Balancing stress and recovery in sports

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Balancing stress and recovery in sports

Michel S. Brink

Contents

Chapter 1 8-9

General Introduction.

Jaarboek voor fysiotherapie (2009), 101-113

Koen A.P.M. Lemmink [1,2], Michel S. Brink [1], Esther Nederhof [1,3]

Overtraining in sports: when more is less

The concept of balancing stress and recovery to improve performance is well known in sport. Regular training is necessary for optimal performance. The training load is determined by the frequency, duration, intensity and variety of exercise. When this physical stress alternates with a sufficient amount of recovery, performance will increase.

This is known as supercompensation and forms the basis of a training program. In contrast, high physical stress levels in combination with inadequate recovery can lead to a local or general overload of the human body with negative consequences such as increased susceptibility to injuries, illnesses and overtraining. When, for example, young athletes are invited to selection teams, this will add up to their normal training load. In addition to physical stress and recovery, psychological factors are also part of the delicate balance. Combining sport with school or work causes extra psychosocial stress. Likewise, major life events such as the death of a loved one can have a significant impact on athletes. Finally, pressuring influences of teammates, friends and parents provides social stress. The combination of these physical and psychosocial stress sources should be in balance with the total amount of recovery (figure 1). Therefore, the first aim of the present thesis was to investigate if stress and recovery are related to performance, injuries, illnesses and overtraining. The second aim was to find markers that are relevant to sports practice for the early detection of overtraining.

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Chapter 1 General introduction

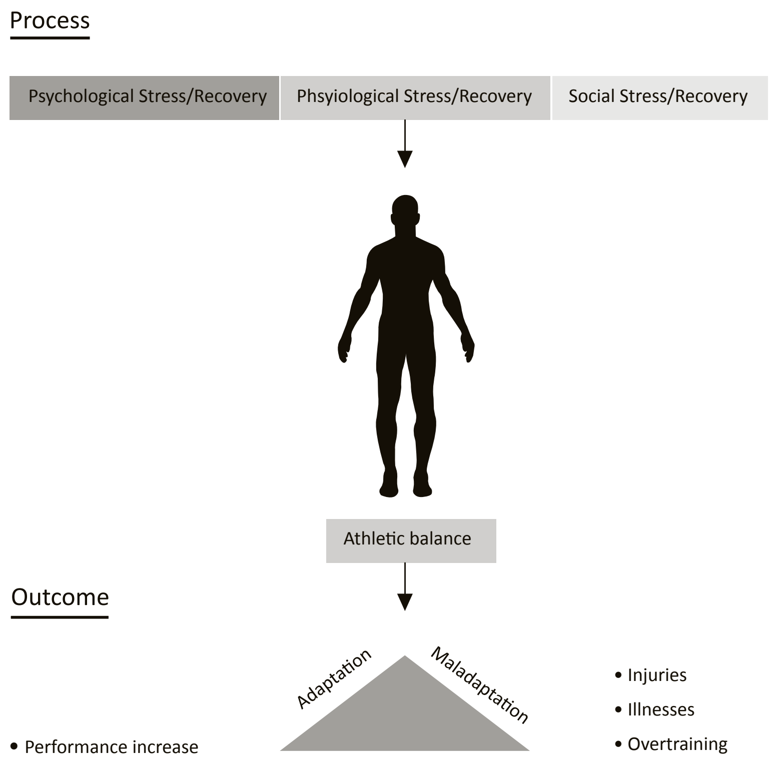

Figure 1. Adapted from: Kenntä & Hassmén, 1998, p 15

Injuries and illnesses

Several studies have examined intrinsic (person-related) and extrinsic (environment-related) risk factors for injuries in soccer players [1-9]. Age and a previous injury are known intrinsic risk factors. Extrinsic risk factors such as physical stress (i.e. training and matches), and psychosocial stress also seem to increase the injury risk. Since these extrinsic factors can be modified by interventions strategies, theoretical models have been developed to explain their influence. Derived from the model of Këntta and Hassmén [10], a mismatch between physical and psychosocial stress and recovery may result(s) in a local overload (injuries) or general overload (illnesses). It is known that moderate exercise stimulates the immune system, but heavy training actually results in immunosuppression and an increased susceptibility to infections [11-14]. However, data that links the psychosocial stress-recovery balance to the occurrence

of illnesses is lacking. Andersen and Williams [15] focused on the underlying mechanism of traumatic injuries. They stated that when athletes experience stressful situations, psychosocial stress contributes to their stress response. The consequences are increases in muscle tension, narrowing of the visual field and increase in distractibility. These changes make athletes more susceptible to traumatic injury [15].

Terminology of overtraining

Since 2006, three stages of overtraining are agreed upon: functional overreaching (FOR), non-funtional overreaching (NFOR) and overtraining syndrome (OTS) [16,17]. FOR refers to a short period of performance decrement and symptoms such as fatigue, which usually occurs after a period of intense training such as a training camp. After a planned recovery period ranging from days to weeks, performance and fatigue will return to normal. This stage is referred to as functional, because there are no lasting negative consequences and it can even lead to better performance, through the supercompensation mechanism. FOR is therefore often deliberately induced by coaches.
If however, performance decrement lasts longer (weeks till months) and coincides with more severe symptoms as mentioned before, this is called NFOR. NFOR has negative consequences, because athletes are too fatigued to execute their planned training schedule. In addition, long periods of rest prescribed as part of their treatment cause deconditioning. The overtraining syndrome (OTS) is the final stage of the continuum with documented recovery periods from months to years. This stage coincides with clinical symptoms such as depression and disturbed eating, sleeping and hormonal patterns [18,19]. These symptoms can, to a lesser extent, be present in NFOR. Since the exact duration and severity of performance decrement and symptoms are not defined, a clear distinction between these three phases is still difficult to make. It is assumed that an early detection of NFOR might prevent athletes from OTS.

Prevalence

In view of this definition, Nederhof and colleagues reconsidered the prevalence [17]. On the basis of three me-thods, they concluded that the prevalence of OTS is probably overrated. First, they carefully looked at the questions that were asked to athletes in overtraining studies. For example, Swedish athletes were asked if they experienced a period of performance decrement and fatigue for at least three weeks during their career, without having an injury or illness [20]. Such a question provides information about the possible prevalence of NFOR, but certainly not OTS. Second, definitions of OTS were investigated in 'high load training' studies. The negative consequences of these studies were often called OTS, but the definition better matched the recovery period of NFOR. The third method investigated case studies of overtrained athletes in scientific literature. Out of 26 studies, two could be diagnosed as OTS on the basis of a new definition. In other words, the prevalence of 20 to 60 percent documented in literature most likely better matches NFOR than OTS.

Diagnosis

The diagnosis of NFOR and OTS is a popular topic in scientific reviews. In the last decade, three important reviews have been published [16,19,21]. These reviews conclude unequivocally, that the diagnosis of NFOR and OTS is based on exclusion of other causes that may explain performance decrement and fatigue. Meeusen et al. [16] provided a checklist of this diagnosis per exclusionum. First, performance decrement and accompanying symptoms such as fatigue, altered eating and sleeping patterns and a disturbed mood should be confirmed. In addition, the training history of the athlete should match the profile of NFOR or OTS. Furthermore, any errors in training structure should be identified, such as large increases in training volume or intensity, training monotony or exposure to environmental factors such as heat or altitude. Other triggers of OTS may be the number of matches, especially when travelling through different time-zones. Finally, psychological stressors (work or financial) may trigger the onset of OTS. After gathering this information, a physical examination and blood tests should follow. If information about a standardised maximal performance test is available, evaluation of performance can be useful [16].

A major limitation of this current diagnosis is that it remains uncertain if an athlete suffers from NFOR or OTS. In essence, this can only be determined by the duration of their recovery period. In 2004, Meeusen and colleagues proposed the use of a double exercise protocol to detect differences in training status. They presented a case study of an OTS motor crosser. This motor crosser underperformed for several months and was not able to finish his training sessions. In this case, recovery took several months and psychological support was required for more than a year.

In this double exercise protocol, hormonal responses of adrenocorticotropic hormone, cortisol, prolactin and growth hormone were assessed. The exercise tests were separated by three hours of rest. In comparison with healthy cyclists, differences in hormonal response could already be observed during the first exercise test, but were even more pronounced during the second test. The healthy cyclists participated before and after a training camp and consistently showed an increase of hormones after exercise. A suppressed response was found in the OTS motor crosser during the second exercise test.

More recently, Nederhof and colleagues published a case study of a NFOR ice speed skater. This skater matched Meeusens checklist for underperformance, fatigue and disturbed sleep [22]. Furthermore, poor academic performances and reduced pleasure in skating was reported by the skater and recovery took up to four months. The hormonal response to the second bout of exercise completely differed from the OTS motorcrosser. The OTS motorcrosser showed a suppressed response, whereas the speed skater showed an overshoot of ACTH and cortisol.

This pattern of altered hormonal response to exercise in NFOR and OTS athletes was recently confirmed in 10 athletes [23]. Five of them required more than a year to fully recover. The other five athletes recovered within one year. Also, the severity of symptoms confirmed a distinction in NFOR and OTS. The hormonal responses paralleled the aforementioned hormonal responses: suppression in OTS and an overshoot in NFOR. It appears that NFOR athletes have a hypersensitivity of the pituitary gland. Continuation of training in NFOR athletes, may lead to exhaustion of the pituitary gland, resulting in OTS.

Treatment

Although in sports practice many different methods are used, there is a general sport medical consensus that relative rest is the most appropriate treatment. Scientific evidence suggesting ways to enhance recovery is not available. Athletes with NFOR are generally advised to reduce their normal training load, but to stay active. Alternative exercise programs may be helpful. For example, distance runners, are advised to play tennis, soccer or skate. OTS athletes are advised to temporarily stop training. In some cases, bed rest is prescribed. Usually, these athletes also need additional treatment, due to the severity of their symptoms.

The lack of a diagnostic tool and effective treatment for NFOR and OTS, highlights the need for prevention. This can be achieved in two different ways. First, one should be aware of possible early markers and second the amount of stress and recovery should be monitored. In the next two paragraphs, currently available early markers and the importance of monitoring stress and recovery will be discussed.

Early markers

Many studies looked for good early markers of NFOR or OTS [19,21-23]. So far, these efforts have not resulted in a accessible marker. One of the causes is the design used in these studies. Several studies used a high load training design, which in some cases led to FOR. However, these studies do not incorporate the normal seasonal variability in training-related and psychosocial stress and recovery. Another cause of conflicting results, is a lack of standardisation of these markers.

Physiological markers

A disturbed stress-recovery balance affects hormonal regulation in the central nervous system. Functioning of the hypothalamus and pituitary gland has frequently been studied (for reviews see [16,24,25]). A major problem in hormonal research, is the degree to which standardisation is needed. Hormonal concentrations vary throughout the day and are influenced by food intake, sleep and physical activity. Furthermore, variation in concentration can also be influenced by the way in which blood is drawn and the equipment used [26]. In addition, evaluation of hormones is invasive and expensive.

Heart rate variability is a relatively new measure and a possible marker to detect NFOR or OTS. Heart rate variability is the variability in length between consecutive heartbeats and measures disturbances in the autonomic nervous system. Nowadays, most heart rate equipment measures heart rate variability, making it an accessible marker. Although heart rate variability has potential to become a good marker, conflicting results are documented in literature [16,27]. Especially the power in low frequency range between 0.0033 and 0.04 is influenced by physical activity in the last 24 hours. This might explain contrasting results and is therefore not suitable for sports practice.

Finally, questionnaires seem to be a good marker for NFOR and OTS. The Profile Of Mood States (POMS) [28] and recovery stress questionnaire (RESTQ-sport) [29] are popular tools. Good results were found with both the POMS [30,31] and RESTQ-sport [32]. It seems that athletes are able to indicate problems at an early stage. However, a possible downside of these questionnaires is that the outcome may be influenced by fear of players to be deselected from the team.

Reaction times as early marker

All previous markers have several limitations: they are invasive, expensive, not applicable in sports practice or are susceptible to manipulation. These limitations do not apply to reaction time as marker for NFOR and OTS. Reaction time can be measured with a regular personal computer in a quiet room. Similarities between NFOR/OTS and depression [33] and chronic fatigue [34] have led to the introduction of reaction time as possible marker. Patients with depression and chronic fatigue typically showed slower reaction times [17]. Psychomotor slowness is therefore expected to coincide with NFOR and OTS.

Recent research shows that reaction times are indeed increased in early stages of overtraining. Rietjens and colleagues studied seven cyclists who doubled their training load during two weeks. Although their performance did not decrease, they did not suffer from FOR, reaction time increased significantly [30]. Similar results were found by Nederhof and colleagues [35]. They studied performance, mood and reaction time of fourteen cyclists before and after a training camp and after two weeks of recovery. Five cyclists were FOR and reaction time was indeed slower [35].
Differences in reaction time were also found in other stages of overtraining. The previous mentioned NFO skater showed slower reaction time [22]. In this reaction time task, stimuli were presented faster every time.

Especially when the stimuli were presented very quickly, the NFOR skater reacted slower, while healthy athletes are usually faster compared to their own baseline. Hynynen and colleagues compared reaction times on a colour word stroop task of twelve overtrained athletes to twelve healthy athletes. In this task, subjects were asked to name the colour in which the word was written and not the word itself. Furthermore, they had to tell if the colour of the word corresponded with the word. The overtrained athletes produced more errors compared to the healthy athletes when the task was executed at a medium or high speed. Unfortunately, it was not clear whether the athletes were NFOR or OTS. These findings suggests that reaction time is a promising tool to detect overtraining.

Training load and recovery

Nederhof and colleagues investigated how many top level athletes use a training log in the Netherlands [36]. Two hundred twenty-four athletes, who performed at national (70%) and international level (30%), filled in a questionnaire. Seventy-four percent of the individual athletes, and eleven percent of team athletes used a training log to monitor their training load. The external training load was usually notated as travelled distance in kilometres, the duration in minutes or the number of training sessions a week. However, the external load does not take individual characteristics of the athlete into account. Therefore, Foster (1998) introduced the session Rating of Perceived Exertion (RPE) as a measure to monitor the internal training load. The session-RPE is a subjective measure, that should be filled in 30 minutes after a session. Athletes are asked to rate the global intensity of the training. Since this measure also incorporates psychosocial aspect, it seems a useful marker to prevent athletes from overtraining [37].
As mentioned before, the outcome of a successful training program does not solely depend on the training load, but also on the amount of recovery. Therefore, the recovery score was introduced as a supplement of the session-RPE [10]. The recovery score is also a subjective score and measured on a similar scale as the session-RPE. Research is required to investigate whether the recovery score can be used to prevent from OTS.

POMS and RESTQ

The POMS and RESTQ were developed to monitor changes in mood state and disturbances in the stress-recovery balance. The main advantage of these questionnaires is the immediate availability of the results and their sensitivity to detect overtraining [30,31,35]. The POMS questionnaire consists of 32 words divided over 5 subscales: depression,

anger, fatigue, vigor and tension. Subjects rate to what degree statements correspond to their feelings on a 5 point scale. Examples are: down, irritated, full of energy and insecure. The hallmark of healthy athletes is the so called 'iceberg' profile, with a typical high score on vigor and low scores on the others scales.

The RESTQ-sport does not focus on the symptoms of overtraining, but on its cause. The questionnaire consists of 77 questions, to which subjects have to respond to how many times an activity occurred using a 7 point scale (from never to always). For example, in the past week I slept restlessly. The outcome of the questionnaire is scored on 19 subscales, including social stress, quality of sleep, fitness/injuries. These subscales are divided over four main categories: general and sport-specific stress and general and sport-specific recovery. Monitoring the subscales may help to detect changes in stress and recovery. It may warn athletes who are at risk and guide specific intervention strategies. These questionnaires need to be filled in on a regular basis to monitor psychosocial stress and recovery. The exact frequency partly depends on the motivation of athletes to complete these questionnaires and the way it fits in the training schedule. In accordance with the definition of NFOR, monthly assessment can be recommended. If a disturbed balance lasts more than two months, further examination may be required.

Performance

In addition to monitoring stress and recovery it is important to measure performance as outcome. Information about game performance is needed, as well as exercise tests to monitor performance changes over time [38]. These tests should be executed under standardised circumstances, for example at a certain point of time and similar weather conditions. Furthermore, heavy exercise should be avoided the day before testing. In recent years, several tests have been developed for individual and team sports, for example the interval shuttle run test [39]. Because maximal testing interferes with the training schedule and lack of motivation can cause unreliable results, submaximal test procedures are more favourable. When, in accordance with the definition of NFOR, performance decrement lasts at least a month(s), information about stress and recovery should be used to explain its cause. Therefore, monthly submaximal testing of sport-specific performance is recommended for the identification of NFOR.

Conclusion

It can be concluded that athletes are balancing on a tight rope with stress in one hand and recovery in the other. A mismatch between stress and recovery can lead to injuries, illnesses and overtraining. In order to prevent athletes from these negative consequences, research is needed that focuses on this delicate balancing act and the development of tools to monitor and evaluate the training process. In addition, we conclude that the overtraining syndrome is a complex phenomenon that is not yet fully understood. This is illustrated by the large number of reviews and small number of research articles. The recently proposed consensus statement contributed to a better understanding of the concept of overtraining, which will be helpful for the interpretation of research. Based on available literature it can be concluded that early markers for overtraining are not yet available, the diagnosis is still based on exclusion and rest is the only effective treatment. Careful documentation of stress, recovery and performance, by means of logs, questionnaires and field tests, seems the best approach to detect a disturbed balance and guide intervention strategies.

Chapter 1 General introduction

Outline thesis

The first aim of the present thesis was to investigate if stress and recovery are related to performance, injuries and illnesses. The second aim was to find markers that are relevant in sports practice for an early detection of over-training. Athletes were asked to fill in a day-by-day training log and a monthly questionnaire to obtain information about the stress-recovery balance. The members of the medical staff recorded the injuries and illnesses according to the FIFA registration system. A general overload was signalled based on unexpected performance decrements. Such a signal provided us with valuable information about the triggers of overload. To find ways to avoid overtraining, clinical diagnostic measurements were linked to changes in performance from the monitor. Ninety-four elite soccer players and 52 middle long distance runners were monitored during two full training seasons. Standardized methods were used to monitor the amount of stress, recovery related activities and performance changes. Additional clinical measurements were carried out at the UMC Groningen and the UMC Utrecht in two subgroups: athletes showing performance decrements in two consecutive months and athletes showing regular performance patterns. The clinical measurements consisted of assessment of haematological and infection related profiles, psychomotor speed and hor-monal profiles before and after two maximal exercise tests. Comparison of monitor data, performance indicators and clinical measurements between both subgroups revealed predictive parameters that are sensitive to an onset of OTS in young elite athletes.

In the current chapter, we presented a theoretical framework and a review of the literature. In Chapter 2 we investigated this relation by monitoring load, recovery and performance in elite soccer players. However, too much stress combined with insufficient recovery, may lead to injuries and illnesses. In Chapter 3 new insights for preven-tion of injuries and illnesses are described. A disturbed balance between stress and recovery is also considered to be the cause of OTS. In Chapter 4 we investigated if a disturbed stress-recovery indeed precedes the onset of OR. Chapter 5 contains a validation study of the Dutch version of the recovery-stress questionnaire.

Since the diagnosis of OTS is not available prevention is urgently warranted. Therefore, several early markers are studied in OR athletes and controls. In Chapter 6 we investigated mood state and hormonal responses to a double bout of maximal exercise as early markers for OR. In Chapter 7 we investigated reaction time to exercise as potential marker. The thesis ends with a general discussion of relevant outcomes and practical implications. Finally, limitations will be discussed that can guide future research.

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Chapter 2 18-19

Monitoring load, recovery and performance in young elite soccer players.

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Abstract

The purpose of this study was to investigate the relation between training load, recovery and monthly field test performance in young elite soccer players in order to develop training guidelines to enhance performance.

In a prospective, nonexperimental cohort design, eighteen young elite soccer players registered training and match duration for a full competitive season by means of daily training logs. Furthermore, session Rating of Perceived Exertion (RPE) and Total Quality of Recovery (TQR) scores were recorded. Weekly duration (TLd), load (duration x session RPE = TLrpe) and TQR scores were calculated for one and two weeks before a monthly submaximal Interval Shuttle Run Tests (ISRT) to determine interval endurance capacity. Participants spent on average 394.4 ± 134.9 minutes per week on training and game play with an average session RPE of 14.4 ± 1.2 (somewhat hard) and TQR of 14.7 ± 1.3 (good recovery). Random intercept models showed that every extra hour training or game play resulted in enhanced field test performance (p < .05). Session RPE and TQR scores did not contribute to the prediction of performance.

The duration of training and game play in the week prior to field test performance is most strongly related to interval endurance capacity. Therefore coaches should focus on training duration to improve interval endurance capacity in elite soccer players. In order to evaluate the group and individual training response, field tests should be frequently executed and be incorporated in the training program.
Keywords: Training load, Interval Endurance Capacity, Hierarchical Linear Model, Football

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Chapter 2 Monitoring load, recovery and performance in young elite soccer players

Introduction

In order to reach the top in professional soccer, extensive training is necessary to improve performance. In individual sports, such as distance running, a positive relation between training and performance has been found and extensively described [22]. However, little is known about the relation between training and performance in ball team sports.

The duration and intensity of the training are the primary determinants of the training load. It is known that because of individual differences (i.e. training status, school exams, injury), the optimal training load varies between athletes. In ball team sports, the training load prescribed by the coach is often called the external load and is expressed in the duration in minutes and for example high, medium and low intensity. The internal training load, on the other hand, is the actual physiological stress imposed on the athlete. The internal load accounts for individual differences, for example starting fitness level and psychosocial aspects [14]. It is assumed that the training load in general should be combined with sufficient recovery to enhance performance. This is also known as the supercompensation effect. Therefore, the focus in a program should not only be on training load, but also on recovery.

In order to monitor performance, sport-specific field tests have been developed to evaluate the training response [29]. These shuttle run tests imitate the physiological profile and are related to quality of play during a match, distance covered, time spent at high intensity and number of sprints [3,12,24]. Gabbett and Domrow incorporated a shuttle run test in their study and investigated the training-performance relation in sub-elite rugby players training. [10]. However, no relationship was observed between training load and field test performance. Although the players were followed over an entire season, only four measurements were taken up to three months apart. It is expected that performance changes occur faster, and more frequent testing is needed [4]. In addition to that, performance seems also related to different periods of the season whereas at the beginning of the season the best aerobic improvement can be expected with the same amount of training [25]. This stresses the need for research which incorporates field test performance on a more regular basis.

In summary, evidence for the training-performance relation in elite soccer is limited, whether this is the external or the internal load. Although recovery is theoretically important to improve performance, evidence in ball team sports is lacking. Therefore, the aim of this study is to monitor training load, recovery and performance of young soccer players for a full season in order to develop training guidelines to enhance performance. We hypothesized that a higher training load (external and internal) combined with good recovery would lead to a better performance.

Methods

Approach to the Problem

To determine training load in soccer, usually a more general team training prescription is applied, because it is difficult to control for training intensity on an individual level during group exercises such as small sided games [6,13,20,26,27]. The training load prescribed by the coach is often called the external load and is expressed in the duration in minutes (TLd). The internal training load on the other hand can be monitored by means of heart rate and session Rating of Perceived Exertion (RPE) scores. Although there is a linear relation between heart rate and oxygen

consumption ($\dot{V}O_2$) during aerobic exercise, it is known that heart rate registration in intermittent sports leads to an underestimation of the actual intensity because of frequent anaerobic exercise [1,27]. Other disadvantages of heart rate registration for monitoring a team during a full season are that the procedures are time consuming and vulnerable to technical problems.

