bien récupéré physiquement (I recovered well physically)	0.64	0.59	0.61/0.64	0.63/0.59
26	***	0.71	0.50	0.73/0.75	0.47/0.44
34	***	0.69	0.53	0.70/0.66	0.52/0.57
Personal accomplishment					
25	Je me suis adapté très efficacement aux problèmes de mes coéquipiers (I dealt very effectively with my teammates' problems)	0.67	0.55	0.72/0.72	0.49/0.48
31	***	0.54	0.71	0.53/0.54	0.72/0.71
36	***	0.56	0.69	0.53/0.52	0.72/0.73
Self-efficacy					
24	J'étais certain que je pouvais accomplir ma performance n'importe quand (I was convinced that I could achieve my performance at any time)	0.57	0.68	0.57/0.55	0.67/0.70
28	***	0.62	0.61	0.62/0.63	0.62/0.61
32	***	0.58	0.67	0.58/0.59	0.66/0.65

*** See items in Kellmann and Kallus.¹⁴

^a Original 12-factor correlated model.

^b The 4 correlated second-order latent variables of general and sport-specific stress and recovery were added to the 12-factor model.

^c The 2 correlated second-order latent variables of stress and recovery were added to the 12-factor model.

Table 2

Mean (M), SD, Akaike information criterion (AIC), composite reliability (ρ) and correlations between latent constructs of the 12-factor correlated model of the RESTQ-36-R-Sport (Study 1).

	Factor											M	SD	AIC	ρ	
	1	2	3	4	5	6	7	8	9	10	11					
First-order factors ^a																
1 General stress	–												2.09	0.81	0.57	0.81
2 Social stress	0.58*	–											2.45	0.82	0.59	0.82
3 Fatigue	0.43*	0.35*	–										2.92	0.81	0.54	0.78
4 Social relaxation	–0.32*	–0.04	–0.11	–									3.84	0.79	0.21	0.56
5 General well-being	–0.64*	–0.40*	–0.21*	0.66*	–								4.13	0.73	0.60	0.82
6 Sleep quality	–0.51*	–0.32*	–0.36*	0.33*	0.65*	–							3.58	0.91	0.56	0.79
7 Disturbed breaks	0.20*	0.20*	0.49*	0.01	–0.05	–0.10	–						1.88	0.65	0.31	0.57
8 Emotional exhaustion	0.38*	0.36*	0.45*	–0.17*	–0.32*	–0.31*	0.66*	–					1.89	0.73	0.33	0.61
9 Injury	0.20*	0.27*	0.68*	0.03	–0.03	–0.15*	0.57*	0.41*	–				2.93	0.84	0.42	0.70
10 Being in shape	–0.35*	–0.14*	–0.46*	0.36*	0.51*	0.60*	–0.34*	–0.50*	–0.38*	–			3.88	0.79	0.46	0.72
11 Personal accomplishment	–0.26*	–0.32*	–0.20*	0.31*	0.55*	0.41*	–0.12	–0.51*	–0.12	0.60*	–		3.85	0.80	0.35	0.62
12 Self-efficacy	–0.21*	–0.15*	–0.26*	0.37*	0.48*	0.38*	–0.09	–0.45*	–0.06	0.84*	0.70*		3.54	0.75	0.35	0.62
Second-order factors ^b																
13 General stress	–												2.49	0.63	0.36	0.92
14 General recovery	–0.71*	–											3.85	0.62	0.31	0.89
15 Sport specific stress	0.56*	–0.25*	–										2.23	0.57	0.25	0.84
16 Sport specific recovery	–0.41*	0.65*	–0.50*										3.76	0.62	0.30	0.85
Second-order factors ^c																
17 Total stress	–												2.36	0.51	0.24	0.94
18 Total recovery	–0.60*												3.80	0.53	0.25	0.93

^a Original 12-factor correlated model.¹⁴

^b The 4 correlated second-order latent variables of general and sport-specific stress and recovery were added to the 12-factor model.

^c The 2 correlated second-order latent variables of stress and recovery were added to the 12-factor model.

* $p < 0.05$.

Table 3

Fit indices for the RESTQ-36-R-Sport (Study 1).

