



HAL
open science

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

Philippe Vacher, Michel Nicolas, Guillaume Martinent, Laurent Mourot

► To cite this version:

Philippe Vacher, Michel Nicolas, Guillaume Martinent, Laurent Mourot. Monitoring stress and recovery states: Structural and external stages of the short version of the RESTQ sport in elite swimmers before championships. *Journal of Sport and Health Science*, 2016, 10.1016/j.jshs.2016.03.007 . hal-03169591

HAL Id: hal-03169591

<https://hal.science/hal-03169591v1>

Submitted on 21 Oct 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial 4.0 International License

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

Michel Nicolas^{a,*}, Philippe Vacher^a, Guillaume Martinet^b, Laurent Mourot^c

^aUniversity of Burgundy, Laboratory of Socio Psychology and Management of Sport (SPMS, EA 4180),
Dijon cedex 21078, France

^bUniv Lyon, University of Claude Bernard Lyon 1, Laboratory of Vulnerabilities and Innovation in Sport
(L-ViS, EA 7428), Villeurbanne 69622, France

^cUniversity of Franche Comté – Prognostic Markers and Regulatory Factors of Heart and Vascular Diseases
and Exercise Performance, Health, Innovation Platform, Besançon 25000, France

Running title: Psychophysiological stress and recovery monitoring

*Corresponding Author.

E-mail address: michel.nicolas@u-bourgogne.fr

Received: 2015-12-29

Revised: 2016-02-16

Accepted: 2016-03-18

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* test 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 (HR-R) 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.

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

1. Introduction

Effective training loads (TL) 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 both 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 questions⁴⁻⁶ 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., 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 questionnaire (RESTQ-Sport)¹⁴ has been recognized as interesting developments on recovery in sport psychology.¹⁵ This self-report mainly embraces physical and psychobiosocial 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 period.^{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 explore 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 to explore 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. Material 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 to this study conducted in accordance with the local IRB. They trained 6.08 ± 3.93 h per week, and practice their sport since 8.57 ± 4.24 years.

2.1.2. Instruments

Like the original version in 76 items,¹⁴ the version used in the present study consisted 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, fatigue) and 3 general recovery subscales (somatic relaxation, general well-being, 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, self-efficacy) processes from a physical, emotional, behavioral, and social perspective.

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 invariance 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 model, respectively) were statistically significant. Nevertheless, the chi-square difference test ($\Delta \chi^2 = 423.76$ and 672.03, $\Delta df = 48$ and 53, $p < 0.001$) and 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 CFAs model fitted the data adequately (i.e., identical number of latent constructs across samples). The metric multiple-sample models fitted the data adequately. The differences of comparative fit index (CFI) value 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 models tested strong factorial invariance by additionally imposing equality constraints on corresponding item intercepts. These models encountered 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 two 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 fit of a second-order model cannot be better than 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 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 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 request. 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. Material and Methods

3.1.1. Participants

Seventy-two swimmers (24 women and 48 men, age = 16.5 ± 2.6 years, h/week = 18.7 ± 6.1) 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. The study 2 was designed in compliance with the recommendations for clinical research of the Declaration of Helsinki of the World Medical Association.

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 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 consisting of an important increase in TL. A last evaluation has been realized after 15-day 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 scale) obtained 30 min after the completion of the training session by the duration (in minutes) of the session.^{28 29} By summated on a weekly base 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 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*,³⁴ all comparisons were also expressed as standardized mean differences (Cohen effect size, d), calculated using the pooled standard deviations for the 3 testing sessions being compared.³⁵ Thresholds of > 0.2 for small, > 0.5 for moderate, and > 0.8 for large effect size were used. Changes in psychological and TL were assessed from a one-way repeated ANOVA and time to time variation was controlled by using the *post-hoc* Tukey's 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: < 0.1 , trivial; 0.1-0.3, small; 0.3-0.5, moderate; 0.5-0.7, large; 0.7-0.9, very large; and 0.9-1.0, almost perfect.³⁴

3.2. Results

3.2.1. Changes in training load and recovery-stress states

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 was 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 for *Being in shape* ($p < 0.001, d = 0.50$), whereas the other recovery factors did not significantly decrease (p -value from 0.06 to 0.92, d from -0.09 to 0.29). *Post-hoc* comparisons between OP and TP showed a moderate increase for Total Recovery ($p < 0.001, d = -0.71$), a large increase for 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 moderate increase in *Sleep quality* ($p < 0.006, d = -0.41$) and in *Personal accomplishment* ($p < 0.002, d = -0.36$), and a large increase in *Being in shape* ($p < 0.001, d = -1.09$) and 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 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 in *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 in *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 in *Injury* ($p < 0.001$, $d = 1.56$).

