RECOVERY RULES

Post-match recovery and load management during match congestion in elite team sport players

STEVEN H. DOEVEN

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SUMMARY

For the elite team sport player and training and coaching staff, it is challenging to strive for optimal performance and, at the same time, prevent injuries or illnesses. Next to adequate load management, sufficient recovery plays a crucial role, especially during fixture congestion. Therefore, the present thesis' main aim is to gain insight into the determinants of recovery and the time course of recovery during intensive competition periods (i.g. fixture congestion) within elite team sports.

Chapter 2 provides an overview of post-match recovery time courses of physical performance tests and biochemical markers in team ball sports, without dense schedules of play. Twenty-eight studies were eligible to evaluate post-match recovery time courses of physical performance and biochemical markers in team ball sport players. Studies were included if they met the following criteria: (1) original research evaluating players' physical recovery post-match; (2) team/intermittent sports; and (3) at least two post measurements were compared to baseline values. Most frequently used performance tests and biochemical markers were the countermovement jump (CMJ) test, sprint tests and creatine kinase (CK), cortisol (C) and testosterone (T), respectively. Based on the findings, it was demonstrated that underlying mechanisms of muscle recovery as indicated by biochemical markers are still in progress while recovery of performance is already reached. Results showed that CK-recovery time courses are up to ≥72 hours. Soccer and rugby players need more time to recover for sprint performance, CK and C in comparison with other team ball sports.

In **chapter 3**, the purpose was to determine match exertion, subsequent recovery and to investigate to what extent the coach is able to estimate players' match exertion and recovery in professional basketball players. In this study players' and coach perception of matches were collected during fixture congestion at the highest national competition level and Euro league. Results emphasized the strong deviation of load between players' perceptions and coach estimates after 1-2 days post-match recovery. Players perceived match exertion hard to very hard and subsequent recovery reasonable. The coach overestimated match exertion and underestimated degree of recovery.

This mismatch potentially leads to inadequate planning of training sessions and performance decrease.

Chapter 4 further assessed load during short-term match congestion (i.g. ≥2-match weeks) but now compared with regular competition (i.g. 1-match weeks) in elite male professional basketball players for a full season. Moreover, differences in well-being, recovery, neuromuscular performance and injuries and illnesses between short-term match congestion and regular competition were determined. It was shown that total load and training load were lower during short-term match congestion compared to regular competition. Next to that, better well-being and less fatigue were demonstrated within short-term match congestion. This might indicate that coaches tend to overcompensate training load within intensified competition.

Further reduced options for recovery could be expected in the study set-up of **chapter 5.** This study had the densest playing schedule at an elite level. Twelve elite women rugby sevens players performed 5 matches during a two-day tournament of the Women's Rugby Sevens World Series. Therewith, within this unique context, the crucial balance between match load and recovery was studied. The influence of match load indicators was assessed. Total distance, low-, moderate- and high-intensity-running (HIR) and physical contacts (PC) during matches were derived of GPS based time-motion analysis and video-based notational analysis, respectively. Internal match load was calculated by session-rating of perceived exertion. Changes in well-being (fatigue, sleep quality, general muscle soreness, stress levels, mood), recovery and neuromuscular performance during and after the tournament were investigated. It was shown that well-being, fatigue, general muscle soreness, stress levels, mood and TQR were significantly impaired after match day 1 and did not return to baseline values until 2 days post-tournament. More HIR was related to more fatigue and a larger number of PC with more general muscle soreness.

Based on the findings in this thesis, trainers and coaches should be vigilant on hidden recovery processes. This can be the case if performance is already at baseline values while biochemical markers remain impaired by previous load. Adequate communication between coach and player adds to more insight

in match exertion and the process of post-match recovery of the player. For optimal performance, discrepancy between coaches' and players' perceptions should be reduced to a minimum. Within intensified competition coaches tend to overcompensate training load. Match load indicators such as HIR and PC influence fatigue and general muscle soreness, respectively and might, therefore, be used as feedback parameters. Moreover, well-being, fatigue and TQR are most useful for their responsiveness to acute increased load.

SAMENVATTING

Topsporters, trainers en coaches streven naar prestatieverbetering en moeten tegelijkertijd blessures en ziektes voorkomen. Naast het adequaat inschatten van belasting, speelt voldoende herstel een belangrijke rol met name tijdens hoog intensieve training- en wedstrijdperiodes. In dit proefschrift worden de determinanten van herstel en het tijdsverloop van herstel tijdens intensieve training- en wedstrijdperiodes binnen teambalsporten op het hoogste niveau onderzocht.