Model	χ^2	p	df	CFI	$RMSEA$	90%CI	AIC	ECVI
12-factor correlated model ^a	1215.36	<0.001	528	0.951	0.05	0.05–0.06	1491.36	3.16
4-factor hierarchical model ^b	1639.12	<0.001	576	0.930	0.06	0.06–0.07	1819.12	3.85
2-factor hierarchical model ^c	1887.39	<0.001	581	0.917	0.07	0.07–0.07	2057.39	4.36
Multiple groups model								
Gender								
Males ($n = 344$)	1028.11	<0.001	528	0.949	0.05	0.05–0.06	1304.11	3.80
Females ($n = 129$)	811.84	<0.001	528	0.904	0.06	0.06–0.07	1087.84	8.50
Configural invariance	1956.79	<0.001	1122	0.935	0.06	0.05–0.06	2376.79	5.05
Metric invariance	2019.38	<0.001	1158	0.934	0.06	0.05–0.06	2367.38	5.03
Level								
Elites ($n = 174$)	893.64	<0.001	528	0.918	0.07	0.06–0.07	1169.76	7.40
Non-elites ($n = 299$)	946.18	<0.001	528	0.947	0.05	0.05–0.06	1222.18	4.24
Configural invariance	1918.54	<0.001	1122	0.936	0.06	0.05–0.06	2338.54	5.24
Metric invariance	1966.24	<0.001	1158	0.935	0.06	0.05–0.06	2314.25	5.19
Sport type								
Individual sports ($n = 204$)	903.90	<0.001	528	0.932	0.06	0.05–0.07	1179.90	5.87
Team sports ($n = 269$)	908.63	<0.001	528	0.947	0.05	0.05–0.06	1184.63	4.42
Configural invariance	1911.27	<0.001	1122	0.938	0.05	0.05–0.06	2331.27	4.97
Metric invariance	1987.67	<0.001	1158	0.936	0.05	0.05–0.06	2335.67	4.98

^a Original 12-factor correlated model.¹⁴

^b The 4 correlated second-order latent variables of general and sport-specific stress and recovery were added to the 12-factor model.

^c The 2 correlated second-order latent variables of stress and recovery were added to the 12-factor model.

Abbreviations: AIC = Akaike information criterion; CFI = comparative fit index; CI = confidence interval; ECVI = expected cross-validation index; $RMSEA$ = root mean square error of approximation.

would likely be most applicable since it provides a more in-depth assessment.

3. Study 2

A structural validity was not sufficient to assert that the RESTQ-36-R-Sport scores were unambiguous indicators of the RSS of athletes. Consequently, an ecological validation was requested. Study 2 was conducted in order to closely monitor the RSS. We assumed that the TL would be negatively correlated to the recovery dimension and positively correlated to the stress dimension of the RESTQ-36-R-Sport.

3.1. Materials and methods

3.1.1. Participants

Seventy-two swimmers (24 women and 48 men, age = 16.5 ± 2.6 years, practice time = 18.7 ± 6.1 h/week) voluntarily participated in the training sessions to assess the relationships between psychological recovery–stress dimensions and TL. They had been competing and training regularly at a national level for at least 2 years before the study. The participants were fully informed of the goals and procedures. They gave their written informed consent to participate in this study and they were free to withdraw from the study at any time. Study 2 was designed in compliance with the recommendations for clinical research of the Declaration of Helsinki of the World Medical Association. The University of Bourgogne Franche-Comté Institutional Review Board granted the permission for conducting this study.

3.1.2. Procedure and measures

Data gathering was carried out during a normal periodization of training in order to test the effectiveness of the RESTQ-36-R-Sport to monitor the RSS of swimmers. Following the training program, 3 periods have been identified. Evaluations began after a week of moderate training load period (MP). A second evaluation has been performed after an overload period (OP) of 3 weeks which consisted of an important increase in TL. The last evaluation has been realized after 15 days of tapering period (TP) leading to a major competition. TL was assessed by multiplying the athlete's "rating of perceived exertion" (RPE, on a 1–10 scales) obtained 30 min after the completion of the training session by the duration (in minutes) of the session.^{28,29} By summing on a weekly basis each "session RPE", we obtained the weekly TL of each swimmer.¹ This method is relevant to quantify TL in numerous sports,^{30–32} including swimming.²⁹

3.1.3. Statistical analysis

Shapiro–Wilk test was applied prior to the statistical analyses and indicated the normality of the distribution. Since the magnitude of an effect is of more practical interest than its statistical significance *per se*,³³ all comparisons were also expressed as standardized mean differences (Cohen's effect size, d), calculated using the pooled standard deviations for the 3 testing sessions being compared.³⁴ Thresholds of >0.2 and ≤ 0.5 for small effect size, >0.5 and ≤ 0.8 for moderate effect size, and >0.8 for large effect size were used. Changes in psychological states and TL were assessed from a one-way

repeated ANOVA, and time to time variation was controlled by using the *post hoc* Tukey HSD. The level of significance for these analyses was corrected using Bonferroni-type adjustment in order to maintain the Type-I error probability at the 0.05 α level. Finally, bivariate correlations were made using Pearson's product–moment correlation (r) between psychological and TL variables of interest. The following criteria were adopted to interpret the magnitude of the correlation (r) between test measures: <0.10 , trivial; $0.10–0.29$, small; $0.30–0.49$, moderate; $0.50–0.69$, large; $0.70–0.89$, very large; and $0.90–1.00$, almost perfect.³³

3.2. Results

3.2.1. Changes in TL and RSS

Firstly, TL significantly changed throughout the 3 evaluations ($F(2, 142) = 300.58, p < 0.001$). *Post hoc* comparisons showed a large increase between MP and OP ($p < 0.001, d = -2.40$), followed by a large decrease between OP and TP ($p < 0.001, d = 3.88$).