3.2.2. Relationships between TL and RSS

Table 4 presents the 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 subscales level, a moderate and negative association was 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. Training load 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 relationships 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.³⁶ In this line, combining HRV, HRR and psychometric measurements is a pertinent way to improve the monitoring of aerobic-oriented athletes.^{1,36} 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. Material 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 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^{37,38} and have to manage both physical and psychological resources 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.

4.1.2.1. HRV and HRR

Among the numerous indices of HRV, the root mean square of successive R-R intervals (RMSSD) is accepted as relevant for athletic monitoring.³⁹ It has been repeatedly shown as uninfluenced by respiratory rate,^{40,41} relatively easy to calculate and interpret,^{36,42} and having a lower typical error of measurement than other spectral indices of HRV.⁴³

RMSSD reflects both training and non-training-related stress^{44,45} and can be indicative of positive or maladaptive responses to training demands.⁴⁵⁻⁴⁷ It has been accepted as a time-domain parameter for assessing parasympathetic modulation, which is crucial for monitoring athletes.⁴⁴ Currently, using spectral indices on the field is strongly discouraged and it is recommended to focus attention on RMSSD, collecting at rest in athletes.³⁶ Concomitantly, recent literature suggest that 5-min of resting aimed at capturing cardiac parasympathetic activity, together with submaximal exercise (last minute of 4-5 min running) HR are likely the most useful monitoring variables.³⁶ In this line, the absolute difference between the average HR was observed during the last 10 s of monitoring at the end of exercise (termed HR_{ex}) and the average HR was recorded at the end of the first minute of recovery was calculated (termed HRR60s).⁴⁸ A second index (nHRR60s) was used for possible changes in HRR60s due to HR_{ex} by calculating nHRR60s as (HRR60s / HR_{ex}).⁴⁹ 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).

4.1.2.2. HRR indices

4.1.3. Statistical analysis

Inherently 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 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, 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-I error probability at the 0.05 α level. In addition, bivariate correlations were made using Pearson's product-moment correlation (r). The same criteria of the 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 T1 and 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*, and *General well-being* largely increased from T1 to T2, whereas no other 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, 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 subscales 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 negatively correlated with Ln nHRR60s ($r = -0.61, p < 0.05$). Those correlations were reflected in the recovery and stress subscales. Specific Recovery ($r = 0.44, p < 0.05$) was moderately while General Recovery ($r = 0.53, p < 0.05$) was largely and positively associated with Ln nHRR60s. In the same time, Specific Stress was moderately ($r = -0.44, p < 0.05$) 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 ($r = -0.55, p = 0.008$), *Fatigue* and Ln nHRR60s ($r = -0.58, p = 0.004$) and a large and positive association 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, 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 to 28 days duration).⁵⁰ 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.⁵¹⁻⁵³

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 (HR_{ex}) and higher recovery capacity (Ln nHRR60s) immediately after submaximal exercise. Our results also underlined that Ln RMSSD is a less practical indices than HR_{ex} and Ln nHRR60s to punctually monitor the physiological response to TL. This findings was expected given that the recent literature assume that for individual sports (like swimming), resting monitoring of HRV need to be realized daily to 3-4 times per week.³⁶ Nevertheless, some scholarships claim that it is theoretically possible to realize HR_{ex} (+HRR) monitoring only once a week on a standardized training day.³⁴ 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 exist 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^{55,56} and HR or blood pressure variability analyses.^{57,58} 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.^{1,36,59} 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 indicate 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.^{1,12,36} 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.⁶⁰ 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.^{4,61} 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 athlete's 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.⁶² 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 the Foster's session-RPE procedure offer 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, heart rate recovery 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.^{63,64}

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 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 on the other hand, the TL, 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 adjust TL.

Acknowledgments

The authors express their gratitude to the athletes and the trainers, for their collaboration to the study. This work was supported by the Conseil Régional de Bourgogne, the club of Alliance Dijon Natation, and the Comité Régional de Natation Bourgogne under Grant number 2013-9201AAO048S02835.