Using session RPE scores is an alternative to heart rate monitoring and was first described by Foster [8]. Impellizeri et al. showed that session RPE in soccer is related to Banister's training impulse (TRIMP) method [13]. Also exercise intensity during resistance training can be monitored with use of session RPE [5]. For theoretical and practical reasons, the continuous use of the session RPE for measuring the internal load (TLrpe) is in favour. In this study, participants were asked to fill in a daily training log. Approximately 30 minutes after each training session or match, the total amount of playing time in minutes was recorded as well as their session RPE score on a scale from 6-20 (figure 1).

In order to monitor recovery, Kenttä and Hassmén proposed the use of a recovery score to quantify the "Total Quality of Recovery" (TQR) [15]. This method has already been successfully used in the prediction of performance in a sprinter's case study [28]. In the current study, participants were asked to record, prior to each training session and match, their recovery score on a scale from 6-20 (figure 1).

In addition to monitoring the training load and recovery, it is of utmost importance to measure performance as outcome. In the last decades, different soccer-specific field tests have been developed to evaluate the effectiveness of training programs. Most of these are characterised by their interval profile and validated with aerobic or anaerobic Wingate tests [17,19,29]. In this study, the submaximal Interval Shuttle Run Test (ISRT) was used to determine interval endurance capacity. The tests were performed every month (figure 1) on an artificial pitch at the start of the training as a substitute for the warm-up.

A prospective, nonexperimental cohort design was used to monitor load, recovery and monthly field test performance. Dutch elite young soccer players were monitored during one competitive season from August 2006 until April 2007. The competitive season followed the preseason that started in July and was separated by a winter break from December until January (figure 1). Training load and recovery were related to changes in field test performance of players.

Subjects

Eighteen young elite soccer players from the same team volunteered to participate in this study for a full season (mean ± SD: age 17 ± 0.5 years, body mass 72.4 ± 7.8 kg, height 180.4 ± 7.3 cm, body fat 9.3 ± 2.7 %). Subjects played a cumulative number of years at the highest level. They received a balanced training program by a professional coach with aerobic, speed, agility, technical and tactical aspects. Once a week, players executed an individualised weight training program. The team competed in the Dutch premier league under 19 years. The study was approved by the Central Committee on Research involving Human Subjects. Written informed consent was obtained from the subjects and both parents.

Chapter 2 Monitoring load, recovery and performance in young elite soccer players

Month	Aug			Sep						Oct					Nov					Dec					Jan					Feb				Mar				Apr
Week	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	1	2	3	4	5	6	7	8	9	10	11	12	13	14						
ISRT			1				2					3				4			Winterbreak					5					6				7						

Figure 1. Study timeline. ISRT = Interval Shuttle Run Test

Procedures

Training log

Participants were asked to fill in a daily training log. Prior to each training session or match they recorded their recovery score on a scale from 6-20 (figure 1) as proposed by Kenttä and Hassmén [15]. Approximately 30 minutes after each soccer session [13] and weight training [5], the total amount of time in minutes was recorded as well as their session RPE score on a scale from 6-20 (figure 2). To control for missing values the coach was asked to fill in a web-based training log to register individual training duration or absence. TLd was calculated by adding training and match duration, and TLrpe was calculated by multiplying duration and session RPE as proposed by Foster [7].

Rating of Percieved Exertion (RPE)		Total Quality Recovery (TQR)	
6		6	
7	Very, very light	7	Very, very poor recovery
8		8	
9	Very Light	9	Very poor recovery
10		10	
11	Fairly light	11	Poor recovery
12		12	
13	Somewhat hard	13	Reasonable recovery
14		14	
15	Hard	15	Good recovery
16		16	
17	Very hard	17	Very good recovery
18		18	
19	Very, very hard	19	Very, very good recovery
20		20	

Figure 2. 15-points Rating of Perceived Exertion and Total Quality Recovery scales (Kenttä, 1998: 26 [1], p. 10).

Interval Shuttle Run Test (ISRT)

To determine interval endurance capacity, a submaximal ISRT was used [18]. Submaximal intensity was set at 70% of the maximal amount of runs at the start of the season. During the ISRT, players alternately ran for 30 seconds and walked for 15 seconds. Running speed increased from 10 km•h^{-1} every 90 seconds until 14, 14.5 or 15 km•h^{-1} depending on maximal running level. Heart rate was recorded at 5-s intervals (Polar, Kempele, Finland). A fixed number of runs was used for every individual during an entire season assuming that heart rate decreases with increasing aerobic fitness [30]. The submaximal ISRT has sufficient validity and reliability (ICC ≥ 0.86) [16-18].

Statistical Analysis

If more than 75 percent of the scores within one week were completed, missing values were replaced with the average session RPE and TQR scores of the week. Weeks with more than 25 percent missing values were replaced with the mean scores of the weeks before and after.

The data were analysed using the multilevel modelling program MLwiN. Multilevel analysis is an extension of multiple regression and is developed for analyzing nested data. The advantage of multilevel modelling is that a different number of measurements per subject is allowed, which is inevitable in full season data collection. Another advantage is that multilevel analyses takes the relations within subjects into account. In all models, subjects represented the upper level and measurement occasion the lower level. Performance was modelled using a random intercept model. First, performance over seven measurements was entered in the model. After that, TLd and TLrpe were added separately to test the hypotheses if higher external and internal load would lead to better performance.

Finally, the contribution of the TQR scores for both models were investigated to test if better recovery would lead to improved performance. These models were calculated for one and two weeks prior to the performance test. Data of four weeks was not incorporated in the analyses, since these data were not available before the first test (figure 1).

A variable significantly contributed to the model if the Z-score reached the critical value for $p < .05$ [11]. Z-scores were calculated by dividing the estimate by its standard error. Models as a total were tested against the χ^2 distribution, taking into account the additional number of degrees of freedom (i.e. extra parameters). Since a higher training load and good recovery was expected to improve performance, significance was tested one-tailed.

Chapter 2 Monitoring load, recovery and performance in young elite soccer players

Results

Data of 1480 training sessions and matches were collected. On average, subjects completed six sessions a week. Table 1 shows the means and standard deviations of TLd, TLrpe and TQR scores of one and two weeks prior to the ISRT. Average session RPE scores were 14.4 ± 1.2 and 14.3 ± 1.1 for one and two weeks, respectively, indicating "somewhat hard" intensity. Average TQR scores for both periods were 14.7 ± 1.3 and 14.6 ± 1.3, which corresponds with "good recovery".

The first model with random intercept represented performance over seven measurements with TLd one week prior to the ISRT (table 2). In total, 93 of 144 data points were included. Missing values were caused by absence during performance tests due to injury, illness, school, playing at the national team or other obligations. Performance was compared to the first submaximal measurement as reference. Heart rate on the second, fifth, sixth and seventh tests were significantly lower than the first. The third and fourth tests did not differ from the first.

TLd significantly predicted performance outcome. For every hour of training or game play, heart rate decreased 0.9 beats per minute at the submaximal field test (figure 3). Adding TLd significantly improved the model.

Table 1. Mean and standard deviation of TLd, RPE, TLrpe and TQR one and two weeks prior to Interval Shuttle Run Test of elite soccer players (n=18).

	TLd (min)	RPE (6-20)	TLrpe (AU)	TQR (6 - 20)
One week	394.4 ± 134.9	14.4 ± 1.2	5697.5 ± 2150.7	14.7 ± 1.3
Two weeks	844.4 ± 194.3	14.3 ± 1.1	12039.3 ± 3340.6	14.6 ± 1.2

TLd = training load measured as duration in minutes, RPE = session Rating of Perceived Exertion, TLrpe = training load calculated by multiplying duration in minutes with session RPE, AU = arbitrary unit, TQR = Total Quality of Recovery.

Table 2. Multilevel regression model for heart rate at fixed submaximal speed during the Interval Shuttle Run Test (ISRT) and TLd per hour (h^{-1}) one week prior to the performance tests. The deviance of three models is given.
First, the empty model, in which submaximal heart rate is estimated according to one fixed factor, the intercept. Second, a model in which heart rate is estimated according to the intercept and the seven test moments (Tests). In the third model (Tests + TLd) training load expressed as training duration in minutes (TLd) was added to the second model (Tests). Estimates and standard errors (SE) are given for the complete model (Tests + TLd) only (n=18).

One week prior to ISRT		
Parameter Fixed	Estimate	SE
Intercept	185.4	2.70
Test 1	reference	
Test 2	-9.6	1.68 *
Test 3	-0.5	1.82
Test 4	-2.4	2.05
Test 5	-5.9	1.86 *
Test 6	-7.9	1.61 *
Test 7	-8.7	1.66 *
$TL_d (h^{-1})$	-0.9	0.33 *
Random		
Level 2 (between tests)	635.8	
Level 1 (between subjects)	18.2	
Deviance		
Empty model -2*loglikelihood	635.8	
Tests -2*loglikelihood	593.5	*
$Tests+TL_d$ -2*loglikelihood	585.4	*

* Statical significance: p<.05

Chapter 2 Monitoring load, recovery and performance in young elite soccer players

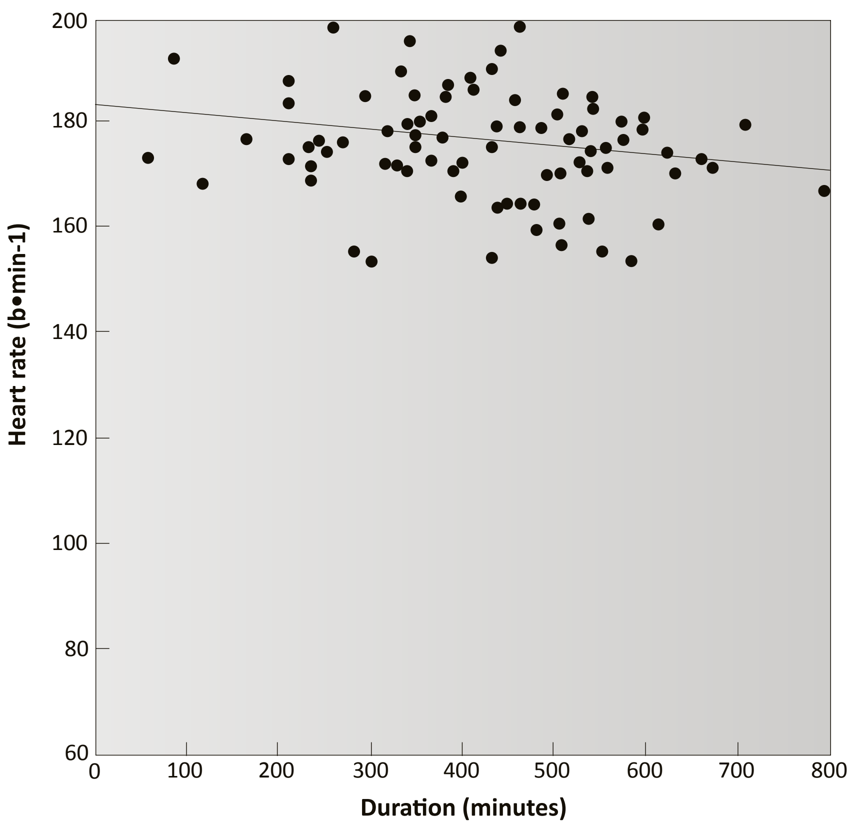

Figure 3. Heart rate at fixed submaximal speed during the Interval Shuttle Run Test (ISRT) against training load expressed as training duration in minutes (TLd) in the week prior to the ISRT. Data points represent repeated measures of young elite soccer players (n=18).

The second model with random intercept represented performance over seven measurements with TLd two weeks prior to the performance test (table 3). Performance was compared to the first measurement as reference. Heart rate on the second, fourth, fifth, sixth and seventh tests were significantly lower than the first. The third test did not differ from the first. This estimation is not exactly the same compared with the first model and caused by different TLd data points.
TLd two weeks prior to the test significantly predicted performance outcome. For every hour training or game play in two weeks, heart rate decreased 0.33 beats per minute at the submaximal field test. Adding TLd did not improve the model significantly.

Table 3. Multilevel regression model for heart rate at submaximal speed during the Interval Shuttle Run Test (ISRT) and TLd per hour (h^{-1}) two weeks prior to the performance tests. The deviance of three models is given. First, the empty model, in which submaximal heart rate is estimated according to one fixed factor, the intercept. Second, a model in which heart rate is estimated according to the intercept and the seven test moments (Tests). In the third model, (Tests + TLd) training load expressed as training duration in minutes (TLd) was added to the second model (Tests). Estimates and standard errors (SE) are given for the complete model (Tests + TLd) only (n=18).

Two weeks prior to ISRT		
Parameter Fixed	Estimate	SE
Intercept	185.2	3.32
Test 1	reference	
Test 2	-10.6	1.67*
Test 3	-2.3	1.81
Test 4	-6.1	1.53 *
Test 5	-7.8	1.75*
Test 6	-7.8	1.68 *
Test 7	-9.9	1.84 *
$TL_d (h^{-1})$	-0.3	0.18 *
Random		
Level 2 (between tests)	63.9	22.62
Level 1 (between subjects)	19.1	3.13
Deviance		
Empty model -2*loglikelihood	635.8	
Tests -2*loglikelihood	593.5	
$Tests+TL_d$ -2*loglikelihood	590.0	

* Statical significance: p<.05

Likewise, for one and two weeks prior to the performance tests, models were calculated with TLrpe instead of TLd. TLrpe did not significantly contribute to the model in either time frame. Finally, for all models TQR, was added to see whether recovery contributed to the prediction of performance outcome. For all cases, TQR did not significantly predict submaximal heart rate, nor did it result in a better model fit.

Chapter 2 Monitoring load, recovery and performance in young elite soccer players

Discussion

The hypothesis that higher training load (TLd and TLrpe) leads to increased performance was partly confirmed in the models presented in this study. Adding TLd for one week improved the model significantly (table 2). The two-weekly TLd variable significantly contributed to the model, but did not improve the model in total. This means that in well-trained soccer players, the amount of training in the week prior to the ISRT is most strongly related to the outcome of the test.

Although it was hypothesized that the TLrpe would lead to a better prediction, the session RPE scores did not contribute to either of the two models. Several factors could explain why session RPE scores did not affect submaximal ISRT performance. First of all, in this study the range of session RPE scores is small compared to the total range of the scale. Foster reported that athletes trained harder than intended on an easy training as prescribed by the coach.

The opposite was found when hard training sessions were prescribed [9]. This tendency to flatten out differences in RPE scores decreases the difference between external and internal training load. Additionally, the duration of the training in team sport is the same in many sessions. Therefore, the number of training sessions (expressed as duration in minutes) over a week becomes the main determinant of training load [14].

Impellizzeri et al. showed a moderate relation between heart rate and calculated training load in soccer during a seven week period, but no information about heart rate in combination with duration was provided [13]. Although the age of the players is similar in the current study, the length of the study is different (7 wk vs full season). It might be difficult for young elite soccer players, with little experience, to adequately score their perceived exertion for a full season.

Finally, other studies focused on the heart rate-perceived exertion relationship during training and taper in individual sports [21] or internal training load (session RPE x duration) in relation to overtraining or injury [2,8,23]. Since ill and injured soccer players were not able to participate in the performance tests, only the fittest players are represented in this study. Therefore, the question arises whether there might be a difference in the additional value of RPE score in relation to overtraining and injury on one hand and performance increase on the other hand. This could be an interesting research question for future studies. The additional value of TQR could also be higher for prediction of overtraining or injury compared to prediction of performance. Even though the TQR score was successfully used in predicting performance in one individual athlete [28], the additional value for the prevention of overtraining and injury should also be further investigated.

Although biological variation in heart rate on an individual level is 2-4 beats per minute [1], on a group level this variability is smaller [17]. To evaluate reliability of the ISRT, Lemmink et al. [17] reported heart rate at two consective measurements with two weeks in between. Heart rate changed 0.8, 0.9 and 1.0 beats per minute at 14, 14.5 and 15 km•h^{-1} respectively. This indicates that the differences between tests in the current study are meaningful. It also indicates that, with almost 400 minutes training in the week prior to the ISRT resulting in a 0.9 beats per minute decrease in heart rate, one extra hour training is needed to exceed the normal variation.

In this study submaximal performance was measured with use of heart rate. There were two main reasons to choose submaximal above maximal testing. First, maximal testing on a monthly basis during a full season can interfere with the training schedule. Second, with such heavy repeated measurements lack of motivation can negatively influence performance outcome of players. However, it is important to be aware of the factors influencing heart rate using a submaximal test procedure.

It is known that physical stress causes an increase in heart rate. Also dehydration caused by high temperature can increase heart rate [1,7]. In this study participants were tested two days after the match with rest in between. The submaximal test lasted between 9 and 12 minutes and was performed at the beginning of the training as a substitute for the warm-up. Therefore the effect of physical stress and dehydration caused by high temperature is expected to be minimal.

This is the first study that monitored training, recovery and performance during a full competitive season in young elite soccer players. The sample size in this study is limited due to the high training frequency which results in a large number of data per individual. Although a repeated measures design improves power, a relatively small sample size limits generalizability.

In conclusion, the duration of training and game play in the week prior to field test performance is most strongly related to interval endurance capacity. Therefore coaches should focus on training duration to improve interval endurance capacity in elite soccer players. Although there is reported evidence that subjective intensity scores are important in relation to overtraining and injury further research is needed to investigate whether this also leads to better prediction of performance in soccer.

Chapter 2 Monitoring load, recovery and performance in young elite soccer players

Practical applications

The best aerobic improvement is shown in the beginning of the season. However, the third and fourth test did not differ from the first, indicating aerobic performance set back in the two months before winter break. Usually, trainers start the preseason with aerobic training and shift to technical and tactical training at the start of the competition. Current results show that to prevent soccer players from aerobic performance decrement, attention should be continuously given to aerobic aspects. This finding also supports the notion that frequent testing is needed to detect performance changes over time.

Since the best relation was found in the week prior to the ISRT, field tests should frequently be executed and be incorporated in the training program to evaluate the group and individual training response. In the week prior to the field test subjects spent almost 400 minutes on training and game play. These rough guidelines for the maintenance of aerobic fitness can be used in professional soccer under 19 years. Although the results suggest that more training would lead to better performance, coaches should always keep the danger of overtraining in mind. Individual databases can provide in more detailed information about the performance response. Monitoring training load, recovery and field test performance might help coaches to warn players with high training load and poor performance.

Based on the results presented in this study, it seems useful to register the duration of every training and match. When both players and coach fill in a daily training log, missing values can be minimised which will improve reliability

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Chapter 3

Monitoring stress and recovery; new insights for the prevention of injuries and illnesses in elite youth soccer players.

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Abstract

Elite youth soccer players have a relatively high risk for injuries and illnesses, due to increased physical and psychosocial stress. The aim of this study is to investigate how measures to monitor stress and recovery, and its analysis provide useful information for the prevention of injuries and illnesses in elite youth soccer players.

Fifty-three elite soccer players between 15 and 18 years of age participated in this study. To determine physical stress, soccer players registered training and match duration and session Rating of Perceived Exertion (RPE) for two competitive seasons by means of daily training logs. The Dutch version of the Recovery Stress Questionnaire for athletes (RESTQ-Sport) was administered monthly to assess the psychosocial stress-recovery state of players. The medical staff collected injury and illness data using the standardized FIFA registration system. Odds ratios (OR) and 95% confidence intervals (CI) were calculated for injuries and illnesses using multinomial regression analyses. The independent measures were stress and recovery.

During the study period, 320 injuries and 82 illnesses occurred. Multinomial regression demonstrated that physical stress was related to both injury and illness (range OR 1.01 – 2.59). Psychosocial stress and recovery were related to the occurrence of illness (range OR 0.56 – 2.27). Injuries are related to physical stress. Physical stress and psychosocial stress and recovery are important in relation to illness. Individual monitoring of stress and recovery may provide useful information to prevent soccer players from injuries and illnesses.

Keywords: football, overuse, trauma, adolescent

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Chapter 3 Monitoring stress and recovery; new insights for the prevention of injuries and illnesses in elite youth soccer players

Introduction

Several studies have examined intrinsic (person-related) and extrinsic (environment-related) risk factors for injuries in soccer players [1-9]. A previous injury and age are known intrinsic risk factors. Extrinsic risk factors such as physical stress (i.e. training and matches), and psychosocial stress also seem to increase the injury risk. Since these extrinsic factors can be modified, theoretical models have been developed to explain their influence.

The model of Këntta and Hassmén [10] describes the athletic balance, which consists of physical and psychosocial stress and recovery components. A disturbed balance between these factors contributes to the development of a local or general overload. Andersen and Williams [11] explained the underlying mechanism between stress and the occurrence of traumatic injuries. They stated that when athletes experience stressful situations, psychosocial stress contributes to their stress response. The consequences are increases in muscle tension, narrowing of the visual field and increase in distractibility. These changes make athletes more susceptible to traumatic injury [11].

Support for these models has been provided in the literature [1-9]. However, the methodological designs of most of these studies are inadequate for the development of prevention strategies. In these studies, training frequency or life event stress was only investigated at the start of the season and therefore, it was not possible to incorporate seasonal changes or to warn and guide soccer players at risk. For this purpose, research that monitors physical and psychosocial stress and recovery continuously is needed. Additionally, practical measures should be used.

So far, a few studies monitored training load longitudinally and investigated its relation with the occurrence of injuries [8,12-14]. However, these studies have three limitations. First, none of these studies made a distinction between traumatic and overuse injuries. A separate analysis is important, since differences exist in the risk factors involved as well as in the mechanisms leading to a traumatic injury or overuse injury. Second, some studies only included injuries that led to time loss, while medical attention injuries should be included to get a more realistic view of the medical problems [12,14]. Finally, illness seems also to be related to the balance between stress and recovery. It is already known that moderate exercise may stimulate the immune system, but that heavy training actually results in immunosuppression and an increased susceptibility to infections [15-18]. However, data about the psychosocial stress-recovery balance in relation to the occurrence of illnesses is lacking.

To our knowledge, no research that monitors the stress-recovery balance and investigates its relation with injuries and illnesses in soccer players has been published so far. Especially, evidence in elite youth players is lacking. These adolescents who strive to become professionals are particularly at risk to sustain injuries and illnesses [6,15-19]. Besides physical stress due to increased training load, psychosocial stress also plays an important role. These players often experience high pressure to succeed from both parents and coaches [20,21]. The aim of this study is to investigate how measures to monitor stress and recovery, and its analysis provide useful information for the prevention of injuries and illnesses in elite youth soccer players.

Methods

Study design

A prospective longitudinal cohort design was used to monitor stress, recovery, injuries and illnesses during two competitive seasons in elite Dutch male soccer players from the ages of 15 to 18 years. The procedures were conducted in accordance with the ethical standards of The Central Committee on Research Involving Human Subjects.

Subjects

During the 2006-2007 and 2007-2008 competitive seasons 53 players participated in this study. Twenty-four participated during two competitive seasons and 29 during one competitive season. These 29 players were selected, deselected or moved to a higher age category at the start of the second season. The teams competed at the highest national competition level in the Netherlands and belonged to the best 1% of players in their age category. The current third place on the FIFA world football ranking illustrates that soccer is played at a high level in the Netherlands. At the start of each season, height, weight and body fat were determined (Table 1).

Table 1. Physical characteristics of the elite youth soccer players.