Secondly, significant changes were observed throughout the 3 evaluations for Total Recovery ($F(2, 142) = 17.86, p < 0.001$), Specific Recovery ($F(2, 142) = 28.72, p < 0.001$), and General Recovery ($F(2, 142) = 5.00, p < 0.01$). Considering recovery subscales, these results were mirrored in *General well-being* ($F(2, 142) = 5.64, p < 0.004$), *Being in shape* ($F(2, 142) = 37.20, p < 0.001$), *Personal accomplishment* ($F(2, 142) = 7.02, p < 0.001$), and *Self-efficacy* ($F(2, 142) = 14.93, p < 0.001$). Contrarily, no significant variation was observed for *Social relaxation* ($F(2, 142) = 0.56, p = 0.57$) and *Sleep quality* ($F(2, 142) = 4.77, p = 0.009$), due to Bonferroni corrections.

Post hoc comparisons showed a small decrease between MP and OP for Total Recovery ($p < 0.04, d = 0.31$), a small and non-significant decrease in Specific Recovery ($p = 0.05, d = 0.30$), and a small and non-significant decrease in General Recovery ($p = 0.09, d = 0.26$). Recovery subscales *post hoc* comparisons showed a moderate decrease in *Being in shape* ($p < 0.001, d = 0.50$), whereas the other recovery factors did not significantly decrease (p values from 0.06 to 0.92, d from -0.09 to 0.29). *Post hoc* comparisons between OP and TP showed a moderate increase in Total Recovery ($p < 0.001, d = -0.71$), a large increase in Specific Recovery ($p < 0.001, d = -0.86$), and a small increase in General Recovery ($p < 0.01, d = -0.37$). At the subscales level, the results showed a small increase in *General well-being* ($p < 0.003, d = -0.40$), a small increase in *Sleep quality* ($p < 0.006, d = -0.41$) and *Personal accomplishment* ($p < 0.002, d = -0.36$), a large increase in *Being in shape* ($p < 0.001, d = -1.09$), and a moderate increase in *Self-efficacy* ($p < 0.001, d = -0.68$), whereas no significant variation was found for *Social relaxation* ($p = 0.77, d = -0.09$).

Thirdly, significant changes were observed throughout the 3 evaluations for Total Stress ($F(2, 142) = 46.83, p < 0.001$), Specific Stress ($F(2, 142) = 39.04, p < 0.001$), and General Stress ($F(2, 142) = 43.19, p < 0.001$). Considering the subscales, significant changes were observed in *General stress* ($F(2, 142) = 13.33, p < 0.001$), *Social stress* ($F(2, 142) = 13.37, p < 0.001$), *Fatigue* ($F(2, 142) = 45.56, p < 0.001$), *Disturbed*

Table 4

Pearson's correlation coefficients between training load (TL) and RESTQ-36-R-Sport for moderate period (MP), overload period (OP), and tapering period (TP) (Study 2).

Variable	TL					
	MP		OP		TP	
	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>
Total stress	0.43	0.000*	0.40	0.000*	0.36	0.002*
<i>Specific stress</i>	0.33	0.004*	0.33	0.005*	0.37	0.001*
Disturbed breaks	0.05	0.698	0.29	0.015	0.03	0.818
Emotional exhaustion	0.17	0.157	0.12	0.300	0.45	0.000*
Injury	0.52	0.000*	0.35	0.002*	0.31	0.007*
<i>General stress</i>	0.47	0.000*	0.42	0.000*	0.31	0.009*
General stress	0.20	0.091	0.22	0.066	0.29	0.015
Social stress	0.38	0.001*	0.26	0.026	0.19	0.103
Fatigue	0.47	0.000*	0.44	0.000*	0.26	0.030
Total recovery	-0.02	0.898	-0.33	0.005*	-0.42	0.000*
<i>Specific recovery</i>	-0.02	0.849	-0.34	0.003*	-0.34	0.003*
Being in shape	-0.15	0.194	-0.35	0.003*	-0.44	0.000*
Personal accomplishment	0.08	0.495	-0.21	0.078	-0.09	0.455
Self-efficacy	0.01	0.964	-0.29	0.014	-0.33	0.005*
<i>General recovery</i>	-0.01	0.963	-0.26	0.026	-0.44	0.000*
Social relaxation	-0.01	0.926	-0.21	0.071	-0.18	0.125
General well-being	0.03	0.808	-0.29	0.015	-0.35	0.002*
Sleep quality	-0.02	0.871	-0.17	0.155	-0.49	0.000*