Authors' Contributions

MN conceived, designed and carried out the studies, the data collections and drafted the manuscript; PV collected data for the study 2 and 3, performed their statistical analyses and participated to the writing of the manuscript; GM performed the statistical analysis for study 1; LM participated to the design and the 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

None of the authors declare competing financial interests.

References

1. Meeusen R, Duclos M, Foster C, Fry A, Gleeson M, Nieman D, et al. Prevention, diagnosis and treatment of the overtraining syndrome: Joint consensus statement of the European College of Sport Science (ECSS) and the American College of Sports Medicine (ACSM). *Eur J Sport Sci* 2013;**13**:1-24.
2. Kellmann M, Altenburg D, Lormes W, Steinacker JM. Assessing stress and recovery during preparation for the World Championships in Rowing. *Sport Psychol* 2001;**15**:151-67.
3. Brink MS, Visscher C, Arends S, Zwerver J, Post WJ, Lemmink KA. Monitoring stress and recovery: new insights for the prevention of injuries and illnesses in elite youth soccer players. *Br J Sports Med* 2010;**44**:809-15.
4. Kellmann M. Preventing overtraining in athletes in high-intensity sports and stress/recovery monitoring. *Scand J Med Sci Sports* 2010;**20** Suppl 2:95-102.
5. Lundqvist C, Kenttä G. Positive emotions are not simply the absence of the negative ones: Development and validation of the Emotional Recovery Questionnaire (EmRecQ). *Sport Psychol* 2010;**24**:468-88.
6. Meeusen R, Duclos M, Foster C, Fry A, Gleeson M, Nieman D, et al. Prevention, diagnosis, and treatment of the overtraining syndrome: joint consensus statement of the European College of Sport Science and the American College of Sports Medicine. *Eur J Sport Sci*. 2006;**6**:1-14.
7. Coutts AJ, Slattery KM, Wallace LK. Practical tests for monitoring performance, fatigue and recovery in triathletes. *J Sci Med Sport* 2007;**10**:372-81.
8. Filaire E, Ferreira JP, Oliveira M, Massart A. Diurnal patterns of salivary alpha-amylase and cortisol secretion in female adolescent tennis players after 16 weeks of training. *Psychoneuroendocrinology* 2013;**38**:1122-32.
9. Halson SL, Jeukendrup AE. Does overtraining exist? An analysis of overreaching and overtraining research. *Sport Med* 2004;**34**:967-81.
10. Kreider RB, Ferreira M, Wilson M, Grindstaff P, Plisk S, Reinardy J, et al. Effects of creatine supplementation on body composition, strength, and sprint performance. *Med Sci Sports Exerc* 1998;**30**:73-82.
11. Urhausen A, Kindermann W. Diagnosis of overtraining: what tools do we have? *Sports Med* 2002;**32**:95-102.
12. Coutts AJ, Wallace LK, Slattery KM. Monitoring changes in performance, physiology, biochemistry, and psychology during overreaching and recovery in triathletes. *Int J Sports Med* 2007;**28**:125-34.
13. Hooper SL, Mackinnon LT, Ginn EM. Effects of three tapering techniques on the performance, forces and psychometric measures of competitive swimmers. *Eur J Appl Physiol Occup Physiol*

1998;**78**:258-63.