Characteristics	Season 2006-2007 (n=37)	Season 2007-2008 (n=40)
Age (years)	16.5 ± 1.2	16.5 ± 1.1
Height (cm)	177.0 ± 7.8	177.3 ± 6.9
Body weight (kg)	66.5 ± 8.7	67.7 ± 6.5
Body fat (%)	8.5 ± 2.1	8.2 ± 2.0

Scores are represented as mean ± SD

Chapter 3 Monitoring stress and recovery; new insights for the prevention of injuries and illnesses in elite youth soccer players

Data collection

Injuries and illnesses

The members of the medical staff, a physician and two physical therapists, diagnosed and recorded injuries and illnesses during the two competitive seasons. Players had free access to the medical staff at all times. The definitions and data collection procedures that were used, follow the recommendations of the consensus statement for soccer injury studies, i.e. the FIFA registration system [22]. An injury was defined as: "Any physical complaint sustained by a player that results from a soccer match or soccer training, irrespective of the need for medical attention or time loss from football activities." Injuries were reported if a player was unable to take a full part in future soccer training or match play (time loss). Additionally, injuries were reported if players received medical attention for more than one day, but still were able to take full part in future soccer training or match play. Traumatic injuries were defined as injuries that resulted from a specific, identifiable event. Overuse injuries were defined as injuries caused by repeated microtrauma without a single identifiable event. In some cases, multiple injuries that resulted from the same activity were counted as one injury event [22,23]. Injuries were classified according to the location, type, mechanism, and severity of injury. The main groupings and categories for classifying the location and type of injury are represented in figure 1 and 2, respectively. The severity of injury was defined as the number of days that the injured player could not fully participate in team training or match play: slight (no absence from training and match), minimal (1-3 days), mild (4-7 days), moderate (8-28 days), severe (more than 28 days), and career-ending injuries [22,23]. An illness was defined as a circumstance in which the subject - after consulting the medical staff - was withdrawn from training or match because he did not feel well and was limited or unable to perform athletic activities due to flu and common cold related symptoms (e.g. fever, muscle aching, diarrea, malaise) [24]. Illness was distinguished from overtraining based on the time to full recovery and the disappearance of flu- and cold related signs and symptoms within a reasonable period of time [25]. In case of prolonged symptoms further clinical and additional blood and/or radiological examinations were performed to find an underlying cause. If no explanation was found and symptoms persisted the subject was diagnosed to be overtrained instead of having an illness. Four players were diagnosed with an early stage of overtraining and excluded from the analyses.

Measures to monitor stress and recovery

Physical stress

Physical stress was quantified in two different ways. First, the duration of training sessions and matches in minutes was used as an objective measure. For every week, the sum of the duration of training and matches over the preceding week was calculated. The total duration over the preceding week was divided by 60 to transform minutes into hours. Second, the rate of perceived exertion (RPE) was used to determine the internal training load [26]. Each player was instructed to rate the global intensity of each training session using the original Borg 15-point scale by answering the simple question, "How was your workout?". Session-RPE scores were obtained 30 minutes after completing the training session to ensure that the perceived effort was referred to the whole session rather than the most recent exercise intensity [26-28]. When compared with heart rate and blood lactate concentration, this method has been shown to be a good indicator of global internal load in soccer [28]. The product of the session-RPE and the duration of the training session was defined as the training session load [12,26,27]. The weekly load was defined as the sum of the load of all training sessions over a 1-week period. If more than 25% of the RPE scores within a week were missing, participants were excluded from further analyses. Otherwise, the missing RPE score was replaced with the mean RPE score of the corresponding week. A zero was notated for days with no training. Monotony was calculated from the daily mean load divided by the standard deviation of the daily mean load over a 1-week period. The strain was defined as the product of weekly load and monotony [12,26,27]. The weekly load, monotony and strain over the preceding week prior to injury or illness were calculated. Similar to duration, weekly load and strain were divided by 60.

Psychosocial stress and recovery

The Dutch version of the Recovery Stress Questionnaire for athletes (RESTQ-Sport) was administered monthly to assess the psychosocial recovery-stress state of players. The RESTQ-Sport consists of 12 general and 7 sport-specific scales with 4 questions per scale and 1 warm-up question. Each player was instructed to rate the 77 items on a Likert-type scale, with anchors of 0: never and 6: always, indicating how often he participated in recovery and stress related activities during the last 4 weeks [29].
In addition, the RESTQ-Sport scores were classified in general stress scores (Σ 7 general stress subscales), sport-specific stress scores (Σ 3 sport-specific stress subscales), general recovery scores (Σ 5 general recovery subscales) and sport-specific recovery scores (Σ 4 sport-specific recovery subscales). In case of missing data, the mean of a subscale was calculated when at least 3 out of 4 of the items were rated. This procedure was executed in 19 out of 586 questionnaires. High scores on the stress-associated scales reflect a frequency of stress activities, whereas high scores on the recovery-oriented scales represent a high frequency of recovery activities [29]. Nederhof et al. [30] showed that the Dutch RESTQ-Sport had sufficient reliability and validity for use in sports practice and research.

Statistical analysis

The injury incidence was calculated as the number of injuries per 1000 match or training hours. The illness incidence was calculated as the number of illnesses per 1000 playing hours [31]. Descriptive statistics (mean and standard deviations) were calculated for the measures of stress and recovery (duration and training load/monotony/strain RESTQ subscales) of injured, ill and healthy players. Data were analyzed using multinomial regression in SPSS 16.0 (SPSS Inc., Chicago, IL). Dependent variable was coded either as traumatic injury, overuse injury and illness. The healthy group was set as the reference category. Odds ratios (OR) and 95% confidence intervals (CI) were calculated for the independent measures of stress and recovery. Differences with a p-value less than 0.05 were considered significant.

Chapter 3 Monitoring stress and recovery; new insights for the prevention of injuries and illnesses in elite youth soccer players

Results

Injuries and illnesses

During the study period, 320 injuries and 82 illnesses occurred. Two-hundred and six (64%) were time loss injuries and 114 (36%) medical attention injuries. The injury incidence was 37.55 per 1000 match hours (26.65 when analyzing only time loss injuries) and 11.14 per 1000 training hours (6.74 when only analyzing time loss injuries). The incidence of illnesses was 5.27 per 1000 playing hours. Most of the injuries were located in the lower extremities (85%) (figure 1). Muscle strain/rupture/tear/cramps (38%) were the most frequently occurring injury type (figure 2). Figure 3 presents the proportion and severity of traumatic and overuse injuries.

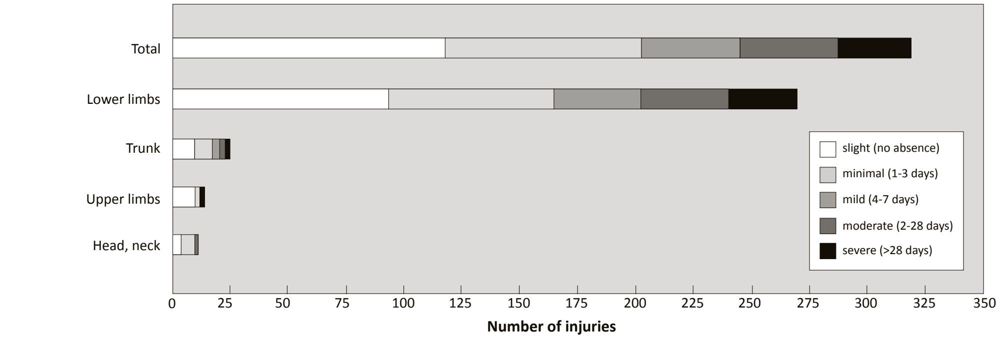

Figure 1. Injury locations and severity in elite youth soccer players. Injuries: number (percentage); 0: slight (no absence from training and match); 1: minimal (1-3 days); 2: mild (4-7 days); 3: moderate (8-28 days); 4: severe (>28 days).

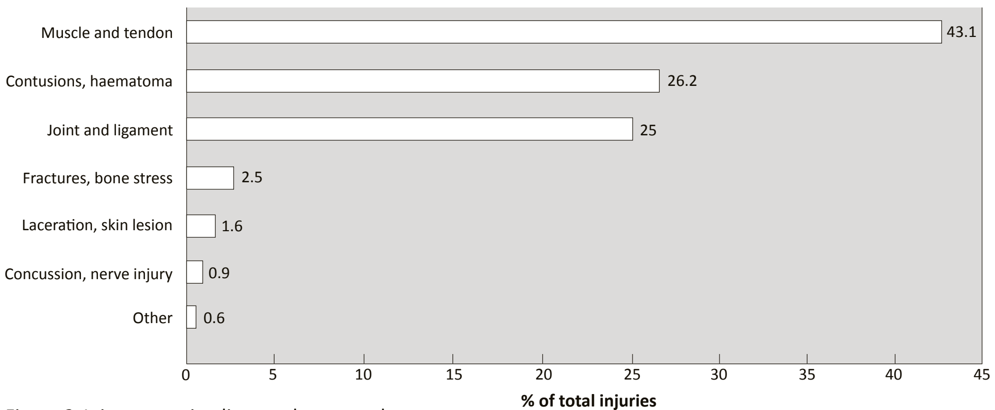

Figure 2. Injury types in elite youth soccer players.

Balancing stress and recovery in sports
Chapter 3

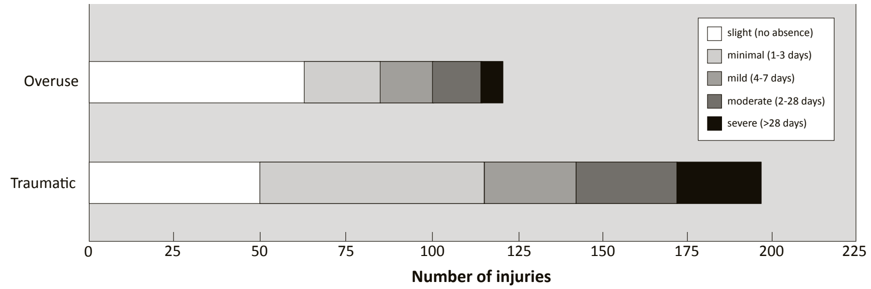

Figure 3. Injury mechanism and severity in elite youth soccer players. 0: slight (no absence from training and match); 1: minimal (1-3 days); 2: mild (4-7 days); 3: moderate (8-28 days); 4: severe (>28 days).

Table 2. Stress and recovery in young elite soccer players.
Scores are represented as mean ± SD; duration: the sum of the duration of training and matches over the preceding week; load/monotony/strain: the sum of the training load, monotony and strain over the preceding week; RESTQ recovery stress questionnaire.

	Healthy	Traumatic injury	Overuse injury	Illness
Duration	6.70 ± 2.00	7.27 ± 1.69	7.16 ± 1.68	6.90 ± 1.42
Load	51.44 ± 17.80	55.87 ± 16.40	56.22 ± 17.47	53.75 ± 15.88
Monotony	1.00 ± 0.27	1.07 ± 0.25	0.99 ± 0.20	1.07 ± 0.25
Strain	90.64 ± 47.20	104.32 ± 50.18	95.88 ± 44.40	99.54 ± 44.55
RESTQ				
General stress	6.70 ± 2.00	10.28 ± 4.09	10.49 ± 4.13	12.77 ± 4.17
General recovery	6.70 ± 2.00	18.65 ± 3.22	18.25 ± 3.17	17.29 ± 3.14
Sport-specific stress	6.70 ± 2.00	4.02 ± 1.95	4.15 ± 1.98	4.93 ± 2.17
Sport-specific recovery	6.70 ± 2.00	13.85 ± 3.07	13.53 ± 2.93	13.29 ± 2.81

Stress and recovery

Table 2 presents descriptive statistics for the measures of stress and recovery. It displays the mean sum of the duration of training and matches and the mean sum of the training load, monotony and strain of injured, ill and healthy players. Furthermore, it displays the general and sport-specific stress and recovery scores for these groups.

Chapter 3 Monitoring stress and recovery; new insights for the prevention of injuries and illnesses in elite youth soccer players

Relation between physical stress and traumatic injuries, overuse injuries and illnesses

Physical stress was related to traumatic injuries, since the weekly duration, training load, monotony and strain over the preceding week were significantly higher for players with a traumatic injury compared with healthy players (table 3). No significant differences were found in physical stress between players suffering from an overuse injury compared with healthy players. The weekly duration over the preceding week was significantly higher for ill players compared with healthy players. Figure 4 displays an example in which the weekly duration is plotted together with medical problems experienced by a player.

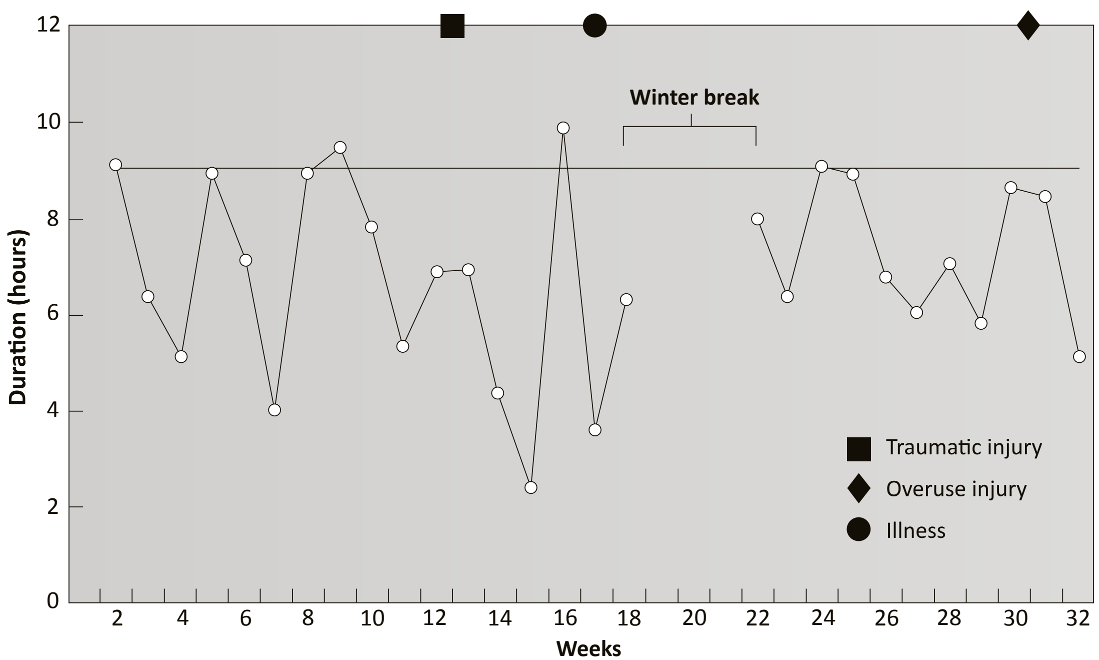

Figure 4. An example of a temporal linkage between weekly duration and traumatic injuries, overuse injuries and illnesses. The horizontal line is set at 8.7 hours (mean + 1 sd of the healthy group) as a threshold. It suggests a relation with part of the medical problems experienced by the player. Note for example the preceding spike before illness.

Balancing stress and recovery in sports
Chapter 3

Table 3. Multinomial regression of physical stress; Odds Ratios (OR) and 95% Confidence intervals (CI) for the three groups: traumatic, overuse and illness.

	Traumatic injury			Overuse injury			Illness		
	OR	CI (95%)		OR	CI (95%)		OR	CI (95%)	
Duration	1.14*	1.06	1.23	1.07	0.98	1.18	1.12*	1.00	1.26
Load	1.01*	1.00	1.02	1.01	1.00	1.02	1.00	0.99	1.02
Monotony	2.59*	1.22	5.50	0.84	0.25	2.76	2.52	0.79	8.08
Strain	1.01*	1.00	1.01	1.00	1.00	1.01	1.00	1.00	1.01

* Statistical difference ($p<0.05$) calculated with respect to the differences from the healthy group.
Duration: the sum of the duration of training and matches over the preceding week; load/monotony/strain: the sum of the training load, monotony and strain over the preceding week.

Relation between psychosocial stress and recovery, traumatic injuries, overuse injuries and illnesses

The analysis of the RESTQ-Sport showed no clear relation between specific components of stress and recovery and the occurrence of injuries (table 4). Subscale fitness/injury was significantly higher for players with a traumatic injury as well as for players with an overuse injury compared with healthy players. Ill players reported significantly more general stress than healthy players in 6 out of 7 subscales, with emotional stress having the highest OR and fatigue the lowest OR. Furthermore, they perceived significantly less social recovery, general well-being and sleep quality. Finally, on the sport-specific components of the RESTQ-Sport, ill players reported significantly more disturbed breaks, emotional exhaustion and felt less fit and less in shape.

Chapter 3 Monitoring stress and recovery; new insights for the prevention of injuries and illnesses in elite youth soccer players

Table 4. Multinomial regression of psychosocial stress and recovery; Odds Ratios (OR) and 95% Confidence intervals (CI) for the three groups: traumatic injury, overuse injury and illness.

	Traumatic injury			Overuse injury			Illness		
	OR	CI (95%)		OR	CI (95%)		OR	CI (95%)	
General stress	0.97	0.74	1.27	1.03	0.75	1.43	1.44	0.98	2.11
Emotional stress	1.04	0.76	1.44	1.24	0.85	1.82	2.27**	1.43	3.61
Social stress	0.96	0.70	1.30	1.07	0.74	1.53	2.07**	1.37	3.13
Conflicts / pressure	0.95	0.74	1.22	0.94	0.70	1.27	1.69**	1.18	2.42
Fatique	0.93	0.72	1.20	0.96	0.70	1.30	1.48*	1.05	2.09
Lack of energy	0.94	0.70	1.26	1.07	0.75	1.52	1.92**	1.27	2.91
Physical complaints	0.99	0.74	1.33	1.02	0.71	1.45	1.88**	1.24	2.83
Success	1.04	0.81	1.35	0.76	0.55	1.04	1.07	0.73	1.59
Social recovery	0.99	0.78	1.26	0.94	0.71	1.26	0.66*	0.47	0.94
Physical recovery	0.88	0.69	1.13	0.89	0.66	1.19	0.62	1.43	0.90
General well-being	1.10	0.85	1.42	0.93	0.68	1.26	0.57**	0.39	0.83
Sleep quality	0.99	0.77	1.27	0.86	0.64	1.16	1.58**	0.40	0.83
Disturbed breaks	0.94	0.72	1.22	1.00	0.73	1.37	1.51*	1.03	2.22
Emotional exhaustion	0.85	0.67	1.09	0.92	0.69	1.23	1.47*	1.06	2.03
Fitness / injury	1.29*	1.01	1.66	1.46*	1.09	1.96	1.60*	1.11	2.31
Being in shape	0.91	0.73	1.13	0.84	0.64	1.09	0.56**	0.40	0.79
Personal accomplishment	1.06	0.84	1.35	0.90	0.68	1.20	0.86	0.59	1.24
Self-efficacy	1.00	0.80	1.25	0.97	0.74	1.27	0.92	0.66	1.30
Self-regulation	0.90	0.75	1.08	0.82	0.66	1.02	0.96	0.73	1.27

Reference category is healthy

* Statistical difference (p<0.05) calculated with respect to the differences with the healthy group.

** Statistical difference (p<0.01) calculated with respect to the differences with the healthy group.

Chapter 3 Monitoring stress and recovery; new insights for the prevention of injuries and illnesses in elite youth soccer players

Discussion

The present prospective study demonstrates that physical stress plays an important role in relation to the occurrence of both injuries and illnesses. In addition, psychosocial stress and recovery are important in relation to illness. The methodological approach used in this study provides new insights for a prevention strategy, since players were monitored with daily training-logs and monthly questionnaires for two competitive seasons. In this way, monitoring stress and recovery can possibly warn and guide soccer players who are at risk for injuries and illnesses.

Regarding the injury incidence we used the recently proposed FIFA registration system, which makes a comparison with previous literature interesting [22]. For time loss injuries, our match injury incidence is comparable to other studies, but our training injury incidence is slightly higher. This might be explained by a difference in injury definition. For example, Le Gall et al. [19] reported an injury incidence of 11.2 injuries per 1000 match hours and 3.9 injuries per 1000 training hours in a 10-season study in elite French youth soccer players. However, they only recorded injuries that prevented the player from participation for more than 48 hours, whereas in our study all injuries resulting in being unable to take full part in future training or match play were recorded as time loss injuries.

As proposed in the FIFA registration system, we additionally registered injuries of players that needed medical attention, but still were able to take full part in future training or match play. These mild injuries explain that the overall injury rate in our study is relatively high. Comparable results were found for the location, type and mechanism of injury [3,6,19].

An illness incidence of youth elite soccer players has not been previously reported in literature, but turned out to be a large part of the reported medical problems (20%).

The relation between physical stress and the occurrence of injuries and illnesses found in this study is in accordance with previous literature [12-14,24,26]. However, these studies differ in type of sport, performance level and gender. Gabbett [13,14] found that high training intensity (session-RPE), training duration and training load were related to injuries in sub-elite rugby-league players, who participated in 2 or 3 organized field-training sessions per week. Additionally, Anderson et al. [12] reported that a high total weekly training load in female collegiate basketball players was related to weekly injuries. In our study, the difference between traumatic and overuse injuries was added. This difference may be interesting, because differences exist in the risk factors involved as well as the mechanisms leading to a traumatic injury or overuse injury [8]. In our study, physical stress seems to be important in relation to the occurrence of traumatic injuries. The difference in OR between monotony and strain is explained by the fact that the OR depend on the unit used in the continuous variable. For every unit increase, the odds of a player being injured increases. Monotony is expressed as a rather small number and consequently has a large OR. In other words, an increase of one unit will have a large effect. One unit strain has a smaller effect, but this is compensated by the fact that extra strain goes together with many units. For overuse injuries, no differences in physical stress were found. However, it is known that an overuse injury is caused by repetitive stress without sufficient time to undergo the natural reparative process [32].

Based on the framework of Këntta and Hassmén, physical stress and recovery are assumed to be most important in relation to overuse injuries [10]. A possible explanation might be that a one week period prior to an overuse injury is too short to find a relevant relation. Our finding that illness is related to a disturbed balance between stress and recovery is also in accordance with findings in literature. Foster [26] and Putlur et al. [24] both found a positive relation between training and illness in competitive athletes and female collegiate soccer players, respectively. It should be noted that in our study we used the original Borg scale instead of the category ratio scale (10 point scale). To avoid the association with marks on school exams, we decided to use the original scale. Although this does not effect the results of our study, a comparison with studies that use the category ratio scale should be done with caution.

The RESTQ subscales of stress and recovery showed no clear relation with the occurrence of injuries in this study, except for subscale fitness/injury, which was significantly higher for injured players compared to healthy players. In relation to illness, several stress and recovery related items appeared to be important. This is in line with literature that showed that the infection risk is increased when a player is exposed to other stressors to the immune system, including lack of sleep or severe psychosocial stress [17,18]. Based on the model of Andersen and Williams [11] about the underlying mechanism of sports injuries a relation between psychosocial stress and recovery and the occurrence of injuries was expected. A possible explanation for the fact that no clear relation between specific components of stress and recovery and the occurrence of injury was found in this study may be that the RESTQ-Sport was administered monthly. Perhaps the questionnaire must be administered more frequently to monitor changes in the recovery-stress state of players accurately.