* Significant association with Bonferroni corrections.

breaks ($F(2, 142) = 16.30, p < 0.001$), *Emotional exhaustion* ($F(2, 142) = 12.51, p < 0.001$), and *Injury* ($F(2, 142) = 45.07, p < 0.001$).

Post hoc comparisons showed a large increase between MP and OP for Total Stress ($p < 0.001, d = -0.86$), Specific Stress ($p < 0.001, d = -0.80$), and General Stress ($p < 0.001, d = -0.80$). Large increases were found for the subscales *Fatigue* ($p < 0.001, d = -1.00$), *Emotional exhaustion* ($p < 0.004, d = -0.40$), and *Injury* ($p < 0.001, d = -1.17$), while no significant variation was noted for *General stress* ($p = 0.03, d = -0.41$), *Social stress* ($p = 0.026, d = -0.33$) or *Disturbed breaks* ($p = 0.053, d = -0.31$). Finally, Total Stress ($p < 0.001, d = 1.53$), Specific Stress ($p < 0.001, d = 1.47$), and General Stress ($p < 0.001, d = 1.38$) largely decreased between OP and TP. Large decreases were found for the subscales *General stress* ($p < 0.001, d = 0.70$), *Social stress* ($p < 0.001, d = 0.75$), *Fatigue* ($p < 0.001, d = 1.56$), *Disturbed breaks* ($p < 0.001, d = 1.01$), *Emotional exhaustion* ($p < 0.001, d = 0.65$), and *Injury* ($p < 0.001, d = 1.56$).

3.2.2. Relationships between TL and RSS

Table 4 presents Pearson's *r* analyses between TL and the RESTQ-36-R-Sport subscales.

3.2.2.1. TL and recovery states. For MP, no association was found between TL and recovery scales and subscales. For OP, moderate and negative associations were found between TL, Total Recovery, and Specific Recovery, while a small and non-significant correlation was found between TL and General Recovery. At the subscale level, moderate and negative associations were found between TL and *Being in shape*, while no other association was found with the other recovery subscales (due to Bonferroni corrections). Finally, for TP, moderate and negative

associations were found between TL, Total Recovery, Specific Recovery, and General Recovery. Moderate and negative associations for the subscales were found between TL, *Being in shape*, *Self-efficacy*, *General well-being*, and *Sleep quality*.

3.2.2.2. TL and stress states. For MP, TL was moderately and positively associated with Total Stress, Specific Stress, and General Stress. Considering stress subscales, a large and positive association was found with *Injury*, and a moderate and positive association with *Social stress* and *Fatigue*. For OP, moderate and positive associations were found between TL, Total Stress, Specific Stress, and General Stress. Moderate and positive associations were found between TL, *Injury*, and *Fatigue*. In addition, small non-significant positive associations were found with *Disturbed breaks*, *General stress*, and *Social stress*. Finally, for TP, moderate and positive associations were found between TL, Total Stress, Specific Stress, and General Stress. For the subscales, moderate and positive associations were observed between TL, *Emotional exhaustion*, and *Injury*.

3.3. Discussion

In this study, TL was (1) negatively associated with perceived recovery and (2) positively associated with perceived stress. In line with previous studies using the RESTQ-Sport,⁴ our results highlighted a linear dose-response relationship between TL and the RSS measures through the RESTQ-36-R-Sport. In agreement with the literature and our findings, psychological questionnaires might provide practical tools for monitoring RSS in a training environment during normal periodization and preparations.^{4,7,14}

As a whole, our findings indicated that for these full expert swimmers, the RESTQ-36-R-Sport offers a parsimonious and

improved fitting model to obtain a comprehensive and multidimensional profile of athletes' perceptions of RSS. The relationships between the psychological stress responses and the TL reinforce the belief that these tools may provide relevant markers for the balance between recovery and stress, and could be used as indicators of training status in athletes.