14. Kellmann M, Kallus KW. *The recovery-stress questionnaire for athletes: user manual*. Champaign, IL: human kinetics; 2001.
15. Davis H, Orzeck T, Keelan P. Psychometric item evaluations of the Recovery-Stress Questionnaire for athletes. *Psychol Sport Exerc* 2007;**8**:917-38.
16. di Fronso S, Nakamura FY, Bortoli L, Robazza C, Bertollo M. Stress and recovery balance in amateur basketball players: differences by gender and preparation phase. *Int J Sports Physiol Perform* 2013; **8**: 618-22
17. Filho E, di Fronso S, Forzini F, Murgia M, Agostini T, Bortoli L, et al. Athletic performance and recovery–stress factors in cycling: An ever changing balance. *Eur J Sport Sci* 2015;**15**:671-80.
18. Kallus, K.W. & Kellmann, M. (in preparation). The recovery-stress questionnaires: user manual. Frankfurt: Pearson.
19. Messick S. Validity of psychological assessment: validation of inferences from persons' responses and performances as scientific inquiry into score meaning. *Am Psychol* 1995;**50**:741-9.
20. Jöreskog, K. G., & Sörbom D. LISREL (Version 8.71)[Computer Software]. Lincolnwood, IL: Scientific Software International. 2004.
21. Gregorich SE. Do self-report instruments allow meaningful comparisons across diverse population groups? Testing measurement invariance using the confirmatory factor analysis framework. *Med Care* 2006;**44**:S78-94.
22. Cheung GW, Rensvold RB. Evaluating goodness-of-fit indexes for testing measurement invariance. *Struct Equ Model A Multidiscip J* 2002;**9**:233-55.
23. Green SB, Yang Y. Commentary on Coefficient Alpha: A Cautionary Tale. *Psychometrika* 2009;**74**:121-35.
24. Sijtsma K. On the use, the misuse, and the very limited usefulness of cronbach's alpha. *Psychometrika* 2009;**74**:107-20.
25. Clark LA, Watson D. Constructing validity: Basic issues in objective scale development. *Psychol Assess* 1995;**7**:309-19.
26. Nicolas M, Martinent G, Campo M. Evaluation of the psychometric properties of a modified Positive and Negative Affect Schedule including a direction scale (PANAS-D) among French athletes. *Psychol Sport Exerc* 2014;**15**:227-37.
27. Martinent G, Decret JC, Isoard-Gautheur S, Filaire E, Ferrand C. Evaluations of the psychometric properties of the recovery-stress questionnaire for athletes among a sample of young French table tennis players. *Psychol Rep* 2014;**114**:326-40.

28. Foster C, Florhaug JA, Franklin J, Gottschall L, Hrovatin LA, Parker S, et al. A new approach to monitoring exercise training. *J strength Cond Res* 2001;**15**:109-15.
29. Wallace LK, Slattery KM, Coutts AJ. The ecological validity and application of the session-RPE method for quantifying training loads in swimming. *J Strength Cond Res* 2009;**23**:33-8.
30. Impellizzeri FM, Rampinini E, Coutts AJ, Sassi A, Marcora SM. Use of RPE-based training load in soccer. *Med Sci Sports Exerc* 2004;**36**:1042-7.
31. Lovell TW, Sirotic AC, Impellizzeri FM, Coutts AJ. Factors affecting perception of effort (session rating of perceived exertion) during rugby league training. *Int J Sports Physiol Perform* 2013;**8**:62-9.
32. Scott TJ, Black CR, Quinn J, Coutts AJ. Validity and reliability of the session-RPE method for quantifying training in Australian football: A comparison of the CR10 and CR100 scales. *J Strength Cond Res* 2013;**27**:270-6.
33. Haddad M, Chaouachi A, Castagna C, Wong del P, Behm DG, Chamari K. The construct validity of session RPE during an intensive camp in young male Taekwondo athletes. *Int J Sports Physiol Perform* 2011;**6**:252-63.
34. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc* 2009;**41**:3-12.
35. Cohen J. A power primer. *Psychol Bull* 1992;**112**:155-9.
36. Buchheit M. Monitoring training status with HR measures: do all roads lead to Rome? *Front Physiol* 2014;**5**:73.
37. Chalencon S, Busso T, Lacour JR, Garet M, Pichot V, Connes P, et al. A model for the training effects in swimming demonstrates a strong relationship between parasympathetic activity, performance and index of fatigue. *PLoS One* 2012;**7**:e52636. doi:10.1371/journal.pone.0052636.
38. Hellard P, Avalos M, Hausswirth C, Pyne D, Toussaint JF, Mujika I. Identifying optimal overload and taper in elite swimmers over time. *J Sport Sci Med* 2013;**12**:668-78.
39. Esco MR, Flatt AA. Ultra-short-term heart rate variability indexes at rest and post-exercise in athletes: evaluating the agreement with accepted recommendations. *J Sport Sci Med* 2014;**13**:535-41.
40. Penttilä J, Helminen A, Jartti T, Kuusela T, Huikuri HV, Tulppo MP, et al. Time domain, geometrical and frequency domain analysis of cardiac vagal outflow: effects of various respiratory patterns. *Clin Physiol* 2001;**21**:365-76.
41. Saboul D, Pialoux V, Hautier C. The impact of breathing on HRV measurements: implications for the longitudinal follow-up of athletes. *Eur J Sport Sci* 2013;**13**:534-42.