In this study, multinomial regression was used to test whether there were differences in stress and recovery between players suffering from an injury or illness compared to healthy players. To take into account that players were repeatedly measured, our first analysis was based on random effects models. However, it turned out that interindividual differences were comparable to intra-individual differences. This implies that no extra information was obtained by using these rather complicated models. Also the GEE approach (an alternative method for taking into account correlated measures) did not reveal other results than multinomial regression. Therefore we chose to present the results of the multinomial regression approach for the sake of simplicity. Since (de)selection of players at the transition of the first season to the second was predominantly based on shifting to a higher age category, we assumed the data are missing at random and not related to the main outcome. The homogeneity of the group is supported by the fact that players belonged to the best 1% in their age category and no significant differences were present in their physical characteristics.

Further studies that prospectively monitor stress and recovery and injury and illness for more than two competitive seasons in several elite youth soccer teams are required to investigate the specific relations of traumatic and overuse injuries. In these studies, the analysis of stress and recovery

Chapter 3 Monitoring stress and recovery; new insights for the prevention of injuries and illnesses in elite youth soccer players

measures should be combined to investigate the relation between the balance of these components and the occurrence of injury and illness. The final goal should be to develop a system that indicates the injury or illness risk of an individual player on the basis of the balance between his personal stress and recovery scores. In this study we monitored measures of stress and recovery to develop a prevention strategy. From this point forward, research is needed that evaluates if this intervention will lead to a reduction of injuries and illnesses.

Based on the results of this study, trainers, coaches and medical staff may consider monitoring the duration of training and matches and the psychosocial recovery-stress state, and possibly also the training load, monotony, strain of each player. Because of the large variations between players, the individual differences over time are most important in relation to injury or illness prevention. Therefore, trainers need to get feedback on individual basis to identify when a player has an increased injury or illness risk. If necessary, they can possibly adapt the training schedule or use interventions in which players are learned to better cope with stress or enhance recovery related activities.

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What is already known on this topic

A disturbed stress-recovery balance is a well known risk factor for the occurrence of injuries and illnesses.

What this study adds

We prospectively monitored stress and recovery and incidence of medical problems in elite youth soccer players by means of daily logs and monthly questionnaires. These measures of stress and recovery may play a role in a prevention strategy for injuries and illnesses in elite youth soccer players.

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Chapter 4 48-49

Changes in perceived stress and recovery in overreached young elite soccer players.

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Abstract

The aim of this study was to prospectively monitor sport-specific performance and assess the stress-recovery balance in overreached (OR) soccer players and controls. During two competitive seasons, 94 players participated in the study.

The stress-recovery balance (RESTQ-Sport) and sport-specific performance (Interval Shuttle Run Test) were assessed monthly. Seven players with performance decrement of at least a month were classified as OR. Stress and recovery measures were assessed between groups (OR vs healthy players) and at different times within the OR group. An unfavourable total recovery score appeared two months before diagnosis when compared to the reference values of the healthy group established at the start of the season (P=0.009) and also over the two seasons (P=0.028). The scales Emotional Stress (P=0.044), Physical Recovery (P=0.009), General Well-being (P=0.001) and Sleep Quality (P=0.045) were sensitive to OR compared to the average of the healthy group over the two seasons. Finally, Fatigue and Being in Shape demonstrated the largest changes in stress and recovery within the OR players (effect size = 1.14 and 1.50). The longitudinal monitoring of performance and changes in stress and recovery may be useful for the detection of OR in its earliest stage. The information obtained from these tests can be used to optimise individual training and recovery programs.

Keywords: overtraining, stress-recovery balance, football, fatigue, staleness

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Chapter 4 Changes in perceived stress and recovery in overreached young elite soccer players

Introduction

A sustained mismatch between stress and recovery in athletes can result in athletes being unable to tolerate training and possibly lead to overreaching (OR). Overreaching is characterized by a short term decrement in sport-specific performance and is often coupled with symptoms such as increased fatigue, poor concentration, disturbed mood and altered eating and sleeping patterns. Moreover, OR can be further classified as either Functional Overreaching (FOR) or Non-functional Overreaching (NFOR) with the criteria for each based on the duration of performance decrement and severity of symptoms [1,2].

FOR refers to a short term performance decrement (i.e. days to weeks) with a planned recovery period, whilst NFOR is the more severe condition where performance decrement lasts longer (weeks or months) and usually presents with more severe symptoms. The overtraining syndrome (OTS) is the final stage of the continuum with documented recovery periods lasting from months to years (figure 1). Since the exact duration and severity of performance decrement and symptoms are not defined, a clear distinction between these three phases is difficult to make.

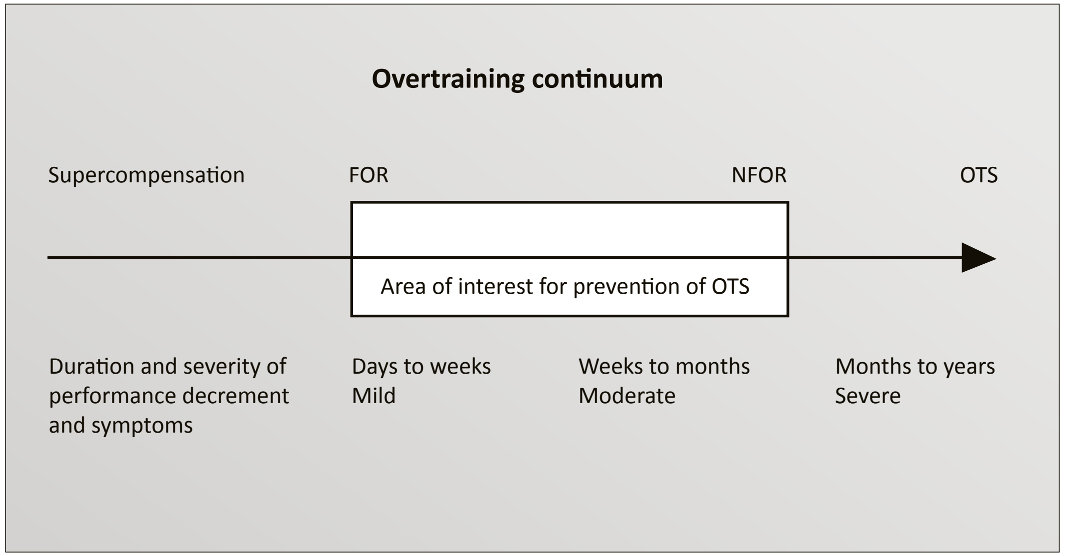

Figure 1. The overtraining continuum. FOR: functional overreaching, NFOR: non-functional overreaching, OTS: overtraining syndrome.

To minimize the risk of OR, it has been recommended that the stress associated with training should be matched with appropriate recovery practices [3]. Indeed, Kenttä and Hassmén [3] have provided a theoretical training model that includes both physical and psychosocial aspects of stress and recovery. According to this model, an athlete's individual risk of OR can be explained by their different physical and psychosocial capacities [3]. Therefore, it has been recommended that each component of the model should be carefully considered when planning an athlete's training schedule and recovery practices.

Regular monitoring for changes in stress and recovery might help identify athletes who are at risk of OR. To achieve this, Kellmann and Kallus [4] developed the Recovery Stress Questionnaire for Athletes (RESTQ-Sport) to systematically assess stress and recovery related activities. The RESTQ-Sport was designed to assess the multi-dimensional nature of stress and recovery in athletes and to enable coaches and athletes to select specific intervention strategies that might assist them avoid unplanned OR. Several previous studies have used the RESTQ-Sport to identify athletes at different stages on the 'overtraining continuum' (figure 1). For example, the RESTQ-Sport has been used to identify acute changes in athlete's stress-recovery status in the weeks leading into major championships [5-8] and during periods of intensified training [9-13]. Each of these previous studies demonstrated that the RESTQ-Sport was able to detect changes in stress and recovery over a short period. These results have also been confirmed in studies monitoring athletes over longer periods (~6 months) [14,15] and in the case of an athlete suffering NFOR [16].

Several studies have shown changes in subjective stress and recovery to be related to changes in physical performance [8-10,12,13] and biological measures such as hormonal levels [9,11-14]. However, only one of these studies used this tool in team-sport athletes [10]. Unfortunately, it is difficult to apply the results from this previous study to practice as the monitoring period during an intensified training period was conducted before the competition season and the results did not account for seasonal variation in stress, recovery and performance.

Soccer players quite often have arduous training regimes, and in competition periods can be required to play up to three matches per week [17]. These high training demands, along with other psychosocial pressures associated with high performance sport can place them at higher risk of NFOR. However, to date, there have been few long-term, prospective studies that have examined OR in soccer players [18-20]. Therefore, to avoid unplanned performance decrements the early detection of a mismatch between stress and recovery (in the context of seasonal variation in these measures) is necessary. Accordingly, the aim of this study was to prospectively monitor sport-specific performance over a season and assess the stress-recovery balance in OR soccer players and controls. We hypothesized that OR soccer players classified with objective performance decrement lasting at least a month, can be distinguished from a control group by their stress-recovery balance.

Chapter 4 Changes in perceived stress and recovery in overreached young elite soccer players

Methods

Study design

A prospective cohort design was used to monitor stress, recovery and sport-specific performance during two competitive seasons in elite Dutch youth male soccer players aged 15 to 18 years. The procedures were conducted in accordance with the ethical standards of The Central Committee on Research Involving Human Subjects. The participants and both parents (if participants were under-aged) gave informed consent.

Subjects

During the 2006-2007 and 2007-2008 competitive seasons a total of 94 players were monitored, for at least one season. All subjects had played for several years at the highest level in the Netherlands and followed a balanced training program which was set by a professional coaching panel. The players were considered to be in best 1% of players in their age category. The training program consisted of aerobic, speed, agility, technical and tactical training. The players also completed an individualised resistance training program once per week. At the time of the study the national soccer team was ranked 3rd in the world by FIFA world demonstrating the high performance level of soccer in the Netherlands.

Soccer players with performance decrement, i.e. measured at two consecutive field tests, were invited to the sports medicine laboratory for medical follow-up. Seven soccer players with a performance decrement of at least one month were included (age: 17 ± 1 y, height: 174.6 ± 6.5 cm, body mass: 71.4 ± 6.1 kg (mean ± SD)).

Stress and recovery

The Dutch version of the Recovery-Stress Questionnaire for Athletes (RESTQ-Sport) was administered monthly to assess the psychosocial stress-recovery balance of players. Nederhof et al. [21] has shown that the Dutch versions of the RESTQ-Sport has acceptable reliability and validity for use in sports practice and research. The RESTQ-Sport consists of 12 general and 7 sport-specific scales with 4 questions per scale and 1 warm-up question. Each player was instructed to rate the 77 items on a Likert-type scale, with anchors of 0: never and 6: always, indicating how often he participated in recovery and stress related activities during the last 4 weeks [4]. While the regular period of reference refers to the last 3 days/nights, it can be extended up to 4 weeks [4]. In case of missing data, the mean of a scale was only calculated when at least 3 out of 4 of the items were rated [4]. High scores on the stress-associated scales reflect subjective stress, whereas high scores on the recovery-oriented scales represent increased recovery activities [7,13]. Total stress and total recovery were calculated as the sum of all stress and recovery scores respectively [4].

Performance

After completing the RESTQ-Sport, the players performed a submaximal Interval Shuttle Run Test (ISRT). The ISRT, which previously been shown to have acceptable reliability and validity [22,23], was performed once per month following a rest day. All ISRTs were completed on an artificial pitch as part of a standardised warm-up. The intensity for the submaximal ISRT was set at 70% of each player's maximal ISRT performance which was determined at the start of each season. During the ISRT, players alternately ran for 30 s and walked for 15 s. Running speed for each subject started 10 km•h^{-1} and increased by 1 km•h^{-1} every 90 s up to 15 km•h^{-1} (depending on baseline maximal running performance). Each player completed the same individualised protocol for each ISRT during the study. Heart rate was recorded at 5-s intervals (Polar, Kempele, Finland) and the mean of the final 60 s of the test was used for later analysis. It was assumed that an elevated heart rate response well beyond the normal test-retest variation (≥ 5 beats•min^{-1}), indicated a state of overreaching [24,25]. The test-retest variation in heart rate during submaximal interval-based running has been reported to be 3 ± 1 beats•min^{-1} [26].

Medical Screening

All injuries and/or illnesses were closely assessed and recorded by the club's medical staff (i.e. physicians and physical therapists) according to the FIFA registration system [27]. An injury was defined as any physical complaint sustained by a player that resulted from match play or training. Injuries were recorded if a player received medical attention for more than one day or was unable to take part in training or were ineligible for selection for matches. An illness was defined as a circumstance in which the player felt that they were limited or unable to perform normal training or match (e.g. flu, cold, virus, etc.). Players who did not suffer from illness and injury along and also had a normal response to the submaximal ISRT were selected as healthy controls (N=87) [28]. The soccer players (N=7) who presented with abnormal heart rate response to the ISRT were invited to the laboratory, one week after the field performance test, for medical follow-up. A sports physician followed previous recommendations for athlete screening [1,29] to exclude other well-known causes of fatigue and performance decrement (e.g. viral infections, anaemia, allergy, diabetes, hypothyreoidea). No players were excluded after these screening procedures. Therefore, the soccer players with and altered response to the sport-specific performance test were diagnosed as being OR.

Statistical analysis

Data were analyzed using SPSS 16 (SPSS Inc., Chicago, IL). Means and standard deviations (SD) were determined for the measures of stress and recovery. Reference values of these measures were set as follows: 1) stress and recovery of the healthy group at the start of the season; 2) stress and recovery of the healthy group over the two seasons; 3) the most favourable stress and recovery scores at the start of the seasons of the players that became OR. The most favourable stress and recovery scores were quantified as the lowest stress and highest recovery scores in the first months of the season. Stress and recovery of the OR group are presented as: a) two months before diagnosis; b) one month before diagnosis; and c) at time of diagnosis. One-way analyses of variance (ANOVA) were used to compare stress and recovery between different groups, followed by Bonferroni post hoc analyses. Differences with a $P<0.05$ were considered significant. Additionally, effect sizes (ES) were determined using Cohen's d. ES values of 0.20-0.49, 0.50—0.79 and 0.8 and above were considered to represent small, medium and large differences, respectively [30].

Chapter 4 Changes in perceived stress and recovery in overreached young elite soccer players

Results

The OR soccer players showed a mean increase in heart rate of 9 ± 1 beats•min^{-1} (range 8-11 beats•min^{-1}) in the submaximal ISRT compared to baseline. The average heart rate at the time of inclusion was 187 beats•min^{-1}, which corresponds to 85 – 90 % of the maximal heart rate. Figure 2 shows mean (±SD) the total stress and total recovery scores in the three reference groups 1) the healthy group at the start of the season; 2) the healthy group over the two seasons; 3) the most favourable total stress and recovery scores at the start of the seasons of the players that developed OR. Furthermore, it depicts the OR group: a) two months before diagnosis, b) one month before diagnosis; and, c) at time of diagnosis. One-way ANOVA revealed no differences for the total stress score. The total recovery score on the other hand appeared to be different between groups ($F_{5,263}$=3.36, P=0.006). Bonferroni post hoc analyses showed a more favourable recovery score in the healthy group at the start of the season (P=0.009) and over the two seasons (P=0.028), compared to 2 months before diagnosis in the OR players.

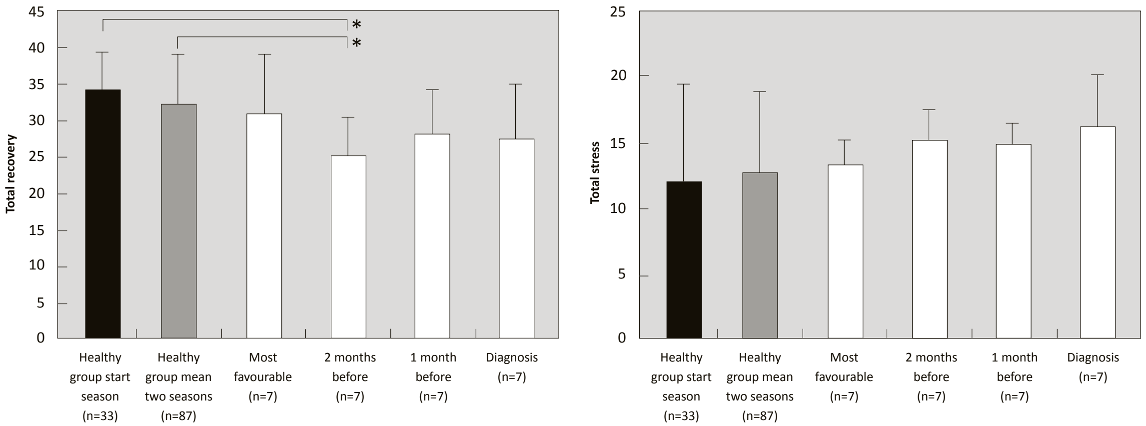

Figure 2. Total stress and total recovery of three reference groups (all mean ±SD). *P<0.05.

Figure 3 presents the 19 stress and recovery scales of the OR players up to two months before diagnosis. The mean (±SD) stress and recovery scores of the healthy group over the two seasons was set as reference group. One-way ANOVA identified between group differences in General Stress ($F_{3,223}$=3.43, P=0.02), Emotional Stress ($F_{3,223}$=2.75, P=0.043), Physical Recovery ($F_{3,223}$=4.62, P=0.004), General Well-being ($F_{3,223}$=4.07, P=0.008), Sleep Quality ($F_{3,223}$=3.75, P=0.012), Being in Shape ($F_{3,223}$=3.13, P=0.027) and Personal Accomplishment ($F_{3,223}$=3.51, P=0.016). Post hoc analyses revealed higher Emotional Stress (P=0.044) and lower Physical Recovery (P=0.009) General Well-being (P=0.001) and Sleep Quality (P=0.045) two months before diagnosis.

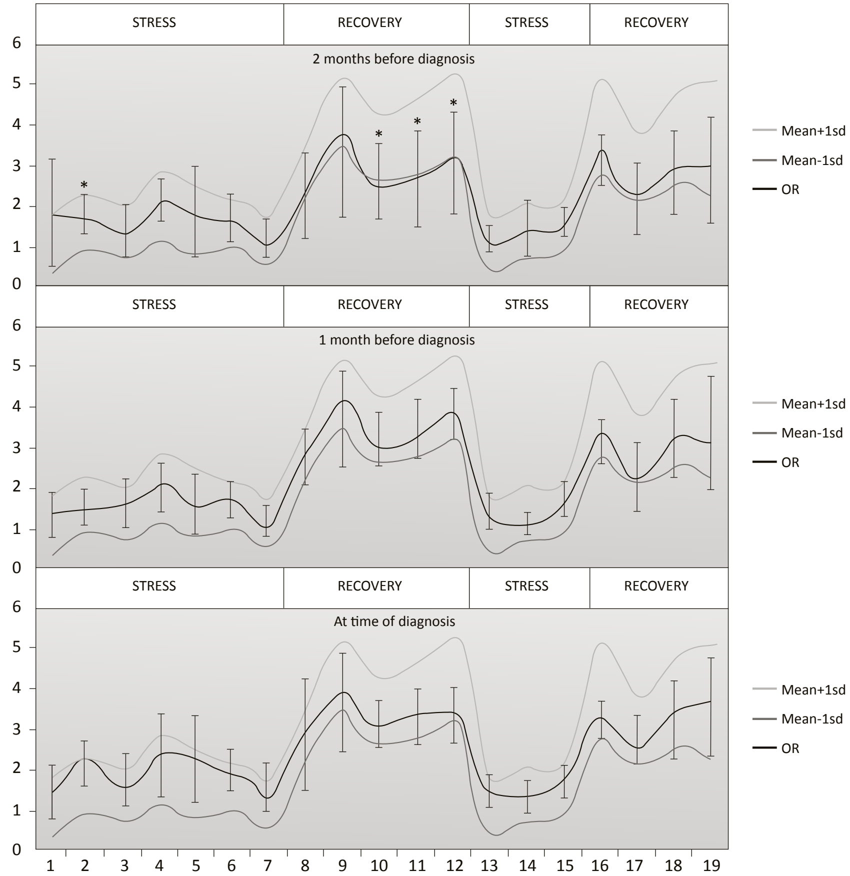

Figure 3. The RESTQ-Sport scores (mean ±SD; in grey lines) of the healthy group (n=87) over the two seasons is set as reference group. The RESTQ-Sport scores of the OR players (mean ±SD; black line with tails) are presented up to 2 months before diagnosis.

1 = General Stress, 2 = Emotional Stress, 3 = Social Stress, 4 = Conflicts/pressure, 5 = Fatigue, 6 = Lack of Energy, 7 = Physical Complaints, 8 = Success, 9 = Social Recovery, 10 = Physical Recovery, 11 = General Well-being, 12 = Sleep Quality, 13 = Disturbed Breaks, 14 = Emotional Exhaustion, 15 = Injury, 16 = Being in Shape, 17 = Personal Accomplishment, 18 = Self-Efficacy, 19 = Self-Regulation. * P<0.05

Chapter 4 Changes in perceived stress and recovery in overreached young elite soccer players

The absolute differences between the RESTQ-Sport stress and recovery scales taken from the OR players 2 months before diagnosis and the most favourable scale scores measured at the start of the season are shown in table 1. Fatigue showed the largest absolute difference (0.93) and ES (1.14) of the stress related scales. The largest absolute difference (-0.89) and ES (1.50) in recovery related activities was found in the Being in Shape scale.

Table 1. Absolute differences between the RESTQ-Sport stress and recovery scale measures (range 0-6) taken from the OR players (n=7) at the 2 months before diagnosis and the most favourable subscale scores measured at the start of the season.

Nr.	Scale	Category	Absolute Difference	ES
	Stress Scales			
1	General Stress	General Stress	0.39	0.40
2	Emotional Stress	General Stress	0.32	0.81
3	Social Stress	General Stress	0.00	0.00
4	Conflicts / Pressure	General Stress	-0.11	-0.24
5	Fatigue	General Stress	0.93	1.14
6	Lack of Energy	General Stress	0.04	0.07
7	Physical Complaints	General Stress	0.21	0.47
13	Disturbed Breaks	Sport-specific Stress	-0.11	-0.26
14	Emotional Exhaustion	Sport-specific Stress	-0.18	-0.13
15	Injury	Sport-specific Stress	-0.11	-0.27
	Recovery Scales			
8	Succes	General Recovery	-0.50	0.50
9	Social Recovery	General Recovery	-0.96	0.80
10	Physical Recovery	General Recovery	-0.82	1.21
11	General Well-being	General Recovery	-0.68	0.76
12	Sleep Quality	General Recovery	-0.82	1.04
16	Being in Shape	Sport-specific Recovery	-0.89	1.50
17	Personal Accomplishment	Sport-specific Recovery	-0.32	0.45
18	Self-Regulation	Sport-specific Recovery	-0.82	0.74
19	Self-Efficacy	Sport-specific Recovery	-0.61	0.70

ES = Effect Size

Discussion

In the present study we hypothesized that OR soccer players classified with objective performance decrement of at least a month, can be distinguished from a healthy control group by their stress-recovery balance. In agreement with our hypothesis, the results demonstrated that OR soccer players show an unfavourable total recovery score up to 2 months before diagnosis of OR. Additionally, the RESTQ-Sport scales of Emotional Stress, Physical Recovery, General Well-being and Sleep Quality were significantly different between the OR group and the controls whilst the subscales of Fatigue, Physical Recovery and Being in Shape were most affected (ES > 1.0) in the players who developed OR. These results also showed that when combined with objective submaximal ISRT measures, the RESTQ-Sport is a good practical tool for assessing risk of OR in soccer players.