4. Study 3

As shown in Study 2, RESTQ-36-R-Sport results are strongly associated with TL. However, a single tool cannot inform on all aspects of athletes' resources states and a multidisciplinary approach is generally recommended to have a more complete vision of athlete states.^{7,8} There is a growing interest in monitoring the autonomic nervous system (ANS) status through measures of HR during sub-maximal tests and during recovery after exercise.³⁵ In this line, combining HRV, HRR, and psychometric measurements is a pertinent way to improve the monitoring of aerobic-oriented athletes.^{1,35} In addition, psychological and physiological interplays would supply support for the relevance of a self-report questionnaire as an external validation in an ecological setting.

This study was conducted during a 2-week tapering period immediately preceding a major competition with elite swimmers in order to closely monitor the RSS. We supposed that the TL would be negatively correlated to the psychometric recovery dimensions, parasympathetic HRV indicators and HRR indices. In contrast, we hypothesized that TL would be positively correlated to the psychometric stress dimension. In addition, we supposed that psychological and physiological dimensions would be associated.

4.1. Materials and methods

4.1.1. Participants

Eleven swimmers (1 woman and 10 men, age = 17.09 ± 1.64 years, height = 1.76 ± 0.06 m, weight = 64.54 ± 6.28 kg, BMI = 20.70 ± 1.15 kg/m²) voluntarily participated in this study. The swimmers were competing at a national level in swimming and practicing 16.00 ± 1.79 h per week. This study has been conducted in accordance with recognized ethical standards of the University of Bourgogne Franche-Comté Institutional Review Board and followed the recommendations for clinical research of the Declaration of Helsinki of the World Medical Association. The participants were fully informed of the goals and procedures. They gave their written informed consent to participate in this study and they were free to withdraw from the study at any time.

4.1.2. Procedure and measures

Psychometric and physiological evaluations were concomitantly performed at the same time of the day, under controlled conditions at the beginning (T1) and end (T2) of a 2-week training phase leading to the national championships, which were the major competitions of the year. Tapering periods consist in a training reduction^{36,37} and both physical and psychological resources have to be managed to induce optimal performance before competitions. As exposed in Study 2, weekly TL was calculated using the session-rate of perceived exertion according to

Meeusen et al.¹ and Foster et al.²⁸ Swimmers were asked to refrain from intense physical exercise and from alcohol and caffeine consumption for 1 day prior to any experimental session.

Among the numerous indices of HRV, the root mean square of successive R–R intervals (RMSSD) is accepted as relevant for athletic monitoring.³⁸ It has been repeatedly shown as uninfluenced by respiratory rate,^{39,40} relatively easy to calculate and interpret,^{35,41} and having a lower typical error of measurement than other spectral indices of HRV.⁴²

RMSSD reflects both training- and non-training-related stress^{43,44} and can be indicative of positive or maladaptive responses to training demands.^{44–46} It has been accepted as a time-domain parameter for assessing parasympathetic modulation, which is crucial for monitoring athletes.⁴³ Currently, using spectral indices on the field is strongly discouraged and it is recommended to focus attention on RMSSD, collected at rest in athletes.³⁵ Concomitantly, recent literature suggests that 5 min of resting aimed at capturing cardiac parasympathetic activity, together with submaximal exercise (last minute of 4–5 min running) HR, is likely the most useful monitoring variable.³⁵ In this line, the absolute difference between the average HR was observed during the last 10 s of monitoring at the end of the exercise (termed HR_{ex}), and the average HR recorded at the end of the first minute of recovery was calculated (termed HRR60s).⁴⁷ A second index (nHRR60s) was used for possible changes in HRR60s due to HR_{ex} by calculating nHRR60s as (HRR60s/HR_{ex}).⁴⁸ Finally, the same lying down posture was imposed since body posture influences HRR.⁴⁸ Beat-by-beat measures of HR were done with a Suunto t6 heart rate monitor (Suunto Oy, Vantaa, Finland).

4.1.3. Statistical analysis

Inherent to a sample of elite athletes before a national competition, the number of athletes during the screening of the strategic tapering phase was quite small (11 participants). Shapiro–Wilk test was applied prior to the statistical analyses and tested the normality of the distribution. When data were skewed, they were transformed by taking the natural logarithm (Ln). Changes in psychological and physiological states and TL were assessed with the signed-rank paired *t* test. The level of significance for these analyses was corrected using Bonferroni-type adjustment in order to maintain the Type 1 error probability at the 0.05 α level. In addition, bivariate correlations were made using Pearson's product–moment correlation (*r*). The same criteria used in Study 2 for the Cohen effect size and the magnitude of correlations were adopted.