42. Plews DJ, Laursen PB, Stanley J, Kilding AE, Buchheit M. Training adaptation and heart rate variability in elite endurance athletes: opening the door to effective monitoring. *Sports Med* 2013;**43**:773-81.
43. Al Haddad H, Laursen PB, Chollet D, Ahmaidi S, Buchheit M. Reliability of resting and postexercise heart rate measures. *Int J Sports Med* 2011;**32**:598-605.
44. Le Meur Y, Pichon A, Schaal K, Schmitt L, Louis J, Gueneron J, et al. Evidence of parasympathetic hyperactivity in functionally overreached athletes. *Med Sci Sports Exerc* 2013;**45**:2061-71.
45. Tian Y, He ZH, Zhao JX, Tao DL, Xu KY, Earnest CP, et al. Heart rate variability threshold values for early-warning nonfunctional overreaching in elite female wrestlers. *J Strength Cond Res* 2013;**27**:1511-9.
46. Chen JL, Yeh DP, Lee JP, Chen CY, Lee SD, Chen CC, et al. Parasympathetic nervous activity mirrors recovery status in weightlifting performance after training. *J Strength Cond Res* 2011;**25**:1546-52.
47. Oliveira RS, Leicht AS, Bishop D, Barbero-Álvarez JC, Nakamura FY. Seasonal changes in physical performance and heart rate variability in high level futsal players. *Int J Sports Med* 2013;**34**:424-30.
48. Buchheit M, Al Haddad H, Laursen PB, Ahmaidi S. Effect of body posture on postexercise parasympathetic reactivation in men. *Exp Physiol* 2009;**94**:795-804.
49. Buchheit M, Simpson MB, Al Haddad H, Bourdon PC, Mendez-Villanueva A. Monitoring changes in physical performance with heart rate measures in young soccer players. *Eur J Appl Physiol* 2012;**112**:711-23.
50. Mujika I, Padilla S. Scientific bases for precompetition tapering strategies. *Med Sci Sports Exerc* 2003;**35**:1182-7.
51. Buchheit M, Millet GP, Parisy A, Pourchez S, Laursen PB, Ahmaidi S. Supramaximal training and postexercise parasympathetic reactivation in adolescents. *Med Sci Sports Exerc* 2008;**40**:362-71.
52. Buchheit M, Chivot A, Parouty J, Mercier D, Al Haddad H, Laursen PB, et al. Monitoring endurance running performance using cardiac parasympathetic function. *Eur J Appl Physiol* 2010;**108**:1153-67.
53. Lamberts RP, Lambert MI. Day-to-day variation in heart rate at different levels of submaximal exertion: implications for monitoring training. *J Strength Cond Res* 2009;**23**:1005-10.
54. Lamberts RP, Swart J, Capostagno B, Noakes TD, Lambert MI. Heart rate recovery as a guide to monitor fatigue and predict changes in performance parameters. *Scand J Med Sci Sport* 2010;**20**:449-57.
55. Bouget M, Rouveix M, Michaux O, Pequignot JM, Filaire E. Relationships among training stress,

mood and dehydroepiandrosterone sulphate/cortisol ratio in female cyclists. *J Sports Sci* 2006;**24**:1297-302.

56. Filaire E, Rouveix M, Duclos M. Training and 24-hr urinary catecholamine excretion. *Int J Sports Med* 2009;**30**:33-9.
57. Portier H, Louisy F, Laude D, Berthelot M, Guézennec CY. Intense endurance training on heart rate and blood pressure variability in runners. *Med Sci Sports Exerc* 2001;**33**:1120-5.
58. Uusitalo AL, Uusitalo AJ, Rusko HK. Heart rate and blood pressure variability during heavy training and overtraining in the female athlete. *Int J Sports Med* 2000;**21**:45-53.
59. Schmitt L, Regnard J, Desmarests M, Mauny F, Mourot L, Fouillot JP, et al. Fatigue shifts and scatters heart rate variability in elite endurance athletes. *PLoS One* 2013;**8**:e71588. doi:10.1371/journal.pone.0071588.
60. Kenttä G, Hassmén P. Overtraining and recovery: A conceptual model. *Sports Med* 1998;**26**:1-16.
61. Simjanovic M, Hooper S, Leveritt M, Kellmann M, Rynne S. The use and perceived effectiveness of recovery modalities and monitoring techniques in elite sport. *J Sci Med Sport* 2009;**12**: S22. doi:10.1016/j.jsams.2008.12.056.
62. Nicolas M, Gaudreau P, Franche V. Perception of coaching behaviors, coping, and achievement in a sport competition. *J Sport Exerc Psychol* 2011;**33**:460-8.
63. Humphrey, JH, Yow, DA & Bowden, WW. Stress in college athletics: Causes, consequences, coping. Binghamton, NY: The Haworth Half-Court Press; 2000.
64. Wilson, G, Pritchard M. Comparing sources of stress in college student athletes and non-athletes. *Athletic insight* 2005;**7**:1-8.