In this study the key criteria for diagnosing OR were a large increase in heart rate during the submaximal ISRT, and the absence of underlying illness or injury. These criteria have previously been observed in many studies that have investigated OR (for review see: [31]) and are included in the European College of Sports Sciences Position Statement on the 'Prevention, diagnosis and treatment of Overtraining Syndrome' [1,2]. A unique aspect of this study was the observation of the signs and symptoms during the development of OR. Indeed, the present results were in accordance with the theoretical OR continuum [31] where the OR players had increased signs and symptoms of OR which accompanied the performance test decrement. These findings suggest that longitudinal monitoring of the stress-recovery balance might be useful for identify players at risk of OR during the season.

The incidence of OR in this study is 7.4% (7/94 players) and is based on objective performance decrement. In comparison with other studies that used self-reported symptoms as main criteria, this is a relatively low incidence for high level team sport athletes. These studies have reported symptoms of OR in 30–50% of high-level Belgian soccer players during a competitive season [19], or reported that 7–30% of all elite athletes may exhibit signs and symptoms of OR at any given time in their career [32]. There may have been a higher incidence of OR within this group of soccer players as there were several occasions where the second follow-up performance test and/or medical screening was not performed because of scheduling difficulties (e.g. clashes with international matches and school exams) and injuries. Regardless of its incidence, OR in professional soccer can have significant impact upon both the team and individual's performance [10,18,20,33]. Therefore, regular monitoring for impending NFOR is important as it may reduce a players risk and improve the physical performance of both individual players and the team.

By conducting this project in the real training environment, we were able to compare the stress and recovery measures of the OR soccer players with a 'healthy' reference group and also in the context of normal seasonal variation. The soccer season typically consists of periods of high training load in the preseason period and periods of increased competition during the season (Coutts et al., 2008b), and these variations can influence the recovery and stress balance. To account for these seasonal variations the mean RESTQ-Sport measures for the whole study cohort was examined over two seasons. Furthermore, to establish

Chapter 4 Changes in perceived stress and recovery in overreached young elite soccer players

baseline reference values for the individual players, their stress and recovery balance was also assessed at the start of the soccer season when the players were relatively free from training-related fatigue and the stressors of competition. The results showed that at the time of diagnosis, the OR soccer players presented with an unfavourable pattern of stress and recovery compared to the start of season reference group.

We also compared the RESTQ-sport scale scores of the OR soccer players with their most favourable scores at the start of the season. In this study, the largest changes (absolute difference and ES) in the OR soccer players were observed in the stress and recovery scales of Fatigue and Being in Shape. Interestingly, these results agree with the consensus of previous studies that show that these RESTQ-Sport scales are most commonly changed during OR. Indeed, 5/10 studies that have reported Fatigue [5,10,12,13] and 4/10 reported Being in shape [10,12,34] to be significantly altered during OR. Taken collectively, these results suggest that changes in these scales are common to OR in a variety of athletes and therefore should be followed closely.

To assist coaches and sport scientists prevent NFOR, markers should be able to detect changes before long term performance decrement manifests. Since we prospectively monitored the player's stress-recovery balance each month, we were able to examine their responses at the time of the diagnosis and also during the previous two months. Not only was the total recovery score state significantly different compared to the reference values of the healthy group taken at the start of the season and over the two seasons, but there were also increases in 5/10 of the stress scales and decreases in all (9/9) of the recovery scales in the RESTQ-Sport. Indeed, the largest changes apparent in the Fatigue scale and the General Recovery scales (Social Recovery, Physical Recovery, Sleep Quality, Being in Shape) of the RESTQ-Sport. These findings suggest that focus on general recovery practices (e.g. regular sleep, social recovery, general well-being) as well as sport-specific recovery activities during the season might help reduce the risk of OR in soccer players. Collectively, these findings further highlight the practical usefulness of the questionnaire for the early identification of NFOR.

It is well established that OR is not only caused by inappropriate training but can also be affected by a range of different psychological and social stressors [3,31]. Indeed, the large between player variation for each of the RESTQ-Sport scales in the OR players, as shown by the standard deviation of each measure, confirms the multidimensional nature and intra-individual differences of OR. One advantage of monitoring stress and recovery with the RESTQ-Sport is that it examines many of the factors that have been reported to be influenced during OR. For example, in this study the general recovery practices such as Social Recovery, Physical Recovery, Sleep Quality, General Well-being, and Success scale scores were all reduced before OR. These results highlight the need for coaches and sport scientists to focus on aspects other than physical training to reduce the risks of OR in soccer players, and indicate that a broad range of recovery related activities should be completed by all players during the soccer season to reduce the risk of OR (e.g. sleep, nutrition, social relaxation etc). The present findings also show that the longitudinal monitoring with

the RESTQ-Sport can be used to guide intervention strategies according to individual player's responses. Future research should investigate if such an intervention strategy can prevent 'at risk' players from OR.

Although in this study coaches were not provided with feedback, a possible limitation of psychometric questionnaires such as the RESTQ-Sport is that the responses can be manipulated to disguise excessive fatigue and/or stress. This is highly possible amongst professional soccer players, where the outcome of subjective measures may be used to decide if they train or are selected for games. Therefore, to limit the impact of any dishonest responses and to obtain a holistic view of the causes of fatigue, a multifactorial approach to fatigue monitoring should be adopted, using both subjective and objective measures. In this study we used a submaximal heart rate test, which has been shown to be useful as an objective measure of fatigue in soccer players [35]. An advantage of this submaximal test is that it is a relatively non-fatiguing test and it can easily be incorporated into a training schedule in professional field-based, team sports such as soccer.

At the start of the study a criterion heart rate increase of 5 beats•min^{-1} to the submaximal ISRT was set as a marker of OR and was set on the basis of a previous study that showed that the day-to-day variation in HR is 3 ± 1 beats•min^{-1} at the intensity of this test (~85–90% HRmax) [26]. In this study the criterion heart rate elevation exceeded by all 7 OR players with the typical magnitude of heart rate increase being 8–11 beats•min^{-1}. These findings agree with Foster et al. [36] who reported a general increase in heart rate during a standardised work bout at ~80% HRmax measured during a warm-up in a cyclist whose performance had stagnated during 12 weeks of self-regulated training. However, these results are in contrast to a recent study that showed no differences in submaximal heart rate during a 20 m shuttle run test at 12 km•h^{-1} between a group of 8 deliberately OR triathletes and a matched group that were coping with training [9].

There are limitations of using submaximal heart rate as a marker of OR. For example, it is known that physical and psychological stress as well as dehydration caused by high temperature can increase heart rate [37,38]. However, since all the submaximal ISRT in this study were conducted after a rest day and at the beginning of the training session, the effects of physical stress and dehydration would have been minimised. Despite these limitations, the findings of this study provide support for the use of the submaximal ISRT to monitor for NFOR in soccer players, especially if used in conjunction with psychological monitoring such as the RESTQ-Sport.

In this study we did not have the opportunity to monitor stress, recovery and performance after the diagnosis of OR, as most of the players were diagnosed at the end of the season before the summer break. Some of these players then moved to a higher age category or a different club which prevented follow-up analysis. It would be interesting for future research to continue monitoring stress and recovery and investigate when performance returns to normal. This might also provide useful information to distinguish between FOR and NFOR.

Chapter 4 Changes in perceived stress and recovery in overreached young elite soccer players

Perspectives

This study presented a simple model that demonstrated how non-invasive practical objective (submaximal ISRT) and subjective (RESTQ-Sport) tests can be used to monitor for fatigue and OR in high performance soccer players. Specifically, the findings demonstrate that reduced general recovery practices and increased fatigue measures from the RESTQ-Sport provide an early warning of impending overtraining. This study also shows that the stress-recovery balance is a useful measure that can be used to monitor for OR in soccer players in a practical setting. Moreover, an increase in heart rate of ≥ 5 beats•min^{-1} to the standard submaximal ISRT can also provide coaches and scientists with useful objective information regarding the fatigue status of soccer players. Taken together, the longitudinal monitoring of changes in stress and recovery may be useful for the detection of OR in its earliest stage (Nicholls et al. 2009). The information obtained from these tests can be used to optimise individual training and recovery programs in high performance soccer players.

Acknowledgements

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Chapter 5 62-63

Reliability and Validity of the Dutch Recovery Stress Questionnaire for Athletes.

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Abstract

The purpose of the present study was to investigate the cross-cultural validity of the Recovery Stress Questionnaire for Athletes (RESTQ-sport) by analysing reliability and validity of a Dutch translation.

Two studies were performed to assess test-retest reliability, internal consistency and factor structure. Criterion validity was assessed in the first study only, with the Profile of Mood States as criterion measure. The test-retest reliability of the Dutch RESTQ-sport was acceptable, especially as the RESTQ-sport aims to measure stress and recovery states. Internal consistency was good for most scales. In both studies, internal consistency was higher at the second compared to the first measurement. Factor analyses confirmed the stress-recovery structure of the Dutch RESTQ-sport. Criterion validity was also supported. Overall, it was concluded that the Dutch RESTQ-sport has sufficient reliability and validity. This gives support to the cross-cultural usefulness of the scale.

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Chapter 5 Reliability and Validity of the Dutch Recovery Stress Questionnaire for Athletes

Introduction

Monitoring stress and recovery has become increasingly important in sports. A disturbed stress-recovery balance can increase an athlete's vulnerability for injuries, overtraining or burn-out [1,2]. The Recovery Stress Questionnaire for Athletes (RESTQ-sport) is a recently developed questionnaire that can be used for this purpose [3]. The RESTQ-sport is an extension of the general Recovery Stress Questionnaire [4], which exists of 12 stress and recovery scales. Three sport-specific stress scales and four sport-specific recovery scales were added to the original questionnaire in the version for athletes. The questionnaire focuses on the frequency of stress and recovery related behaviours (e.g. I had a good time with friends) as well as on psychophysical states (e.g. I was in a bad mood).

The RESTQ-sport has predominantly been used in endurance athletes such as rowers [e.g. 5,6], cyclists [7,8], and triathletes [9]. Currently, the RESTQ-sport is being used in team ball sports such as soccer as well.

The RESTQ-sport was successfully used in the monitoring of training load in adolescent [e.g. 5] and adult athletes [e.g. 6]. In other studies the RESTQ-sport has been used to measure the effect of high load training on perceived stress and recovery [e.g. 8,9]. The questionnaire has been used successfully in different countries (e.g. Australia, Estonia, France, Germany, Netherlands) which can be seen as indirect proof of its cross-cultural usefulness.

However, the RESTQ-sport is not all good news. Davis et al. [10] performed a validation study on the individual items of the questionnaire. Davis and colleagues could not confirm the 19 subscales of the RESTQ-sport. This type of validation had not been performed by the original authors [3].

The purpose of the present study is to examine cross-cultural usefulness by analysing reliability and validity of the scales in the Dutch version. As the RESTQ-sport has shown to be a useful tool in research and practice the authors decided to validate the Dutch version following the procedures of the original psychometric evaluation.

Study 1

The purpose of the first study was to test initial reliability and validity of the Dutch RESTQ-sport. The questionnaire was translated from English into Dutch by a native Dutch speaker who was an expert in English as well as in the field of sports. The translation was checked by two other experts of whom one was a native English speaker. Consistency and test-retest reliability of the translated questionnaire were determined as well as construct and criterion validity. The RESTQ-sport was compared to the Profile of Mood States (POMS) for the determination of criterion validity.

Method

Subjects

Participants in the first study were 116 athletes (59 male, 57 female) with a mean age of 23.1 (SD = 3.6) years. The mean amount of training hours in the week before the first data collection was 6.8 (SD = 3.2) hours. Participants trained for basketball (n = 11), korfball (n = 16), rowing (n = 11), speed skating (n = 31) and volleyball (n = 47).

Instruments

Recovery Stress Questionnaire for Athletes (RESTQ-sport). The RESTQ-sport consists of 77 questions. Questions are answered on a seven point Likert type scale.

The first question is a practice question. The 19 scales of the RESTQ-sport consist of the other 76 questions. Each scale consists of four questions. There are 12 general and 7 sport-specific scales of which seven scales measure general stress, five general recovery, three sport-specific stress and four scales measure sport-specific recovery [3].

Test-retest reliability of the RESTQ-sport is better for shorter measurement intervals. Test-retest reliability lies above .7 for most scales over three days, it declines to around .5 over 9 days. Longer measurement intervals give even lower test-retest reliabilities [3]. This finding is consistent with the construct the questionnaire measures, stress and recovery vary over time.

Internal consistency of the RESTQ-sport is good for most scales with Cronbach's alpha of .7 and higher. Although differences between samples and fluctuations over time are present in nearly all scales, in some samples insufficient reliability has been found for the scales *Conflicts/Pressure, Lack of Energy, Success and Disturbed Breaks* [3].

Construct validity of the RESTQ-sport has been shown to be good. Both the general and the sport specific scales loaded on either the factor stress or on the factor recovery. In some samples some scales loaded negatively on the other factor as well [3,10].

Criterion validity with the POMS as criterion measure has also been shown to be good. Correlations were all in the expected direction. The stress scales correlated positively with negative mood states and the recovery scales correlate positively with the positive mood state and vice versa [3].

Profile of Mood States (POMS)

The Dutch POMS is a shortened version of the original questionnaire and consists of the five scales *Depression, Anger, Fatigue, Vigour* and *Tension*. It consists of 32 items that are answered on a five point Likert scale. The Dutch POMS has shown to have good reliability and validity [11].

Procedure

Coaches and trainers were asked for permission to get in touch with their athletes before or after a training session. If permission was given the procedure was explained to the athletes and they were asked if they agreed on participation. The athletes who agreed filled out the RESTQ-sport and the POMS before or after a regular training session. The second measurement occasion took place exactly one week after the first. This time only the RESTQ-sport was filled out. Procedures of the study were in accordance with ethical standards of the Helsinki declaration.

Statistical analysis

If more than one out of four values within a scale were missing, participants were excluded from further analyses. Otherwise, the missing value was replaced with the mean score of the corresponding scale.

Chapter 5 Reliability and Validity of the Dutch Recovery Stress Questionnaire for Athletes

Both absolute and relative test-retest reliability were calculated. Absolute reliability was calculated with the Bland and Altman [12] method. The mean difference between the scores on both days was calculated. The 95% confidence interval to the mean difference was calculated as follows:

$$95\ \%\ CI = \bar{d} - t \times (s_d / \sqrt{n})$$

With $\bar{d}$ the mean difference, t the critical t value for the number of degrees of freedom and s_d the standard deviation of $\bar{d}$. If zero lays within the 95% confidence interval, it was concluded that no bias existed. Intra Class Correlation was calculated for determination of relative test-retest reliability. Crohnbach's alpha was calculated for internal consistency. A maximum likelihood analysis with oblique rotation and two fixed factors was done to examine the stress-recovery factorial structure. Factor loadings smaller than 30 were omitted from the tables for increased clarity. Finally, Pearson's correlations between RESTQ-sport scales and POMS scales were calculated for criterion validity. All analyses were performed using SPSS (version 11.01).

Results
The first questionnaire of one of the subjects was excluded from further analyses, because too many data were missing. 27 participants did not participate in the second measurement because they were absent from training practice. Absolute and relative test-retest reliability were sufficient for most scales (Table 1). The absolute test-retest reliability of the scale *Success* was insufficient with a mean difference significantly different from zero. The 95% confidence interval of the mean difference [12] of the scale Success ranged from -0.33 to -0.02. The scales *Physical Complaints* and *Sleep Quality* showed poor relative test-retest reliability with ICC below .50.

[Tables can be found at the end of the manuscript]

Internal consistency was sufficient for most scales (Table 1). Crohnbach's alpha for the first sample was above .60, except for the scales *Conflicts/Pressure* and *Self-regulation*. In the second sample only the scale *Conflicts/Pressure* was below .60. In general, internal consistency was better for the second measurement.

Factor structure of the Dutch RESTQ-sport was comparable to the original version. The stress recovery factor structure showed to be the strongest structure (Table 2). All general and sport-specific stress scales loaded on the first and all general and sport-specific recovery scales loaded on the second factor. The factor structure of the second measurement was generally stronger than the factor structure of the first measurement. The scales *General Stress, Physical Recovery, General Well-Being* and *Being in Shape* gave additional negative loadings to the other factor. The scale *Self-Regulation* loaded positively on both scales.

Criterion validity was good for most scales (Table 3). Stress scales of the RESTQ-sport correlated positively with the negative mood scales of the POMS and negatively with the positive mood scale. Recovery scales of the RESTQ-sport correlated positively with the positive mood scale and negatively with the negative mood scales of the POMS.

Study 2
All items of the scales with insufficient reliability or validity in study 1 were evaluated and changed if appropriate. Additional changes were made according to our experience with the preliminary Dutch RESTQ-sport. In total, 13 out of 76 items were changed. The purpose of the second study was to evaluate reliability and validity of the improved version of the Dutch RESTQ-sport.

Method
Subjects, Instrument and Procedure
Participants were 123 athletes (66 male, 57 female) who participated in basketball (n=14), gymnastics (n=11), handball (n=13), rowing (n=53) and soccer (n=32). Their mean age was 21.9 (±2.5) years and they practiced on average 8.6 (±4.6) hours a week. The subjects filled out the improved version of the Dutch RESTQ-sport. The same procedures as in study 1 were followed.

Statistical Analysis
The same analyses were performed as in study 1. Absolute test-retest reliability was calculated with the Bland and Altman [12] method. Intra Class Correlations were calculated for relative test-retest reliability. Two factor structure was studied using a confirmatory maximum likelihood factor analysis with oblique rotation.

Results
The second questionnaire of one of the subjects was excluded from analysis, because too many data were missing. 32 Subjects did not participate in the second measurement because they were absent from training practice.
Test-retest reliability can be found in Table 4.

Absolute test-retest reliability was insufficient for the scales *Conflicts/Pressure, Lack of Energy, Success, Physical Recovery* and *Emotional Exhaustion*. Relative test-retest reliability was insufficient for the scales *General Stress, Emotional Stress, Social Stress, Physical Complaints, Success, General Well-Being* and *Sleep Quality* with Intra Class Correlation coefficients below .50.

Internal consistency was good for most scales, except *Physical Complaints* and *Success* in both samples and *Self-Regulation* in the first sample.

The factor structure was good for both samples (Table 5). All general and sport-specific stress scales of the Dutch RESTQ-sport loaded on the first factor. All general and sport-specific recovery factors loaded on the second factor. The scales *General Well-Being* and *Sleep Quality* had additional negative factor loadings on the other factor. *Self-Regulation* loaded positively on both scales in the second sample

[Tables can be found at the end of the manuscript]

Chapter 5 Reliability and Validity of the Dutch Recovery Stress Questionnaire for Athletes

Discussion

Both absolute and relative test-retest reliability were acceptable in both studies. It is hard to draw conclusions from these reliability analyses, as the RESTQ-sport measures stress and recovery states, which are assumed to be unstable constructs [3]. Indeed, test-retest reliabilities of the original RESTQ-sport decreased with larger test-retest intervals. Intra Class Correlations in the present study were comparable to those of the original version. It is remarkable that test-retest reliability was lower in the second study compared to the first study of the present paper. Another remarkable finding is that absolute and relative test-retest reliability scores were insufficient for different scales. For example, in the second study only the scale *Success* had insufficient absolute and relative test-retest reliability. The other scales that were found to have insufficient test-retest reliability scored good on either absolute or relative reliability. Although this supports our conclusion that test-retest reliability is sufficient for the Dutch RESTQ-sport, it also stresses the need to perform both analyses.

Internal consistency of the Dutch RESTQ-sport was also comparable to the original version. In general, internal consistency was better in the second compared to the first measurement. This probably reflects the higher level of familiarity with the instrument. It is remarkable that scales with Crohnbach's alphas below .60 in the Dutch RESTQ-sport also scored low in the original version. The only exception is the scale *Lack of Energy* which scored below .60 in our second study. Overall, we conclude that the reliability of the Dutch RESTQ-sport is sufficient.

The factor structure of the Dutch RESTQ-sport clearly distinguished the stress scales from the recovery scales. Indeed, the stress recovery structuring was the strongest factor structure in the original version as well [3,10]. This gives support for the cross-cultural validity of the questionnaire. As was the case with internal consistency, the factor structure was stronger for the second measurement. Apparently, it is important for athletes to become familiar with the RESTQ-sport for better reliability and validity. Like for the original version, it is our advise to always familiarise athletes with the RESTQ-sport before using it in research or in practice.

Criterion validity of the Dutch RESTQ-sport was determined only in the first study. Correlations with the POMS were in the expected directions. Moderate correlations between the RESTQ-sport and the POMS show that similar but not identical constructs are measured. Thus, it can be concluded that the Dutch RESTQ-sport has good validity, which supports its cross-cultural usefulness.

The overall conclusion of the present paper is that the Dutch RESTQ-sport has sufficient reliability and validity for use in sports practice and research. The RESTQ-sport seems to be a tool that has cross-cultural validity.

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Balancing stress and recovery in sports Chapter 5

Chapter 5 Reliability and Validity of the Dutch Recovery Stress Questionnaire for Athletes

	Bland and Altman (*n* = 88)				ICC (*n* = 88)			Crohnbach's Alpha	
Scale	$\bar{d}$	S_d	95% CI	$\bar{d}$	ICC Coefficient	95% CI	ICC	T1 (*n* = 115)	T2 (*n* = 89)
1. General Stress	-0.09	0.75	-0.24	0.07	.66	.52	.76	.84	.88
2. Emotional Stress	0.00	0.78	-0.17	0.16	.53	.36	.66	.81	.86
3. Social Stress	0.01	0.77	-0.16	0.17	.55	.38	.68	.74	.84
4. Conflicts / Pressure	0.01	0.71	-0.14	0.16	.56	.40	.69	.47	.55
5. Fatigue	0.05	0.98	-0.16	0.26	.54	.37	.67	.75	.71
6. Lack of Energy	-0.12	0.74	-0.27	0.04	.51	.34	.65	.62	.70
7. Physical Complaints	0.07	0.89	-0.12	0.26	.37	.18	.54	.69	.75
8. Success	0.17	0.73	0.02	0.33	.54	.38	.68	.61	.67
9. Social Recovery	0.05	0.80	-0.12	0.22	.55	.39	.68	.78	.78
10. Physical Recovery	-0.07	0.77	-0.23	0.09	.54	.38	.68	.67	.76
11. General Well-Being	0.07	0.73	-0.09	0.22	.63	.48	.74	.88	.90
12. Sleep Quality	0.00	0.58	-0.12	0.13	.44	.26	.60	.80	.75
13. Disturbed Breaks	-0.03	0.75	-0.19	0.13	.54	.37	.67	.72	.83
14. Emotional Exhaustion	-0.01	0.80	-0.18	0.16	.62	.47	.73	.67	.76
15. Fitness / Injury	0.14	0.92	-0.05	0.34	.64	.50	.75	.70	.77
16. Being in Shape	-0.08	0.89	-0.27	0.11	.67	.54	.77	.91	.90
17. Personal Accomplishment	0.03	0.85	-0.16	0.21	.54	.38	.67	.64	.74
18. Self-Efficacy	-0.14	0.82	-0.32	0.03	.67	.53	.77	.78	.87
19. Self-Regulation	-0.02	0.94	-0.22	0.18	.60	.45	.72	.53	.76

Table 1. Absolute and Relative Test-Retest Reliability and Internal Consistency for the Preliminary Version of the Dutch RESTQ-sport.