4.2. Results

4.2.1. Changes in TL, RSS, HR, and HRV

Table 5 presents the data, the level of significance, and the effect size for the variations between beginning (T1) and end (T2). A large decrease of $61.87\% \pm 9.72\%$ was observed in the scoring of TL from T1 to T2. Total Recovery, Specific Recovery, and General Recovery largely increased. The subscales *Being in shape*, *Self-efficacy*, *Sleep quality*, and *General well-being* largely increased from T1 to T2, whereas no other

Table 5
Characteristics of the training load (TL), heart rate variability, heart rate, and the RESTQ-36-R-Sport for the beginning (T1) and end (T2) of the tapering period (Study 3).

Variable	T1	T2	<i>p</i>	<i>d</i>
TL (arbitrary units)	3776 ± 753	2362 ± 659	<0.001	1.99
Ln RMSSD (ms)	3.61 ± 0.85	4.05 ± 0.54	0.060	-0.62
HRex (bpm)	157 ± 21	136 ± 15	<0.001	1.40
HRR60s (bpm)	62 ± 12	63 ± 6	0.82	-0.08
Ln nHRR60 (ratio)	-0.94 ± 0.23	-0.65 ± 0.18	0.002	-1.44
Total stress	2.64 ± 0.57	2.14 ± 0.39	0.003	1.00
Specific stress	2.66 ± 0.62	2.18 ± 0.52	0.007	0.83
Disturbed breaks	2.09 ± 0.65	1.61 ± 0.59	0.034	0.77
Emotional exhaustion	2.42 ± 1.01	1.85 ± 0.72	0.100	0.65
Injury	3.45 ± 0.78	3.09 ± 0.97	0.179	0.41
General stress	2.62 ± 0.67	2.10 ± 0.40	0.018	0.93
General stress	2.21 ± 1.16	1.82 ± 0.82	0.242	0.39
Social stress	2.36 ± 0.84	2.03 ± 0.35	0.232	0.51
Fatigue	3.27 ± 0.66	2.45 ± 0.73	0.009	1.18
Total recovery	3.31 ± 0.51	4.05 ± 0.59	0.002	-1.33
Specific recovery	3.00 ± 0.80	3.90 ± 0.68	0.003	-1.21
Being in shape	2.67 ± 0.94	3.97 ± 0.92	0.001	-1.40
Personal accomplishment	3.52 ± 1.17	4.12 ± 0.96	0.132	-0.56
Self-efficacy	2.82 ± 1.02	3.61 ± 0.84	0.007	-0.85
General recovery	3.63 ± 0.53	4.20 ± 0.66	0.017	-0.94
Social relaxation	3.97 ± 0.81	4.03 ± 0.90	0.806	-0.07
General well-being	3.88 ± 0.64	4.48 ± 0.67	0.004	-0.92
Sleep quality	3.03 ± 0.67	4.06 ± 1.04	0.019	-1.18

Notes: Data are presented as mean ± SD for T1 and T2. Possible significant variations between T1 and T2 are reported for each variable (*p*), and Cohen's effect size (*d*) is proposed. Ln RMSSD: square root of the mean of the sum of the squares of differences between adjacent normal R-R intervals; HRex: submaximal exercise heart rate; HRR60s: HR recorded 60 seconds after submaximal exercise; Ln nHRR60: Index compensated for possible changes in the HR at the end of submaximal exercise by expressing HRR60s as a ratio of this value (HRR60s/HRex). Normalized by logarithm.

significant variation was noted for the other subscales with Bonferroni corrections. On the other hand, Total Stress, Specific Stress, and General Stress largely decreased. HRex largely decreased, whereas Ln nHRR60s largely increased, with no significant variations for HRR60s. Ln RMSSD moderately but not significantly increased.

4.2.2. Relationships between TL and psychological and physiological indices

Correlational analyses showed that Total Recovery ($r = -0.55$, $p < 0.05$) and Specific Recovery ($r = -0.53$, $p = 0.010$) were largely and negatively associated with TL. On the other hand, Total Stress ($r = 0.58$, $p < 0.05$) and Specific Stress ($r = 0.62$, $p = 0.002$) were largely and positively associated with TL. No significant association was found between TL and General Recovery ($r = -0.40$, $p > 0.05$) and Stress ($r = 0.42$, $p > 0.05$). At the subscale level, correlational analyses showed a large and positive association between TL and *Injury* ($r = 0.61$, $p = 0.002$), and a very large and negative association between TL and *Being in shape* ($r = -0.70$, $p < 0.001$). Correlational analyses showed that HRex ($r = 0.58$, $p < 0.01$) was largely and positively associated with TL. On the other hand, Ln nHRR60s ($r = -0.46$, $p < 0.05$) was moderately and negatively associated with TL. No significant association was

found between TL and HRR60s ($r = 0.13$, $p > 0.05$) and Ln RMSSD ($r = -0.26$, $p > 0.05$).