Table 1

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

Items		12-factor correlated			
		Model		Hierarchical models	
		SFL	SEV	SFL	SEV
<i>General stress</i>					
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
<i>Social stress</i>					
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
<i>Fatigue</i>					
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
<i>Social relaxation</i>					
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
<i>General well-being</i>					
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
<i>Sleep quality</i>					
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
<i>Disturbed breaks</i>					
23	J'avais l'impression qu'il n'y avait pas assez de pauses (I had the impression	0.68	0.53	0.63/0.60	0.60/0.65
29	there were too few breaks) ***	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
<i>Emotional Exhaustion</i>					
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
<i>Injury</i>					
19	J'avais mal partout (Parts of my body was 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

<i>Being in shape</i>						
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
<i>Personal accomplishment</i>						
25	Je me suis adapté très efficacement aux problèmes de mes coéquipiers (I dealt	0.67	0.55		0.72/0.72	0.49/0.48
31	very effectively with my teammates' problems)	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
<i>Self-efficacy</i>						
24	J'étais certain que je pouvais accomplir ma performance n'importe quand (I was	0.57	0.68		0.57/0.55	0.67/0.70
	convinced that I could achieve my performance at any time)					
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

Note: *** see items in Kellmann & Kallus¹⁴. 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. * $p < 0.05$

Table 2

Means, 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)

	Factors											<i>M</i>	<i>SD</i>	<i>AIC</i>	ρ
First-order factors ^a	1	2	3	4	5	6	7	8	9	10	11				
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	14	15												
13 General stress												2.49	0.63	0.36	0.92

14 General recovery	- 0.71*											3.8 5	0.6 2	0.3 1	0.8 9
15 Sport specific stress	0.56*	- 0.25*										2.2 3	0.5 7	0.2 5	0.8 4
16 Sport specific recovery	- 0.41*	0.65*	- 0.50*									3.7 6	0.6 2	0.3 0	0.8 5
Second-order factors ^c	17														
17 Total stress												2.3 6	0.5 1	0.2 4	0.9 4
18 Total recovery	- 0.60*											3.8 0	0.5 3	0.2 5	0.9 3

Note: ^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	<i>p</i>	<i>df</i>	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
<i>Multiple groups model</i>								
<i>Gender</i>								
Males (<i>n</i> = 344)	1028.11	<0.001	528	0.949	0.05	0.05-0.06	1304.11	3.80
Females (<i>n</i> = 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
<i>Level</i>								
Elites (<i>n</i> = 174)	893.64	<.001	528	0.918	0.07	0.06-0.07	1169.76	7.40
Non-elites (<i>n</i> = 299)	946.18	<.001	528	0.947	0.05	0.05-0.06	1222.18	4.24
Configural invariance	1918.54	<.001	1122	0.936	0.06	0.05-0.06	2338.54	5.24
Metric invariance	1966.24	<.001	1158	0.935	0.06	0.05-0.06	2314.25	5.19
<i>Sport type</i>								
Individual sports (<i>n</i> = 204)	903.90	<.001	528	0.932	0.06	0.05-0.07	1179.90	5.87
Team sports (<i>n</i> = 269)	908.63	<.001	528	0.947	0.05	0.05-0.06	1184.63	4.42
Configural invariance	1911.27	<.001	1122	0.938	0.05	0.05-0.06	2331.27	4.97
Metric invariance	1987.67	<.001	1158	0.936	0.05	0.05-0.06	2335.67	4.98

Note. ^a Original 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.

Abbreviations: CFI = comparative fit index; RMSEA= root mean square error of approximation; 90%CI = 90% confidence interval; AIC = Akaike information criterion; ECVI = expected cross-validation index.

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)

Variables	Training load					
	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*

Note. * significant association with Bonferroni corrections.

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)

Variables	T1	T2	<i>p</i>	<i>d</i>
	<i>M</i> ± <i>SD</i>	<i>M</i> ± <i>SD</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

Note. 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*) are proposed.