Chapter 5 Reliability and Validity of the Dutch Recovery Stress Questionnaire for Athletes

	T1 (n = 115)		T2 (n = 89)	
Scale	Factor 1	Factor 2	Factor 1	Factor 2
1 General Stress	.71	-.30	.75	
2 Emotional Stress	.75		.88	
3 Social Stress	.71		.90	
4 Conflicts / Pressure	.61		.68	
5 Fatique	.69		.69	
6 Lack of Energy	.69		.59	
7 Physical Complaints	.72		.78	
8 Success		.51		.70
9 Social Recovery		.57		.60
10 Physical Recovery	-.42	.65	-.42	.62
11 General Well-Being	-.32	.67	-.35	.63
12 Sleep Quality		.32		.33
13 Disturbed Breaks	.71		.42	
14 Emotional Exhaustion	.67		.61	
15 Fitness / Injury	.39		.51	
16 Being in Shape	-.33	.57		.69
17 Personal Accomplishment		.50		.69
18 Self-Efficacy		.72		.68
19 Self-Regulation	.30	.60	.44	.60
Eigenvalue	5.55	3.80	6.07	4.41

Table 2. Maximum Likelihood Factor Analysis of the Preliminary Version of the Dutch RESTQ-sport.

Balancing stress and recovery in sports
Chapter 5

Scale	Depression	Anger	Fatique	Vigour	Tension
1 General Stress	0.78	0.44	0.64	-0.56	0.47
2 Emotional Stress	0.65	0.68	0.56	-0.52	0.39
3 Social Stress	0.52	0.68	0.39	-0.20	0.30
4 Conflicts / Pressure	0.45	0.35	0.44	-0.21	0.47
5 Fatigue	0.35	0.37	0.55	-0.45	0.31
6 Lack of Energy	0.55	0.42	0.50	-0.45	0.41
7 Physical Complaints	0.53	0.40	0.64	-0.51	0.29
8 Success	-0.23	0.01	0.01	0.31	0.06
9 Social Recovery	-0.33	-0.07	-0.15	0.44	-0.21
10 Physical Recovery	-0.60	-0.35	-0.47	0.69	-0.33
11 General Well-Being	-0.62	-0.32	-0.40	0.68	-0.30
12 Sleep Quality	-0.30	-0.30	-0.17	0.26	-0.30
13 Disturbed Breaks	0.32	0.32	0.45	-0.22	0.25
14 Emotional Exhaustion	0.52	0.44	0.53	-0.42	0.27
15 Fitness / Injury	0.25	0.20	0.38	-0.13	0.11
16 Being in Shape	-0.49	-0.22	-0.49	0.60	-0.23
17 Personal Accomplishment	-0.32	-0.23	-0.06	0.16	-0.24
18 Self-Efficacy	-0.44	-0.15	-0.30	0.57	-0.21
19 Self-Regulation	0.25	0.17	0.12	0.21	0.03

Table 3. Pearson's Correlations between the POMS and the Preliminary Version of the Dutch RESTQ-sport.

Chapter 5 Reliability and Validity of the Dutch Recovery Stress Questionnaire for Athletes

	Bland and Altman (n = 90)				ICC (n = 90)			Crohnbach's Alpha	
Scale	$\bar{d}$	S_d	95% CI	$\bar{d}$	ICC Coefficient	95% CI	ICC	T1 (n = 123)	T2 (n = 90)
1. General Stress	0.02	0.86	-0.17	0.20	.35	.16	.52	.84	.84
2. Emotional Stress	0.15	0.79	-0.02	0.31	.43	.24	.58	.77	.77
3. Social Stress	0.13	0.68	-0.02	0.27	.48	.30	.62	.75	.72
4. Conflicts / Pressure	0.23	0.81	0.05	0.40	.60	.45	.72	.62	.73
5. Fatigue	0.01	0.90	-0.18	0.20	.53	.37	.67	.78	.79
6. Lack of Energy	-0.21	0.73	0.05	0.36	.50	.33	.64	.60	.70
7. Physical Complaints	0.08	0.66	-0.06	0.21	.44	.26	.59	.58	.53
8. Success	0.25	0.74	0.09	0.41	.40	.21	.56	.56	.59
9. Social Recovery	0.03	0.66	-0.11	0.17	.70	.58	.79	.74	.84
10. Physical Recovery	-0.17	0.71	-0.32	-0.02	.51	.35	.65	.64	.70
11. General Well-Being	0.04	0.86	-0.14	0.22	.49	.32	.63	.87	.89
12. Sleep Quality	0.09	1.04	-0.31	0.13	.40	.21	.56	.83	.80
13. Disturbed Breaks	-0.03	0.66	-0.12	0.17	.60	.44	.71	.73	.83
14. Emotional Exhaustion	-0.19	0.78	-0.36	-0.03	.52	.35	.65	.67	.72
15. Fitness / Injury	0.14	0.80	-0.03	0.31	.68	.56	.78	.73	.74
16. Being in Shape	-0.07	0.80	-0.24	0.10	.68	.55	.77	.85	.84
17. Personal Accomplishment	0.14	0.88	-0.05	0.33	.50	.33	.64	.63	.69
18. Self-Efficacy	-0.04	0.75	-0.20	0.12	.69	.56	.78	.76	.80
19. Self-Regulation	-0.10	0.83	-0.27	0.08	.61	.46	.73	.56	.71

Table 4. Maximum Likelihood Factor Analysis of the Preliminary Version of the Dutch RESTQ-sport.

Chapter 5 Reliability and Validity of the Dutch Recovery Stress Questionnaire for Athletes

	T1 (n = 123)		T2 (n = 90)	
Scale	Factor 1	Factor 2	Factor 1	Factor 2
1 General Stress	.86		.75	
2 Emotional Stress	.93		.88	
3 Social Stress	.89		.90	
4 Conflicts / Pressure	.66		.68	
5 Fatigue	.52		.69	
6 Lack of Energy	.68		.59	
7 Physical Complaints	.50		.78	
8 Success		.38		.58
9 Social Recovery		.53		.60
10 Physical Recovery		.70		.74
11 General Well-Being	-.47	.56	-.38	.60
12 Sleep Quality	-.55	.24	-.58	.29
13 Disturbed Breaks	.27		.59	
14 Emotional Exhaustion	.51		.68	
15 Fitness / Injury	.18		.22	
16 Being in Shape		.75		.78
17 Personal Accomplishment		.50		.68
18 Self-Efficacy		.66		.79
19 Self-Regulation		.34	.39	.56
Eigenvalue	5.73	3.87	5.89	4.77

Table 5. Maximum Likelihood Factor Analysis of the Dutch RESTQ-sport.

Balancing stress and recovery in sports Chapter 5

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Chapter 6 78-79

Mood state and hormonal responses to a repeated bout of maximal exercise as early markers for overreaching in adolescent elite athletes.

(Submitted)

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Abstract

Purpose: The aim of this study was to find diagnostic tools that are relevant in sport practice for an early detection of overreaching.

Methods: In a group of adolescent elite athletes mood state and hormonal responses to exercise were assessed in overreached athletes and controls. Overreaching was characterized by a sport-specific performance decrement, which was prospectively monitored by means of monthly field tests during one competitive season. Out of 129 athletes, 8 overreached players could be included in the study, together with 7 controls. Mood states of the included athletes were assessed with the shortened version of the Profile of Mood States (POMS). Responses of ACTH, cortisol and prolactin to exercise were evaluated during two graded incremental exercise tests to exhaustion on a treadmill, separated by 3 hours of rest.

Results: The overreached athletes reported more feelings of depression and anger than controls (Mann-Whitney test, $p<0.05$). No significant differences were found in the scores of other subscales of the POMS, i.e., fatigue, vigor and tension. An ANOVA for repeated measures revealed significantly lower ACTH responses ($p<0.05$), and lower overall cortisol levels before and after exercise ($p<0.05$) in the overreached group compared to the control group.

Conclusion: This information provides coaches and sport physicians with early markers about changes in the training status of adolescent athletes, which can be helpful in preventing them for unfavourable and unwanted signs and symptoms of overreaching.

Keywords: overtraining, hypothalamic-pituitary-adrenal axis; football, staleness

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Chapter 6 Mood state and hormonal responses to a repeated bout of maximal exercise as early markers for overreaching in adolescent elite athletes

Introduction

In competitive athletes the balance between stress and recovery in order to improve performance is a delicate one and can easily lead to overreaching (OR). OR is considered to be caused by a disturbed balance in physical and psychosocial stress combined with insufficient recovery [1]. This disturbed balance results in sport-specific performance decrement and symptoms such as fatigue, concentration problems and disturbed mood, eating and sleeping patterns. Kenttä et al.[2] reported the prevalence to be 48% in individual sports and 30% in team sports.

Based on the duration of performance decrement and severity of symptoms, recently new terminology has been proposed that divides OR in: functional overreaching (FOR) and nonfunctional overreaching (NFOR) [3,4]. FOR refers to performance decrement with a planned recovery period varying from days to weeks. If however, performance decrement lasts longer (weeks till months) and coincides with more severe symptoms as mentioned before, this is called NFOR. The overtraining syndrome (OTS) is the final stage of the continuum with documented recovery periods from months to years. Since the exact duration and severity of performance decrement and symptoms are not defined, a clear distinction between these three phases is still difficult to make.

Nowadays, FOR, NFOR and OTS are diagnosed, mainly based on exclusion.[3] This situation is unsatisfactory for athletes, coaches and sport physicians. Because long periods of rest cause deconditioning, athletes need to be confident about the diagnosis before they decide to temporarily stop training as part of a treatment.

Therefore, early detection of a disturbed stress-recovery balance is necessary to prevent athletes from unfavourable and unwanted signs and symptoms of OR and long periods of rest.

One of the consequences of a disturbed stress-recovery balance is hormonal dysfunction caused by maladaptation of the hypothalamic-pituitary-adrenal (HPA) axis [3,5-7]. It is well known that activation of the HPA axis results in increases in the blood levels of adrenocorticotropic hormone (ACTH), cortisol and prolactin (PRL), which is considered to be an adequate reaction of the human body to these stressful events [8]. De Vries et al. [9] observed in healthy subjects that after maximal exercise blood levels of ACTH, cortisol and PRL were significantly elevated compared to baseline rest values. If however, physical and psychosocial stress were combined with insufficient recovery over a relatively long period of time, it is assumed that maladaptation of the HPA axis can develop [10,11]. To investigate the hypothalamic-pituitary recovery capacity of FOR and NFOR athletes, recent research focused on the hormonal responses after a double maximal exercise bout on one day [10-12]. Based on these findings, different hormonal responses in subjects with FOR and NFOR could be observed, indicating a hypo- and hypersensitivity of the HPA-axis, respectively.

All previous mentioned studies are limited by a lack of objective parameters for performance decrement, related to the definition of OR by Meeusen et al. [3]. To prevent such a flaw in the study design, and to incorporate the normal seasonal variability in training-related and psychosocial stress and recovery, performance changes should be monitored longitudinally. In order to prevent athletes from serious health problems, research should focus on OR at an early stage. Furthermore, mood state should be assessed to confirm the characteristic symptoms. Therefore, the aim of this study was to prospectively monitor sport-specific performance changes and to assess mood state and the responses of ACTH, cortisol, and PRL to exercise in OR adolescent athletes and controls. We hypothesize that OR athletes, classified with a performance decrement lasting at least one month, can be distinguished from a control group by differences in mood state and hormonal responses to maximal exercise.

Methods

Subjects

Seventy-seven soccer players and 52 middle-long distance runners performed monthly sport-specific field tests during one competitive season (figure 1). Eight athletes with performance decrement lasting at least one month, i.e. measured at two consecutive field tests, were included (Age (years):16.9 ± 1.1, Height (cm) 174.6 ± 6.5, Body weight (kg) 70.4 ± 6.4; mean ± SD). The players competed at the highest national competition level in the Netherlands and belonged to the best 1% of players in their age category. Five times a week, they received a balanced training program by a professional coach with aerobic, speed, agility, technical and tactical aspects. In addition, players executed an individualised weight training program and played a match once a week. The control group consisted of seven healthy athletes: four middle-long distance runners and three soccer players (mean ± SD: Age (years): 18.7 ± 1.6, Height (cm) 183.0 ± 9.4, Body weight (kg) 68.7 ± 6.5). These seven healthy controls were matched for age category, body composition, training and performance level. The study was approved by the Central Committee on Research involving Human Subjects. All participants and both parents if participants were under-aged gave informed consent.

Interval Shutle Run Test (ISRT)

To determine performance changes in soccer players, a submaximal Interval Shuttle Run Test (ISRT) was used with sufficient reliability and validity [13,14]. The tests were performed every month on an artificial pitch at the start of the training as a substitute for the warm-up. All tests were performed after a rest day. Submaximal intensity was set at 70% of the maximal amount of runs at the start of the season. During the ISRT, players alternately ran for 30 seconds and walked for 15 seconds. Running speed increased from 10 $km \bullet h^{-1}$ every 90 seconds up to 15 $km \bullet h^{-1}$ depending on baseline maximal running performance. A fixed number of runs was used for every individual during an entire season. Heart rate was recorded at 5-s intervals (Polar, Kempele, Finland) and the average was calculated over the last 60 seconds of running. It was assumed that an elevated heart rate response indicated a state of overreaching [7,15]. Since variations in heart rate on an individual level during submaximal interval-based running is reported to be 3 ± 1 $b \bullet min^{-1}$ [16], players with a heart rate increase of ≥ 5 $b \bullet min^{-1}$ were included as OR .

Chapter 6 Mood state and hormonal responses to a repeated bout of maximal exercise as early markers for overreaching in adolescent elite athletes

Zoladz Test for runners

The Zoladz test proved to be a reliable and valid method of measuring performance capacity of runners [17]. During the test, subjects ran for 6 minutes in three heart rate zones (20, 30, and 40 beats per minute below maximal heart rate). To determine maximal heart rate, athletes performed an all-out 200 meter run at the start of the season. Between the 6-minute runs of the Zoladz test, the subjects walked for two minutes. The total distance in each zone was measured [17]. After the baseline test, which requires maximal effort, consecutive monthly tests were performed submaximal. Subjects with performance decrement of at least 5% at consecutive measurements compared with the baseline measurement were included [18].

Screening

All included athletes were invited to the laboratory one week after the field performance test for evaluation of mood state and hormonal responses to exercise. All athletes arrived 2 hours before the first exercise test at the sport medicine laboratory and received a standardised meal (approximately 71% CHO, 19% protein, 10% fat). Before participation to the maximal exercise test, a sports physician screened all athletes according to recent recommendations to exclude cardiovascular contra-indications (Lausanne protocol), as well as to exclude well-known causes of fatigue and performance decrement (e.g. viral infections, anemia, allergy, diabetes, hypothyreoidea) [3,19]. None of the athletes were excluded by this procedure. Since sport-specific performance changes were monitored prospectively and clinical inclusion occurred one week after the field test, we assumed that the physiological status of the included athletes was determined adequately. After this, the athletes with sport-specific performance decrement were classified as OR in accordance with the definition, proposed in the consensus statement [3]. Controls were considered as healthy athletes.

Mood state

Mood states of all included athletes were assessed prior to the screening with the shortened version of the Profile of Mood States (POMS), consisting of 32 items divided over 5 subscales: depression (8 items), anger (7 items), fatigue (6 items), vigor (5 items) and tension (6 items). Subjects rated to what degree statements correspond to their feelings on a 5 point scale, ranging from 0 = not at all to 4 = very much. The average score per items was calculated as outcome. This version of the POMS has sufficient reliability and validity [20].

Two bout exercise protocol

To evaluate hormonal responses to exercise a two graded incremental test to exhaustion on a treadmill separated by 3 hours of rest was performed as a repeated stress test. To reduce the influence of diurnal variation in hormonal responses, the first test was always performed between 13.30 and 14.00 hours. A sports physician supervised all exercise tests.

All included players started with a 3 minute warm-up at 8 km•h^{-1}. Every 2 minutes, the speed increased by 1 km•h^{-1} starting at 10 km•h-^{1} until volitional exhaustion. Heart rate was monitored continuously at 5-sec intervals using a sports tester (Polar, Kempele, Finland). To match the time to exhaustion, distance runners ran at a slightly higher speed. Adjusted to their sport, they started with a 3-minute warm-up at 10 km•h^{-1}. After that, every 1.5 minutes, speed increased by 1 km•h^{-1} starting from 12 km•h-^{1}.

Blood samples drawn from an antecubital vein were collected in Dickinson vacutainer tubes (Becton Dickinson, Franklin Lakes, NJ, USA) before and immediately after both exercise tests. SSTII tubes were used for cortisol and PRL, K2E EDTA tubes for plasma ACTH which were immediately stored on ice and transported to the hospital laboratory for further analysis. Cortisol and PRL samples were analysed by radio-immuno-assay and ACTH by chemiluminescence-immuno-assay.

Statistical analysis

Statistical analyses were performed with SPSS 16 (SPSS Inc., Chicago, IL). Mann-Whitney tests were used to assess differences in POMS scores, maximal heart rate and time to exhaustion between OR athletes and controls. Hormonal responses were analysed using ANOVA for repeated measures, with group (OR or control) as between-subject factor and test (first and second exercise bouts) and time (pre- or post test) as within-subject factors. Significance level was set at $p<0.05$.

Results

The OR soccer players showed, with a fixed number of runs at the ISRT, a mean increase in heart rate response of 10 ± 5 b•min^{-1} compared to baseline. Average heart rate at time of inclusion was 182 ± 11 b•min^{-1}. The middle-long distance runner showed an 8% performance decrease in zone 1 (1050 m at baseline and 970 m after two consecutive monthly tests) compared with a 3% increase in the control runners. The OR athletes reported significantly more feelings of depression and anger compared to the control group (figure 1). No significant differences were found in the other subscales of the POMS.

Chapter 6 Mood state and hormonal responses to a repeated bout of maximal exercise as early markers for overreaching in adolescent elite athletes

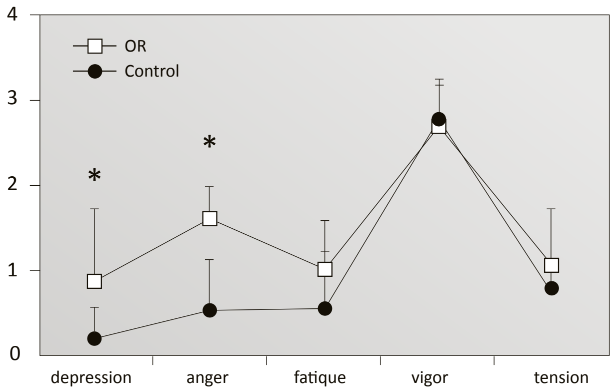

Figure 1. Scores of the shortened version of the Profile of Mood States (mean±SD) in the overreached (OR) and control group. * P<0.05

Mean time to exhaustion in the OR group was 1096 ± 133 s during the first and 1062 ± 168 s during the second exercise test with a mean heart rate of 189 ± 12 and 191 ± 11 b•min^{-1}, respectively. Mean time to exhaustion in the control group was 1155 ± 126 s after the first and 1124 ± 84 s after the second exercise test. Mean heart rate was 197 ± 11 and 194 ± 11 b•min^{-1}, respectively. No significant differences were found in maximal heart rate and time to exhaustion between the first and second exercise bout, nor between groups. Figure 2 shows the results of the hormonal responses to a repeated bout of maximal exercise in the OR and control group.

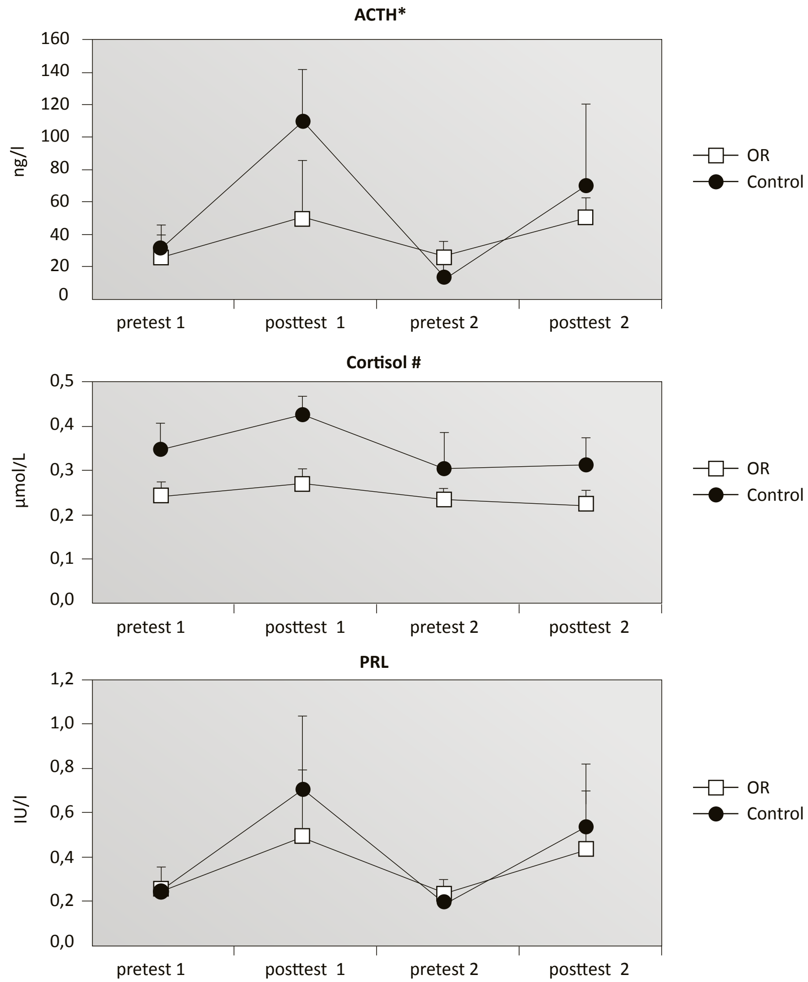

Figure 2. Responses of ACTH, cortisol and PRL (mean±SEM) to a repeated bout of maximal exercise in the overreached (OR) and control group. * p<0.05 interaction effect time x group, indicating a supressed ACTH response in the OR group
# p<0.05 between-subjetcs effect, indicating that overall cortisol levels were lower in the OR group.

Chapter 6 Mood state and hormonal responses to a repeated bout of maximal exercise as early markers for overreaching in adolescent elite athletes

There was a significant main effect of time only for ACTH ($F_{1,13}$=56.75, P<0.001) and PRL ($F_{1,13}$=27.92, P<0.001), indicating elevated post test concentrations compared with pre test values. Furthermore, a main effect of test was found for ACTH ($F_{1,13}$=7.89, P=0.015), indicating higher levels at the first compared to the second exercise test. Between-subjects tests revealed that overall cortisol levels were significantly lower in the OR group compared to the control group ($F_{1,12}$ = 6.24, P=0.027). No between-subjects effects were found in overall ACTH and PRL levels. The interaction effect time x test revealed no significant differences, indicating that there were no differences in responses between the first and second exercise test. The interaction effect time x group showed a significant lower ACTH response in the OR group compared to the control group ($F_{1,13}$=9.94, P=0.008). Finally, three-way interaction (test x time x group) showed no significant differences in hormonal responses during the first and second test between both groups.

Discussion

Our hypothesis that OR athletes classified with an objective performance decrement for at least one month can be distinguished from a control group by mood state and hormonal responses to exercise was confirmed.