Correlational analyses indicated that Total Recovery was largely and positively associated with Ln nHRR60s ($r = 0.55$, $p < 0.05$). Moreover, Total Stress was largely and negatively correlated with Ln nHRR60s ($r = -0.61$, $p < 0.05$). Those correlations were reflected in the recovery and stress subscales. Specific Recovery was moderately and positively associated with Ln nHRR60s ($r = 0.44$, $p < 0.05$), while General Recovery was largely and positively associated with Ln nHRR60s ($r = 0.53$, $p < 0.05$). At the same time, Specific Stress was moderately and negatively associated with Ln nHRR60 ($r = -0.44$, $p < 0.05$), while General Stress ($r = -0.66$, $p < 0.05$) was largely and negatively associated with Ln nHRR60. Finally, correlational analyses indicated that General Recovery was moderately and negatively associated with HRex ($r = -0.50$, $p < 0.05$), while General Stress was largely and negatively associated with HRR60s ($r = -0.53$, $p < 0.05$). Furthermore, large and negative associations between *Social stress* and HRR60s ($r = -0.55$, $p = 0.008$), and between *Fatigue* and Ln nHRR60s ($r = -0.58$, $p = 0.004$) were found, whereas large and positive associations between *General well-being* and Ln nHRR60s ($r = 0.56$, $p = 0.006$) were found. However, no clear association was observed between RESTQ-36-R-Sport subscales and Ln RMSSD indices (r values from 0.00 to 0.17 and p values from 0.46 to 0.97 for Recovery scales; r values from -0.05 to -0.38 and p values from 0.08 to 0.84 for Stress scales).

4.3. Discussion

This study aimed to examine changes and relationships between the TL, subjective RSS, and physiological indices to provide evidence for the relevance of the RESTQ-36-R-Sport. Changes in TL and psychological and physiological indices indicated that the reduction in TL ($61.87\% \pm 9.72\%$) and the duration of the training period (15 days) are in line with the literature recommendations to characterize a tapering period (60%–90% TL reduction; between 4 and 28 days' duration).⁴⁹ Simultaneously, the increase in the subjective recovery and the decrease in the subjective stress suggested an effective adjustment of the recovery–stress balance during the tapering period.¹⁴ Concomitantly, the decrease in HRex, the increase in HRR (Ln nHRR60s), and the moderate (non-significant) increase in vagal-related HRV indices (e.g., Ln RMSSD) are generally associated with improved cardiorespiratory fitness and physical performance.^{50–52}

During this tapering period, TL was associated with psychometric scales and physiological indices. Lower values of TL are mirrored by lower scores in stress scales and higher scores in recovery scales. Such results are coherent with the literature¹⁴ and reinforce the RESTQ-36-R-Sport as a sufficiently sensitive tool to detect the effect of training stress. In a consistent way, lower values of TL are mirrored by lower HR at submaximal exercise (HRex) and higher recovery capacity (Ln nHRR60s) immediately after submaximal exercise. Our results also underlined that Ln RMSSD is a less practical index than HRex and Ln nHRR60s to punctually monitor the physiological response to TL. These findings were expected given that the recent

literature assumes that for individual sports (like swimming), resting monitoring of HRV need to be realized daily to 3–4 times per week.³⁵ Nevertheless, some scholarships claim that it is theoretically possible to realize H_Rex (+HRR) monitoring only once a week on a standardized training day.³³ In this line, our results are consistent with the literature, and reinforce the appropriateness of HR measurement for athletes who have limited time for monitoring their states of fatigue.

Finally, we also report correlations between perceived RSS and physiological indicators such as HR measures. Such results showed that during tapering periods, a dose–response relationship exists between psychometric scales, cardiac response to submaximal effort, and heart rate recovery indices. More precisely, the capacity to recover during the first minute after sub-maximal exercise (Ln nHRR60s) is positively associated with the subjective recovery and negatively with the subjective stress. These findings are in agreement with studies investigating the corresponding changes between training volume and ANS activity with biomarkers^{53,54} and HR or blood pressure variability analyses.^{55,56} However, none of these studies reported a dose–response relationship with correlations between perceived RSS and physiological indicators such as HR measures, which are recognized to be a relevant indicator of neuro-vegetative balance and overtraining.^{1,35,57} Furthermore, these previous findings were mainly found in overtraining periods and not during the more sensitive periods of tapering training in elite athletes just before the most important competition of the season.