In contrast to previous studies, we compared mood state and hormonal responses to exercise between OR athletes and controls based on objective performance parameters at an early stage. The suppressed responses of ACTH and low cortisol levels in OR athletes indicate a maladaptation of the HPA-axis to exercise. Consistent with findings of Meeusen et al. [10], PRL responses did not significantly differ between both groups. Although, performance decrement is considered to be the most important aspect of OR [3], additional information from the POMS and hormonal responses may indicate a real disturbed stress-recovery balance. The OR athletes reported more feelings of depression and anger, which has been reported previously as sensitive subscales for OR in soccer [21,22]. Concerning the observed hormonal responses, we do not know whether the OR group in the present study can be classified as FOR or NFOR. Because we did not have the opportunity to retest our OR athletes, it remains unclear when hormonal responses were normalized. Based on our results, it would be necessary for future research to repeat monitoring and testing procedures in order to know when performances, mood state, and hormonal responses to exercise will normalize. This might also provide useful information to distinguish between FOR and NFOR.

For a number of reasons we evaluated in this study changes in submaximal instead of maximal performances by using heart rate registration. First, maximal testing on a monthly basis during a whole season interferes too much with the training schedule of coaches. Second, with such maximal measurements lack of motivation can negatively influence performance outcome. However, during a submaximal test procedure one should be aware of additional factors that may influence heart rate responses. It is known that physical and psychological stress as well as dehydration caused by high temperature can increase heart rate [23,24]. In this study all athletes were tested after a rest day. As the submaximal tests were performed at the beginning of the training, effects of physical stress and dehydration caused by high temperature can be excluded. Although an increase of 5 b•min^{-1} during the ISRT seems to be a small difference for categorization of our groups, variations in heart rate were reported to decrease when submaximal intensity increases [16]. An average heart rate at the time of inclusion was 182 b•min^{-1}, which corresponds to 85 – 90 % of the maximal heart rate. This intensity showed indeed the least variations [16]. Therefore, our cut-off score of an increase of 5 b•min^{-1} is significant, especially when a decreased heart rate as a result of regular training could be expected. Furthermore, the real heart rate increase of our OR players turned out to be higher than 5 b•min^{-1} with a minimum of 8 b•min^{-1}.

Evaluating performance with a submaximal test could have been one of the explanations for the small number of athletes included. Submaximal tests are considered as less sensitive to performance changes than maximal tests [25]. In addition, several athletes with performance decrement could not participate in the laboratory study because of international matches, school exams and injuries. Unfortunately, small numbers of subjects in overtraining studies are not uncommon [10-12]. This can also be explained by the fact that inducing OTS is ethically unacceptable.

In the present study we assumed that an elevated heart rate response at a fixed number of runs indicated OR [7,15]. However, lower heart rates and equal heart rates at submaximal exercise have also been reported in OR [7,26]. This might be an indication for a selection bias in the present study. We postulate that the reported mood states and hormonal responses to exercise support the diagnosis of OR. Nevertheless, further research is needed to explore if similar mood states and hormonal responses are present in subjects with equal or lower submaximal heart rate responses over time.

Several studies show a great variability in blood levels of ACTH, cortisol and PRL before and immediately after exercise [9,10,12,27]. These differences can partially be caused by the effects of diurnal variations. In the present study exercise tests were performed in the afternoon, mainly because participants were not able to arrive at the lab in the morning due to travel time and school obligations. It can be argued that in this way more reliable results can be obtained, because hormonal variability is smaller in the afternoon compared with morning values [28-30].

Chapter 6 Mood state and hormonal responses to a repeated bout of maximal exercise as early markers for overreaching in adolescent elite athletes

Practical Applications

The combination of performance decrement and negative mood state is indicative for OR in soccer and can be used by coaches and athletes. Feedback is needed on a regular basis to identify when a player is at risk. If necessary, coaches can adapt the training schedule or use interventions in which athletes are learned to better cope with stress or enhance recovery related activities. The altered hormonal responses as result of a dysfunction of the HPA axis can support sport physicians in their diagnosis. Finally, sport scientists should focus on monitoring sport and non-sport stressors and recovery related activities over the course of a season, to see if this can prevent athletes from unfavourable and unwanted signs and symptoms of overreaching in the first place.

Conclusions

We conclude that OR athletes, classified with objective performance decrement have a negative mood state and a lower ACTH response after a repeated bout of exercise compared to healthy controls. Furthermore, they have lower overall cortisol levels before and after exercise. This information provides coaches and sport physicians with early markers about changes in the training status of adolescent athletes, which can be helpful in preventing them for unfavourable and unwanted signs and symptoms of overreaching.

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Chapter 7 90-91

Is psychomotor speed also an early marker for overreaching in soccer players?

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Abstract

The aim of the present study was to find early markers for overreaching that are applicable in sport practice. In a group elite soccer players aged 15-18, the stress-recovery balance and reaction times before and after exercise were assessed.

Overreaching was characterized by a sport-specific performance decrement (Interval Shuttle Run Test), which was prospectively monitored by means of monthly field tests during two competitive season. Out of 94 players, 7 overreached players could be included in the study, together with 7 controls, matched for age, body composition, training and performance level. The stress-recovery balance was assessed with the Dutch version of the recovery stress questionnaire (RESTQ-sport). The overreached soccer players reported a disturbed stress-recovery balance (Mann-Whitney test, $p<0.05$). An ANOVA for repeated measures of reaction times revealed a significant main effect of time ($F_{1,12} = 13.87$, $P < 0.01$) indicating an improvement of psychomotor speed. No differences between groups were found. We conclude that overreached soccer players, share a disturbed stress-recovery balance, but they could not be distinguished from controls based on reaction time after a strenuous exercise. Although reaction time as early marker for OR has potential, this could not be confirmed in our study.

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Chapter 7 Is psychomotor speed also an early marker for overreaching in soccer players?

Introduction

For long, researchers, athletes, coaches and sports physicians have been searching for early markers of overreaching (OR) [1]. It is assumed that an early detection of OR might prevent athletes from overtraining syndrome (OTS) [2]. Characteristic symptoms of OR such as fatigue, disturbances in perception, coordination and concentration problems have led to the introduction of reaction time as possible marker to recognize OR at an early stage [3-5]. This idea was supported by findings of psychomotor slowness in patients with chronic fatigue syndrome and major depression, showing symptoms and hormonal dysfunction similar to OR [4,6-9]. Nederhof et al. (2006) proposed that psychomotor speed might be such a marker. Measuring reaction time certainly has some advantages over other early markers. A reaction time test is objective, applicable in training practice, not to demanding for athletes, and can be performed on a regular personal computer [4].

A few studies investigated reaction times in OR so far [3,9-11]. In two studies OR was induced in well trained cyclists by increasing training load during a training camp [3,10]. Both studies showed longer reaction time in the OR group compared to a control group. Consistent with these findings Nederhof et al. (2008c) found longer reaction times in a clinically diagnosed OR ice skater. Furthermore, it has been shown that psychomotor slowness is related to reduced perceived performance in varsity rowers over the course of a season [11].

In the present study we hypothesize that assessing reaction time immediately after maximal exercise enlarges differences between healthy and OR athletes. It is known that acute exercise facilitates choice reaction times in healthy athletes [12-16] and is associated with activity of the sympathoadrenal system and the hypothalamic-pituitary-adrenal axis [17]. Recent studies have shown that neuroendocrine differences between healthy and OR athletes become apparent after acute exercise [18]. This lead to the hypothesis that acute exercise would also enlarge the difference in reaction time between healthy and OR athletes.

Since it is ethically unacceptable to induce OTS, overtraining studies usually include athletes who are clinically diagnosed. In order to prevent athletes from OTS, research is needed that focuses on the earliest stages of OR. Inducing fatigue with a short intensified training period, such as a training camp, seems a valid alternative. However, these studies do not incorporate the normal seasonal variability in training-related and psychosocial stress and recovery. Furthermore, inducing fatigue does not necessarily lead to performance decrement, which is considered to be the hallmark of OR [2]. Therefore, longitudinal research is needed that monitors performance changes in a large sample of athletes, in order to detect the onset of OR. Finally, stress and recovery should be assessed to confirm a disturbed balance as the cause of OR.

In the current study we applied such a design and monitored performance changes in elite youth soccer players with a monthly graded exercise test. In this way we were able to include OR soccer players at an early stage. The aim of this study was to prospectively monitor sport-specific performance changes and to assess the stress-recovery balance and reaction time to exercise. We hypothesized that OR soccer players classified with objective performance decrement, can be distinguished from a control group by a disturbed stress-recovery balance and slower reaction time before and after a maximal bout of exercise.

Methods

Subjects

During the 2006-2007 and 2007-2008 competitive seasons a total of 94 players were monitored, for at least one season. All subjects had played for several years at the highest level in the Netherlands and followed a balanced training program which was set by a professional coaching panel. The players were considered to be in the best 1% of players in their age category. The training program consisted of aerobic, speed, agility, technical and tactical training. The players also completed an individualised resistance training program once per week. At the time of the study the national soccer team was ranked 3rd in the world by FIFA world demonstrating the high performance level of soccer in the Netherlands. Soccer players with performance decrement, i.e. measured at two consecutive field tests, were invited to the sports medicine laboratory for medical follow-up (figure 1). Seven players with performance decrement were included (mean ± SD: Age (years) 17 ± 1, Height (cm) 174.6 ± 6.51, Weight (kg) 71.4 ± 6.05), together with seven controls (mean ± SD: Age (years) 17 ± 1, Height (cm) 178.9 ± 5.44, Weight (kg) 68.9 ± 7.17). The study was ethically approved by the Central Committee on Research involving Human Subjects. All participants (and both parents of under-aged participants) gave informed consent.

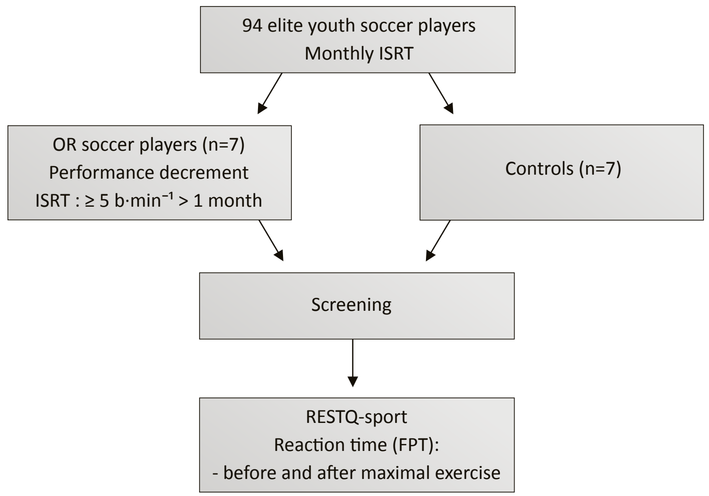

Figure 1. Flowchart study design, OR: overreached; ISRT: Interval Shuttle Run Test; RESTQ-sport: Recovery Stress Questionnaire; FPT: Finger Pre-cuing Task.

Chapter 7 Is psychomotor speed also an early marker for overreaching in soccer players?

Interval Shuttle Run Test

To determine performance changes in soccer players, a submaximal Interval Shuttle Run Test (ISRT) with sufficient reliability and validity was used [19,20]. The tests were performed every month on an artificial pitch at the start of the training as a substitute for the warm-up. All tests were performed after a day of rest. Submaximal intensity was set at 70% of the maximal amount of runs at the start of the season. During the ISRT, players alternately ran for 30 seconds and walked for 15 seconds. Running speed increased from 10 km•h^{-1} every 90 seconds up to 15 km•h^{-1} depending on baseline maximal running performance. A fixed number of runs was used for every individual during an entire season. Heart rate was recorded at 5-s intervals (Polar, Kempele, Finland) and we calculated the average over the last 60 seconds of running. Since variations in heart rate on an individual level during submaximal interval-based running is reported to be 3 ± 1 bpm [21], players with a heart rate increase of ≥ 5 bpm were included as OR. An elevated heart rate response at two consecutive months indicated a state of OR [8,22].

Medical Screening

All injuries and/or illnesses were closely assessed and recorded by the club's medical staff (i.e. physicians and physical therapists) according to the FIFA registration system (Fuller et al., 2006). An injury was defined as any physical complaint sustained by a player that resulted from match play or training. Injuries were recorded if a player received medical attention for more than one day or was unable to take part in training or were ineligible for selection for matches. An illness was defined as a circumstance in which the player felt that they were limited or unable to perform normal training or match (e.g. flu, cold, virus, etc.). The soccer players (N=7) who presented with abnormal heart rate response to the submaximal ISRT were included in the study, together with controls (N=7) who did not suffer from illness and injury along and also had a normal heart rate response (Brink et al. 2010). All players were invited to the laboratory, one week after the field performance test, for medical follow-up. A sports physician followed previous recommendations for athlete screening to exclude cardiovascular contra-indications, as well as to exclude other well-known causes of fatigue and performance decrement (e.g. viral infections, anaemia, allergy, diabetes, hypothyreoidea) (Uusitalo, 2001;Meeusen et al., 2006). No players were excluded after these screening procedures. The soccer players with and altered response to the sport-specific performance test were diagnosed as being OR.

Recovery Stress Questionnaire (RESTQ-Sport)

The Dutch version of the RESTQ-Sport was administered to assess the psychosocial stress-recovery state of players. The RESTQ-Sport consists of general and sport-specific stress and recovery categories. Each player was instructed to rate the 77 items on a Likert-type scale, with anchors of 0: never and 6: always, indicating how often he participated in recovery and stress related activities during the last 4 weeks [23]. High scores on the stress-associated scales reflect subjective stress, whereas high scores on the recovery-oriented scales represent recovery activities. The stress-recovery state was calculated as the sum of the recovery scores minus the sum of the stress scores [24-26]. Nederhof et al. [27] showed that the Dutch RESTQ-Sport had sufficient reliability and validity for use in sports practice and research.

Maximal exercise protocol

The OR and control soccer players were invited to the laboratory within one week after the field performance test. They were not allowed to eat or consume products containing caffeine 2 hours before the first exercise test. A graded incremental exercise test until exhaustion on a treadmill was performed. The tests were performed between 13.00 and 18.00 hours. The soccer players started with a 3 minute warm-up at 8 km•h^{-1}. Every 2 minutes, speed increased by 1 km•h^{-1} starting at 10 km•h^{-1}. Heart rate was monitored at 5-sec intervals using a sports tester (Polar, Kempele, Finland). A sports physician supervised all exercise tests.

Finger Pre-cuing Task

Reaction times were measured using the Finger Pre-cuing Task (FPT) [28] before and after the maximal exercise test. Subjects responded to stimuli displayed on a computer screen with button press responses by index and middle fingers of both hands (the two left most and two right most). Stimuli were plus (+) signs shown in the middle of the computer screen. The stimulus display consisted of a warning signal, a cue signal and target signal. The warning signal was a row of four plus signs. After a preparation interval of 500 ms, the target interval appeared on the computer screen in a position indicated by the cue. The target signal consisted of one plus sign indicating the final cue location. Four pre-cue conditions were distinguished. In the uncued condition the cue signal consisted of four plus signs in all four positions, preventing the possibility of selective response preparation. In the hand cued condition, the cue signal consisted of two plus signs at the two left most or two right most positions, indicating the middle finger and index finger of the left hand or the right hand respectively. In the finger cued condition the cue signal consisted of two plus signs at the two outer or the two inner positions, indicating the two middle fingers or two index fingers. In the neither cued condition the cue indicated the middle and index finger of different hands. An inter trial interval of 1000 ms separated the response from the start of the next trial. Subjects were familiarized with the FPT and performed 10 practice trials before each test session. A test session consisted of 160 trials. Mean reaction times were calculated for each cue condition. Incorrect responses as well as reaction times shorter than 150 ms or longer than 1000 ms were omitted in the calculation of mean reaction time.

Statistical Analysis

Statistical analyses were performed with SPSS 16.0 software (SPSS Inc., Chicago, IL). Mann-Whitney tests were used to analyse differences in stress, recovery and the outcome measures of the maximal exercise protocol, between OR soccer players and controls. Reaction times were analysed using ANOVA statistics for repeated measures, with group (OR or control) as between-subject factor and time (pre- or posttest) and finger pre-cuing condition (uncued, handcued, finger cued and neither cued) as within-subject factors. T tests were used for post-hoc analyses with Bonferoni correction for multi comparison. Significance level was set at $p < 0.05$.

Chapter 7 Is psychomotor speed also an early marker for overreaching in soccer players?

Results

Field test performance and maximal exercise protocol

The OR soccer players showed, with a fixed number of runs at the ISRT, a mean increase in heart rate of 9 ± 1 b•min^{-1} (range 8-11) compared to baseline. No significant differences were found in mean time to exhaustion and maximal heart rate during the maximal exercise test in the OR group (17:36 ± 2:13 min, 188 ± 12 b•min^{-1}) and the control group (17:31 ± 2:22 min, 199 ± 6 b•min^{-1}).

Stress and recovery

The OR soccer players showed a tendency to have higher stress and lower recovery scores, for both general and sport-specific categories (figure 2). The stress-recovery state was significantly lower for the OR soccer players compared to controls indicating a disturbed balance.

Reaction times

Table 1 displays mean ± std reaction times [ms] of the uncued, hand cued, finger cued and neither cued condition pre- and posttest of OR and control soccer players. There was a significant main effect of time ($F_{1,12}$ = 13.87, $P < 0.01$) indicating shorter reaction times posttest compared to pretest. Furthermore, a main effect of finger pre-cuing condition ($F_{3,36}$ = 22.43, $P < 0.001$) was found, indicating different reaction times between the four conditions. Post hoc t test revealed that reaction times were slowest during the uncued and neither cued condition followed by the finger cued condition. Reaction times were fastest during the hand cue condition. None of the interaction effects that included group were significant. Finally, between-subjects tests revealed no overall differences in reaction time.

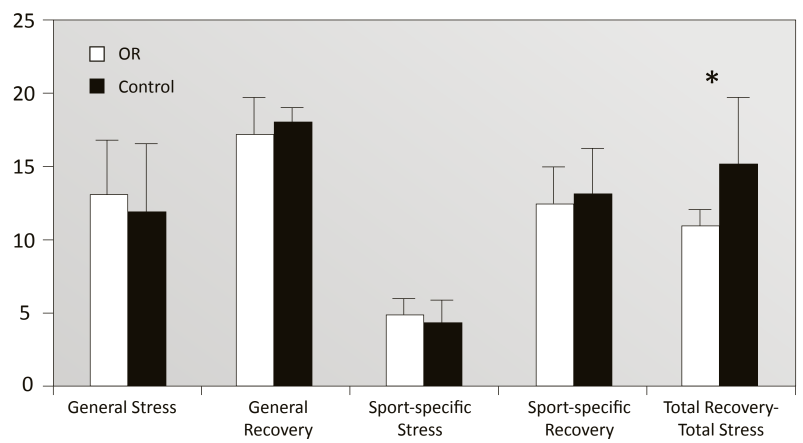

Figure 2. General and sport-specific stress and recovery in overreached (OR) soccer players and controls. * P < 0.05.

Table 1. Mean ± SD reaction times [ms] of the uncued, hand cued, finger cued and neither cued condition pre- and posttest of overreached (OR) and control soccer players. * p < 0.01 between pre- and posttest in both groups # p < 0.001 between cue conditions in both groups.

		Uncued #	Hand cued	Finger cued	Neither cued
Pretest	OR	470 ± 72	420 ± 54	446 ± 58	480 ± 77
	Control	445 ± 57	412 ± 81	434 ± 89	471 ± 76
Prosttest*	OR	423 ± 32	371 ± 29	390 ± 29	418 ± 46
	Control	441 ± 65	378 ± 46	402 ± 66	420 ± 75

Discussion

In this study we hypothesized that OR soccer players, classified with objective performance decrement, can be distinguished from a control group by a disturbed stress-recovery balance and slower reaction times before and after a maximal exercise bout. In this study the key criteria for diagnosing OR were a large increase in heart rate during the submaximal ISRT, and the absence of underlying illness or injury. These criteria are included in the European College of Sports Sciences Position Statement on the 'Prevention, diagnosis and treatment of Overtraining Syndrome' [2] and have previously been reported [29,30]. The fact that objective performance decrement as a hallmark of OR coincides with a disturbed stress-recovery balance, is in line with previous research that consistently showed that subjective ratings of stress and recovery are sensitive for recognizing OR in team sport at an early stage [26,31]. Although in this study coaches were not provided with feedback, a possible limitation of psychometric questionnaires such as the RESTQ-Sport is that the responses can be manipulated by players. Especially when applied in team sports, the outcome of subjective measures may be influenced by fear of players to be deselected from the team. Therefore, an objective measure such as reaction time is warranted. The fact that we did not find signs for psychomotor slowness could be explained by the way players were included in this study. Previous research included OR athletes in three different ways. First after a training camp, second by monitoring perceived performance and third by clinical diagnosis. This means that the athletes were included in different stages on the overtraining continuum with symptoms varying in duration and severity. The second explanation is the type of reaction time task used. We choose to use the FPT because it has proven to be sensitive to short term OR after a training camp [10]. Furthermore, this simple task meets the requirements for early detection of OR [4].

Chapter 7 Is psychomotor speed also an early marker for overreaching in soccer players?

It is applicable in training practice, not to demanding for athletes, and can be performed on a regular personal computer. However, the FPT is not a sport-specific task. Future research should use a sport-specific reaction time task without violating the requirements of an usable marker for OR. In line with previous literature, subjects produced shorter reaction times after exercise [12-16]. In addition, the fastest reaction times were performed at the hand and finger cue condition, respectively [3,10,11,32]. Given that the uncued condition is the most sensitive for OR, we expected that the OR soccer players would produce slower reaction times especially in this condition [3,10]. We hypothesized that this effect would be enlarged by the facilitating effect of maximal exercise. However, this could not be confirmed. Apparently, the FPT lacks sensitivity to detect changes in training status in soccer players, even if performance is monitored objectively and with the facilitating effect of maximal exercise.

Since sport-specific performance was monitored prospectively and clinical inclusion occurred one week after the field test, the physiological status of the OR athletes was determined adequately. This was confirmed by the disturbed stress recovery balance and previous research, in which we found altered hormonal profiles and negative mood state with the same methodological approach [29]. Although there were no significant differences in maximal heart rate and time to exhaustion during the incremental exercise test, the maximal heart rate of the OR soccer players tended to be lower. This is in line with the recently published review of Bosquet et al. [33] who reported that maximal heart rate is decreased during OR. In this study, we evaluated changes in submaximal instead of maximal performances by means of heart rate registration. Firstly, maximal testing on a monthly basis during a whole season interferes too much with the training schedule of coaches. Secondly, with such maximal measurements a lack of motivation can influence performance outcome negatively. However, during a submaximal test procedure one should be aware of additional factors that may influence heart rate responses. It is known that physical and psychological stress as well as dehydration caused by high temperature can increase heart rate [34,35]. In this study all players were tested after a rest day. As the submaximal tests lasted between 9 and 12 minutes and were performed at the beginning of the training, effects of physical stress and dehydration caused by high temperature can be excluded. Although an increase of 5 bpm seems to be a small difference for categorization of our groups, variations in heart rate were reported to decrease when submaximal intensity increases [21]. An average heart rate at the time of inclusion was 187 bpm, which corresponds to 85 – 90 % of the maximal heart rate. This intensity showed indeed the least variations [21]. Therefore, our cut-off score of an increase of 5 bpm is significant, especially when a decreased heart rate could be expected as a result of regular training.

We conclude that OR soccer players with an objectively determined performance decrement lasting at least one month, show a disturbed stress-recovery balance, but similar reaction time before and after exercise compared with controls. Although reaction time as early marker for OR has potential, this could not be confirmed in our study. We emphasize that research should measure objective performance over the course of a season to incorporate seasonal variability. Furthermore, a sport-specific reaction time task should be used without violating the requirements of an usable marker for OR.

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General discussion and conclusion.

General discussion

The first aim of the present thesis was to investigate whether stress and recovery are related to performance, injuries, illnesses and overtraining. The second aim was to find markers that can be used in sports practice for the early detection of overtraining.

To achieve these goals we prospectively monitored 94 young elite soccer players and 52 middle long distance runners using a multidisciplinary approach. Athletes filled in daily-logs and monthly questionnaires measuring both physical and psychosocial stress and recovery. These measures were compared to performance and health related problems. Finally, clinical measurements were carried out in overreached (OR) athletes and controls to assess both hormonal responses and choice reaction time to exercise.

Summary of main findings

With respect to the first aim, we concluded in Chapter 2 that the duration of training and game play in the week prior to field test performance was most strongly related to interval endurance capacity. The more time players spent training and playing matches the better they performed on the monthly field tests. Furthermore, we have seen in Chapter 3 that the likelihood of becoming injured or ill also increased with higher training load. In addition, psychosocial stress and recovery were associated with illnesses. Although self-reported intensity scores were important in relation to injuries and illnesses, this could not be confirmed when related to performance on the submaximal ISRT. In Chapter 4, we found that a disturbed stress-recovery balance also precedes the onset of OR. Monitoring both physical and psychosocial stress and recovery may help to optimize performance and prevent a local or general overload. Chapter 5 addressed the reliability and validity of the Dutch Recovery-Stress Questionnaire

Chapter 8 General discussion and conclusion

for Athletes (RESTQ-Sport). This questionnaire showed sufficient reliability and validity for use in both sports practice and research settings.

With respect to the second aim, Chapter 6 described the relevance of mood state and hormonal responses to a double bout of exercise as early markers for OR. OR athletes scored higher on the depression and anger score of the profile of mood state (POMS). Furthermore, they showed a blunted ACTH response to exercise and overall lower cortisol levels. Chapter 7 explored the usefulness of reaction time before and after exercise to detect OR. Although the OR players indeed reported a disturbed stress-recovery balance, no differences in reaction time before and after exercise where found.

Theoretical considerations

The model of Kenntä & Hassmén [1] contains both physical and psychosocial stress and recovery components. In line with this model, the present thesis showed that monitoring should not only focus on physical aspects of training, but also include psychosocial factors. This multidimensional approach is essential to understand the delicate stress-recovery balance, enhance performance, and prevent athletes from a local or general overload. It is suggested that the inter-individual differences in susceptibility depend on the capacities of the athlete. In this thesis we assumed that the capacity of the athletes is implicitly integrated in the self-reported ratings. One with a low physical capacity would rate a similar training as more exhausting, compared to an athlete with a high physical capacity. This also accounts for the other psychological/social stress and recovery factors.

Within this delicate stress-recovery balance subtle differences between physical and psychosocial aspects are likely to exist. For example, it can be argued that physical aspects dominate in cyclic endurance sports, whereas in team sport psychosocial aspects are more important. Even within the same type of sport, individual differences in physical and psychosocial stress and recovery were presented in this thesis. This could be one explanation for why the underlying mechanism is difficult to examine. The mechanisms explaining OR are believed to have peripheral and/or central origins. The cytokines hypothesis explains overtraining from a peripheral perspective [2]. It links excessive training to repetitive tissue trauma, leading to acute and chronic inflammation. The cytokines interact with the central nervous system and result in activation of the hypothalamic-pituitary-adrenal (HPA)–axis, causing sickness behaviour. The disturbed hormonal responses to exercise as described in Chapter 6 are based on the central fatigue hypothesis. The disturbed hormonal responses are assumed to be caused by exhaustion of the HPA-axis. The HPA-axis in turn, is under the control of higher brain centres and neurotransmitters such as serotonin and dopamine [3]. Dysfunctions of these systems are associated with feelings of fatigue, depression and sleep disturbances. These feelings were indeed reported by the OR athletes.
The underlying mechanism of psychomotor slowness also needs to be unravelled. Little is known about the origin of the psychomotor slowness. Although in our study psychomotor slowness could not be confirmed in OR players, previous work indicated that longer reaction times might be caused by peripheral processes [4]. On the other hand, recent work showed altered EEG

coherence in OR athletes pointing into the direction of a central origin [5]. Taken together, peripheral and central mechanisms, such as immunological and neuroendocrine, probably interact and perhaps depend on the specific dominating factor that is causing the disturbed balance. These factors may trigger specific systems in order to restore the internal homeostatis.

Limitations and recommendations for future research

In the present thesis we adopted a multidisciplinary approach and prospectively monitored athletes' stress and recovery. The main advantage of this design is that the exposure variables (stress and recovery) occur before the onset of changes in performance and health related problems. In addition, these variables are measured in the real environment at the individual level. Therefore, this thesis adds to the current body of knowledge as presented in Chapter 1. However, some limitations need to be discussed.

A limitation of a repeated measurement design is that it may interfere with the daily training routine of coaches and athletes. In addition, repeated measurements can result in missing data caused by motivational problems. Chapter 6 presented a clinical study with soccer players and middle-long distance runners. A limitation of this study was that soccer players and distance runners were unequally divided over the case and control groups. Unfortunately, we were not able to include a sufficient number of healthy soccer players during the competitive season as the clinical protocol interfered too much with the training program. Evidence for sport-specific differences in hormonal responses to exercise is not available, therefore cannot be excluded. Although the number of athletes in each group were limited in this study, we did not find any evidence that the type of sport influenced the main outcome. This is supported by the normal mood state of the athletes in the control group and their hormonal response to exercise. In Chapter 7 we studied psychomotor speed with a simple computerised task as this could be very suitable for repeated measurements. In contrast to previous studies, that used reaction time as marker for OR in endurance sports, we did not find differences in OR soccer players and controls. One of the reasons might be, that the Finger Pre-cuing Task is not a sport-specific task.

In this thesis performance changes were measured using submaximal field tests, predominantly measured with the Interval Shuttle Run Test (ISRT). It can be argued that this test reflects physiological changes of fitness, but does not measure real match performance. It is known that distance covered during such a test is related to physical characteristics during matches such as, distance covered, time spent at high intensity and number of sprints [6-8]. These factors are considered as causal indicators of performance, as they indeed are related to the FIFA ranking list [9]. However, to confirm this causal relation, we need to know if improving physical performance would lead to a higher ranking [10]. Furthermore, we do not know if changes in submaximal ISRT performances reflect changes in physical performance during matches in a similar way. With the development of accurate video, GPS and electronic player tracking technologies like LPM [11], it can be expected that future research

Chapter 8 General discussion and conclusion

will focus on more detailed monitoring of physical and tactical performance in the real environment during training and match settings.

The inclusion of OR players, was based on a heart rate cut off score of ≥ 5 beats•min^{-1}. The altered hormonal response, unfavourable mood state and changes in the stress-recovery balance support that this cut off score is sensitive to detect OR. However, it is possible that we may have missed cases below this cut off score. Additionally, lower heart rates and equal heart rates at submaximal exercise have been reported in OR too [12,13]. Further research is warranted to explore the responsiveness of the submaximal ISRT.

Monitoring changes in 'physical' performance to detect OR may seem obvious since fatigue and the inability to complete training sessions are well known symptoms. In addition, research on overtraining predominantly focused on endurence sports with a strong physical component [14]. A number of physiological markers have been proposed based on these studies. However in team sports, tactical and technical aspects are also important. These constructs may provide new insights to detect OR at an early stage. Symptoms such as concentration problems and fatigue combined with the possibility of psychomotor slowness, suggest that tactical and technical aspects become likely markers to detect OR. Technical performance, for example could be measured with a simple dribble [15,16] or pass tests in conjunction with a cognitive task [17]. Technical performance could also be assessed with notational analyses in a real match situation, counting successful and unsuccessful activities (i.e. passing).

Finally, we were not able to compare session-RPE and TQR scores between OR and control soccer players, because of missing values. It would be interesting to investigate if these self-reported ratings are able to identify soccer players at risk of OR at an early stage. In particular, little is known about the TQR score. Since the introduction of this score by Kenntä & Hassmén in 1998, only two studies have used this score in relation to performance [18,19]. Evidence for the validity of the TQR score is still lacking. Similar to the validation of the session-RPE, research is needed that compares TQR scores with other physiological measures of recovery, for instance before and after a training camp. The fact that recovery is an important factor is supported by the results from the RESTQ-Sport presented in Chapter 3 and Chapter 4. Several scales (Being in Shape, General Well-being, Sleep Quality and Physical Recovery) proved to be sensitive in the earliest stages of OR as well as in relation to illnesses. This underscores the idea that attention should not solely focus on training, but also on recovery. The question that now arises is, can players benefit from recovery modalities to optimize performance and prevent them from maladaptation? Research on recovery modalities mainly focused on recovery between training sessions (for extensive review see: [20]). So far, there is little to no evidence to support the use of recovery modalities, such as massage, active recovery, stretching. Less is known on recovery at other stages on the overtraining continuum, i.e. FOR, NFOR and OTS. As a consequence, it is still unclear whether OR athletes need to reduce stress, improve recovery or apply a combination of both.

Conclusion and implications

This thesis demonstrated that physical and psychosocial stress and recovery are associated with sport performance and health related problems, such as injuries, illnesses and overtraining in soccer players and middle-long distance runners. Monitoring stress and recovery may help to optimize performance and prevent a local or general overload. Clinical measurements showed that mood state and hormonal responses to a double maximal exercise protocol provided valuable information to confirm the diagnosis of overtraining. The usefulness of reaction time as potential marker could not be confirmed.

Based on the results of this thesis, trainers, coaches and medical staff may consider monitoring the duration of training and matches and the psychosocial stress-recovery balance state, and possibly also the training load, monotony and strain of each individual athlete. Because of the large variations between athletes in stress and recovery, the individual differences over time are most important in relation to injury or illness prevention. Therefore, trainers need to get feedback on individual basis to identify when an athlete has an increased injury or illness risk. If necessary, they can possibly adapt the training schedule or use interventions in which athletes are taught to cope with stress or enhance recovery related activities. Therefore, coaches and sport scientists should identify the athlete's individual threshold in order to optimize performance and prevent a local or general overload. One of the challenges for sport scientists, coaches and athletes is to find the optimal frequency of measurements. However, from a sport science perspective, intervals between measurements should be short to provide a sufficient level of detail. From a practical point of view, the burden of daily-logs, questionnaires and testing should be minimal. Finding an optimal balance between the two is critical for successful implementation. In the case of unexplained performance decrement, the exclusion of other pathology served as the gold standard for the diagnosis of OR. The findings presented in this thesis show that diagnosis of OR can also be supported by other methods. To confirm this diagnosis, sports physicians may use the profile of mood state to verify a negative mood. Likewise, the Recovery-Stress Questionnaire for Athletes can be used to verify a disturbed balance. If available, a comparison with individual baseline values is preferable to group comparison. Furthermore, a lower ACTH response after a repeated bout of exercise and overall lower cortisol levels are indicative for OR. Caution is necessary when interpreting these measurement tools, as cut off scores for these questionnaires and altered hormonal patterns still require further investigation.

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Summary

The present thesis investigates the delicate balance between stress and recovery in sports. In order to improve performance athletes continuously challenge their personal boundaries. This may lead to a local or general overload of the human body that results into injuries, illnesses and the overtraining syndrome. Monitoring stress and recovery possibly helps to optimize performance and prevent athletes from health related problems.

Chapter 1 presents a theoretical framework that contains physical and psychosocial stress and recovery components. It is suggested that the total amount of stress should be in balance with the total amount of recovery for optimal performance. Furthermore, this chapter describes possibilities for the diagnosis and treatment of overtraining and presents several markers for its early detection. Based on available literature it is concluded that the diagnosis is still based on exclusion, rest is the only effective treatment and early markers for overtraining are not yet available. Careful documentation of stress, recovery and performance, by means of logs, questionnaires and field tests, seems the best approach to detect a disturbed balance and guide intervention strategies.

In Chapter 2 we investigated the relation between training load, recovery and monthly field test performance in young elite soccer players. In a prospective, nonexperimental cohort design, eighteen young elite soccer players registered training and match duration for a full competive season by means of daily training logs. Furthermore, session Rating of Perceived Exertion and Total Quality of Recovery scores were recorded. It turned out that the duration of training and game play in the week prior to field test performance is most strongly related to interval endurance capacity. Therefore coaches should focus on training duration to improve interval endurance capacity in elite soccer players. In order to evaluate the group and individual training response, field tests should be frequently executed and be incorporated in the training program.

The aim of Chapter 3 was to investigate how measures to monitor stress and recovery provide useful information for the prevention of injuries and illnesses in elite youth soccer players. Fifty-three elite soccer players between 15 and 18 years of age participated in this study. To determine physical stress, soccer players registered training and match duration and session Rating of Perceived Exertion (RPE) for two competitive seasons by means of daily training logs. The Dutch version of the Recovery Stress Questionnaire for athletes was administered monthly to assess the psychosocial stress-recovery state of players. The result show that injuries are related to physical stress. Physical stress and psychosocial stress and recovery are important in relation to illness. Individual monitoring of stress and recovery may provide useful information to prevent soccer players from injuries and illnesses.

The purpose of Chapter 4 was to prospectively monitor sport-specific performance and assess the stress-recovery balance in overreached soccer players and controls. An unfavourable total recovery score appeared two months

Summary

before diagnosis when compared to the reference values of the healthy group established at the start of the season and also over the two seasons. The scales Fatigue and Being in Shape demonstrated the largest changes in stress and recovery within the OR players (effect size = 1.14 and 1.50). The longitudinal monitoring of performance and changes in stress and recovery may be useful for the detection of OR in its earliest stage. The information obtained from these tests can be used to optimise individual training and recovery programs.

Chapter 5 studied the reliability and validity of the Dutch Recovery Stress Questionnaire for Athletes (RESTQ-sport). Overall, it was concluded that the Dutch RESTQ-sport has sufficient reliability and validity. Chapter 6 and Chapter 7 investigated different diagnostic tools that are relevant in sport practice for an early detection of overreaching.

In Chapter 6 mood states of the included athletes were assessed with the shortened version of the Profile of Mood States (POMS). Responses of ACTH, cortisol and prolactin to exercise were evaluated during two graded incremental exercise tests to exhaustion on a treadmill, separated by 3 hours of rest. The overreached athletes reported more feelings of depression and anger than controls. Furthermore, lower ACTH responses and lower overall cortisol levels before and after exercise were found in the overreached group compared to the control group. Chapter 7 studied the usefulness of the stress-recovery balance and reaction times before and after exercise as potential markers for overreaching. It is concluded that overreached soccer players share a disturbed stress-recovery balance, but they could not be distinguished from controls based on reaction time after a strenuous exercise. The information obtained from Chapter 6 and Chapter 7 provides coaches and sport physicians with early markers about changes in the training status of adolescent athletes, which can be helpful in preventing them for unfavourable and unwanted signs and symptoms of overreaching.

In Chapter 8 it is concluded that physical and psychosocial stress and recovery are associated with sport performance and health related problems, such as injuries, illnesses and overtraining in soccer players and middle-long distance runners. Monitoring stress and recovery may help to optimize performance and prevent a local or general overload. Clinical measurements showed that mood state and hormonal responses to a double maximal exercise protocol provided valuable information to confirm the diagnosis of overtraining. The usefulness of reaction time as potential marker could not be confirmed.

Samenvatting

Dit proefschrift onderzoekt het wankele evenwicht tussen stress en herstel in de sport. Voor optimale prestaties zijn sporters continu bezig met het verleggen van grenzen. Dit kan leiden tot een lokale of algemene overbelasting, zich uitend in blessures, ziekte en overtraindheid. Het systematisch monitoren van stress en herstel kan mogelijk helpen om prestaties te verbeteren en overbelasting te voorkomen.

Hoofdstuk 1 beschrijft een theoretisch model dat bestaat uit fysieke en psychosociale stress en herstel. Uitgangspunt is dat voor optimale prestaties de totale hoeveelheid stress in evenwicht moet zijn met de totale hoeveelheid herstel. Daarnaast geeft het hoofdstuk aanknopingspunten voor de diagnose en behandeling van overtraindheid en worden potentiële vroegtijdige markers voor overtraindheid besproken. Op basis van de literatuur wordt geconcludeerd dat de diagnose van overtraindheid gesteld wordt door het uitsluiten van andere oorzaken. Daarnaast is er geen goede behandeling beschikbaar en ontbreken vroegtijdige markers. Het monitoren van stress, herstel en prestatie lijkt voorals-nog de beste benadering om een verstoorde balans vroegtijdig te detecteren en sturing te geven aan de behandeling.

Hoofdstuk 2 onderzoekt de relatie tussen trainingsbelasting, herstel en maandelijkse prestaties op een veldtes bij jeugdige topvoetballers. In een prospectief cohort design registreerden jeugdige topvoetballers het aantal trainings- en wedstrijdminuten gedurende één seizoen. Daarnaast registreerden ze de Ervaren Mate van Inspanning (EMI) en de Ervaren Mate van Herstel (EMH). Het totale aantal trainings- en wedstrijdminuten in de week voorafgaand aan de veldtest liet de beste relatie zien met interval uithoudingsvermogen. Voor het verbeteren van het interval uithoudingsvermogen zouden trainers met name aandacht moeten besteden aan de trainingsduur in de week voor de prestatie. Om effecten van trainings-programma's op groeps- en individueel niveau in kaart te brengen, wordt geadviseerd regelmatig veldtesten af te nemen.

In Hoofdstuk 3 wordt onderzocht of het monitoren van stress en herstel ook kan bijdragen aan de preventie van blessures en ziektes. Drieënvijftig jeugdige topvoetballers werden gedurende twee seizoenen gevolgd. Fysieke belasting werd berekend door het aantal trainingsminuten te vermenigvuldigen met de EMI. De Nederlandse versie van de Recovery Stress Questionnaire for Athletes (RESTQ-Sport) werd maandelijks afgenomen om psychosociale stress en herstel te meten. De resultaten laten zien dat fysieke belasting de kans op acute blessures en ziekte vergroot. Psychosociale stress en herstel bleken tevens gerelateerd aan ziektes. Het monitoren van stress- en herstel geeft aanknopingspunten die gebruikt kunnen worden voor de preventie van blessures en ziektes.

Hoofdstuk 4 onderzoekt veranderingen in stress en herstel die voorafgaan aan overtraindheid. Vierennegentig jeugdige topvoetballers werden gedurende twee seizoenen gevolgd. Op basis van prestatiedaling op maandelijkse veldtesten en een medische screening werden zeven voetballers geïncludeerd. Twee maanden voor de diagnose was een verstoorde stress-herstel balans zichtbaar in

Samenvatting

vergelijking met een gezonde controle groep aan de start van het seizoen en het gemiddelde van de gezonde groep over de twee seizoenen. De RESTQ-Sport schalen 'Vermoeidheid' en 'In vorm zijn' lieten op individueel niveau het grootste verschil zien. Het monitoren van stress en herstel en prestatie, biedt dus ook aanknopingspunten voor de vroege herkenning van overtraindheid. Informatie die met deze testen wordt verkregen kan worden gebruikt voor het optimaliseren van trainingsschema's en het verbeteren van herstel.

In Hoofdstuk 5 wordt de betrouwbaarheid en validiteit van de Nederlandstalige RESTQ-sport onderzocht. Geconcludeerd wordt dat betrouwbaarheid en validiteit van de Nederlandstalige RESTQ-Sport voldoende is voor het gebruik bij onderzoek en in de sportpraktijk.

Hoofdstuk 6 en Hoofdstuk 7 bestuderen verschillende diagnostische middelen die relevant zijn voor de sportpraktijk voor een vroege herkenning van overtraindheid.
In Hoofdstuk 6 wordt met behulp van een vragenlijst (verkorte Profile of Mood States (POMS)) de gemoedstoestand van overtrainde sporters gemeten. Daarnaast wordt de hormonale reactie van ACTH, cortisol en prolactine na een dubbele maximale inspanningstest onderzocht. Tussen de twee inspanningstesten krijgen de sporters drie uur rust. In vergelijking met gezonde sporters scoren de overtrainde sporters hoger op de schalen depressie en angst van de POMS. Daarnaast laten zij, in lijn met voorgaand onderzoek, een verminderde ACTH reactie op inspanning zien en lagere concentraties cortisol. Dit wijst in de richting van een verstoring op het niveau van de hypothalamus-hypofyse-bijnier as.

In Hoofdstuk 7 wordt de stress- en herstelbalans en reactietijd voor en na een maximale inspanning onderzocht als vroegtijdige markers van overtraindheid. De uitkomsten laten zien dat de overtrainde sporters een verstoorde stress-herstel balans hebben, maar de reactietijd voor en na inspanning niet afwijkt. De informatie uit Hoofdstuk 6 en Hoofdstuk 7 geeft coaches en (sport) artsen relevante informatie over de trainings- en herstelstatus van sporters, die mogelijk kan bijdragen aan de preventie van overtraindheid.

Hoofdstuk 8 bevat de discussie en conclusie. Geconcludeerd wordt dat fysieke en psychosociale stress en herstel gerelateerd zijn aan prestatie en gezondheids-problemen, zoals blessures, ziektes en overtraindheid bij sporters. Het monitoren van stress en herstel draagt mogelijk bij aan het optimaliseren van de prestaties en het voorkomen van een lokale of algemene overbelas-ting. De klinische metingen laten zien dat gemoedstoestand en hormonale reactie op dubbele maximale inspanning relevante informatie geven om de diagnose van overtraindheid te ondersteunen. Verder onderzoek is nodig naar de bruikbaarheid van reactietijd als kenmerk van overtraindheid.

Curriculum Vitae and list of publications

Curriculum Vitae

MIchel Sanne Brink is geboren op 15 april 1981 te Hengelo. Hij studeerde van 1998 tot 2002 fysiotherapie aan de Hanzehogeschool te Groningen waar hij de afstudeerscriptie 'Spierkramp bij inspanning' schreef. Aansluitend combineerde hij de studie Bewegingswetenschappen aan de Rijksuniversiteit Groningen met een parttime baan als fysiotherapeut in een particuliere praktijk. Bij zijn afstuderen in 2005 heeft hij bijgedragen aan de ontwikkeling van een balanstaak voor het meten van functioneel herstel na een voorste kruisband reconstructie.

In 2006 kwam hij als promovendus in dienst bij het Interfacultair Centrum voor Bewegingswetenschappen te Groningen. In een samenwerkingsverband met het UMC Utrecht werkte hij aan de ontwikkeling van een monitor ter preventie van blessures, ziekte en overtraindheid bij jeugdige sporters. Daarnaast onderzocht hij lichamelijke en neuropsychologische kenmerken van overtraindheid, zoals hormoonprofielen en reactietijden. Dit promotieonderzoek rondde hij in 2010 af.

Sinds 2007 is Michel ook als docent bij het Centrum voor Bewegingswetenschappen werkzaam. Hij is betrokken bij de mastervakken trainingsfysiologie en de specialisatie sport en begeleidt bachelor- en masterafstudeerprojecten. Vanaf 1 september 2010 is hij tevens aangesteld bij het Hanze Instituut voor Sportstudies aan de Hanzehogeschool in Groningen. Binnen de kenniswerkplaats 'optimalisatie van sportprestaties' verricht hij, samen met studenten, docenten en professionals uit de beroepspraktijk praktijkgericht onderzoek.

Curriculum Vitae
and list of publications

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Balancing stress and recovery in sports

Balancing stress and recovery in sports