5. General discussion

This study aimed to examine changes and relationships between the RSS perceived by elite swimmers, TL, and HR (V) while providing evidence for the factorial validity of the short French version of the RESTQ Sport. The series of CFAs in addition to the relationships between TL, HR (R), and the RESTQ-36-R-Sport provided strong support for the validity and reliability of the short version of the RESTQ-Sport (i.e., RESTQ-36-R-Sport) and indicated the usefulness of the RESTQ-36-R-Sport for regular monitoring to improve training adaptations.

5.1. Theoretical, methodological, and practical implications

From a theoretical point of view, these results offer additional insights into the recovery and stress processes to counteract detrimental psychological outcomes related to intense training. Monitoring is considered as the best prevention of maladaptive psychological and physiological states and their impaired effects.¹ However, only 1 marker is not currently sufficient for a satisfactory examination of recovery states.^{1,12,35} Furthermore, it would be reductive to conclude that recovery is merely the absence of stress markers.^{5,14} Recovery can be considered as a psychophysiological process involving an active re-establishment of individual athletes' psychological and physical resources for regaining vitality.⁵⁸ In this individualized process, the recovery and stress balance, depending on personal resources rather than the absolute value of recovery and stress, is essential.

Methodologically, there is a need to simultaneously evaluate both recovery and stress states to improve understanding of the complex and dynamic ways in which athletes deal with the demands of competitive sport. Most coaches recognize that recovery is essential in the organization of TL, yet their knowledge of the instruments available for monitoring recovery and stress balance is often limited.^{4,59} Tools such as the RESTQ-36-R-Sport offer monitoring of the balance in RSS in their several dimensions (e.g., psychological, social, physical), which can help sport professionals to become aware of their specific needs in recovery.

Practically, these findings have some implications for coaches and sport psychologists. Monitoring RSS should enable (a) coaches to adapt TL related to athletes' individual resource capacities, and (b) for sport psychologists and consultants, to propose more precise and proper interventions according to the period of the season and the cycle of preparation. However, supportive relationships between coaches and athletes are the key to improve coping abilities and goal attainments in sport performance.⁶⁰ Benefiting from individualized feedback, trainers could adapt the TL, and better explain its necessity to gain the athlete's adherence or propose interventions to improve recovery depending on the athlete's preferred leisure activities.

5.2. Limits and future directions

Some potential limits should be put forward. Despite the use of Foster's session-RPE procedure, which offers many benefits to quantify internal TL placed on swimmers,²⁹ it could be proper to include other variables to monitor TL like volume or frequency of training sessions (considered as external TL variables), lactate concentrations, HRR capacity or biochemical/hormonal/immunological assessment variables (considered as internal TL indices). In this line, the influence of intermediate psychological variables such as group variables (e.g., coach–athlete relationship, leadership, cohesion) and individual variables (e.g., emotions, coping strategies, defense mechanisms) should be investigated in future research, which must take into account sport discipline, performance level, age, and gender before generalizations can be made.

Kellmann and Kallus's¹⁴ model of recovery from stress presents the great interest to indicate the impact of various sources of stress and to compare perceived stress levels to the person's own capabilities to recover. However, recommendations seem warranted considering that stress experienced by athletes is likely to include further dimensions not yet taken into account. Frequently, athletes' experience levels of stress are due not only to athletic but also to academic or occupational demands. The interaction of these multiple stressors presents a unique problem for these athletes as suggested by previous investigations, indicating that the combination of these stressors has negative effects on their well-being and performance.^{61,62}

Notwithstanding these limits, the 3 present studies might contribute to the knowledge of previous investigations underlining that the RESTQ-Sport is a reliable and valid tool to estimate the RSS of athletes and thus to help avoid overtraining in its early stages.

6. Conclusion

Our findings indicate that for these elite swimmers, the 12-factor 36-item instrument (RESTQ-36-R-Sport) offers a parsimonious and improved fitting model to obtain a comprehensive and multidimensional profile of athletes' perceptions of stress and recovery states. The relationships between the psychological stress responses and HRV on one hand, and the TL on the other hand, reinforce the belief that these tools may provide relevant markers for the balance between stress and recovery, and could be used as indicators of training status in athletes.

Despite some limitations, these findings might have implications for sport psychologists and sport practitioners, and raise several questions and recommendations in terms of methodology and application, which seem warranted when one considers the importance of stress–recovery balance for both performance and well-being. If this self-report tool is included in intervention programs based on satisfying coach–athlete relationships, it can be useful for coaches and managers to obtain feedback on coaching practices and to adjust TL.

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Authors' contributions

MN conceived of, designed, and carried out the studies and the data collections and drafted the manuscript; PV collected data for Studies 2 and 3, performed statistical analyses, and participated in the writing of the manuscript; GM performed the statistical analysis for Study 1; LM participated in the design and writing of the manuscript. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interests

The authors declare that they have no competing interests.

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