Hoofdstuk 2 richt zich op het evalueren van het herstel van de wedstrijd met fysieke prestatietests en biochemische waardes in teambalsporten zonder een intensief speelschema. Achtentwintig studies kwamen in aanmerking voor evaluatie van fysieke prestaties en biochemische waardes bij teambalsport spelers. Studies werden geïncludeerd als ze aan de volgende criteria voldeden: (1) in het originele onderzoek is fysiek herstel van spelers na de wedstrijd geëvalueerd; (2) team-/ intermitterende sporten; en (3) ten minste twee metingen achteraf werden vergeleken met basiswaarden. De meest gebruikte prestatietests en biochemische waardes waren de countermovement jump (CMJ) -test, sprinttests en respectievelijk creatinekinase (CK), cortisol (C) en testosteron (T). Op basis van de bevindingen werd aangetoond dat de onderliggende mechanismen van spierherstel nog bezig zijn terwijl prestatieherstel al is bereikt. De resultaten toonden aan dat CK-hersteltijden tot 72 uur duren. Voetbal- en rugbyspelers hebben meer tijd nodig om te herstellen voor sprintprestaties, CK en C-waardes in vergelijking met andere teambalsporten.

In **hoofdstuk 3** was het doel om de inspanning tijdens de wedstrijd en het daaropvolgende herstel te bepalen en te onderzoeken in hoeverre de coach in staat is de wedstrijdinspanning en het herstel van professionele basketbalspelers in te schatten. In deze studie werd de perceptie van spelers en coaches onderzocht van een professioneel basketbalteam dat op het hoogste nationale competitieniveau en Euro league speelt tijdens een intensieve wedstrijdperiode. De resultaten lieten een sterke afwijking tussen de percepties van spelers en de inschattingen van de coach zien na 1-2 dagen herstel na de wedstrijd. Spelers ervaarden de wedstrijdinspanning

als zwaar tot zeer zwaar en het daaropvolgende herstel als redelijk. De coach overschatte de wedstrijdinspanning en onderschatte mate van herstel. Deze mismatch kan leiden tot een inadequate planning van trainingssessies en prestatievermindering.

In **hoofdstuk 4** is bij professionele basketbalspelers gedurende een volledig seizoen de belasting tijdens hoog intensieve wedstrijdweken (≥ 2 wedstrijden per week) verder onderzocht, maar nu vergeleken met de reguliere competitie (1 wedstrijd per week). Verschillen in welzijn, herstel, neuromusculaire prestaties en blessures en ziektes tussen hoog intensieve wedstrijdweken en reguliere competitie zijn onderzocht. Er werd aangetoond dat de totale weekbelasting en trainingsbelasting lager waren tijdens hoog intensieve wedstrijdweken dan in reguliere competitie. Daarnaast werd een beter welbevinden en minder vermoeidheid aangetoond binnen hoog intensieve wedstrijdweken. Dit zou erop kunnen wijzen dat coaches de neiging hebben om de trainingsbelasting te overcompenseren tijdens intensievere competitie.

In de onderzoeksopzet van **hoofdstuk 5** zijn verdere verminderde opties voor herstel onderzocht. Deze studie heeft het meest drukke speelschema op topniveau. Twaalf top rugby sevens speelsters speelden 5 wedstrijden tijdens een tweedaags toernooi van de Women's Rugby Sevens World Series. In deze unieke context werd de cruciale balans tussen wedstrijdbelasting en herstel bestudeerd. Ook werd de invloed van belastingindicatoren in kaart gebracht. Op basis van GPS gebaseerde tijd-bewegingsanalyse en op video gebaseerde notatieanalyse werden de totale afstand, hardlopen met lage, gemiddelde en hoge intensiteit en fysieke contacten tijdens wedstrijden afgeleid. Interne wedstrijdbelasting werd berekend door ervaren inspanning te meten. Veranderingen in welzijn (vermoeidheid, slaapkwaliteit, algemene spierpijn, stressniveaus, stemming), herstel en neuromusculaire prestaties tijdens en na het toernooi werden onderzocht. Aangetoond werd dat welzijn, vermoeidheid, algemene spierpijn, stressniveaus, stemming en herstel significant verminderd waren na wedstrijddag 1. Pas 2 dagen na het toernooi keerde dit terug naar de basiswaarden. Hardlopen op hoge intensiteit was gerelateerd aan meer vermoeidheid en een groter aantal fysieke contacten met meer algemene spierpijn.

Gebaseerd op de bevindingen in dit proefschrift moeten trainers en coaches zich bewust zijn van verborgen herstelprocessen. Dit kan het geval zijn als onderliggende mechanismen van spierherstel, zoals aangegeven door biochemische markers, nog in volle gang zijn terwijl herstel op prestatietests al is bereikt. Adequate communicatie tussen coach en speler draagt bij aan meer inzicht in de wedstrijdinspanning en het proces van herstel na de wedstrijd van de speler. Voor optimale prestaties moet de discrepantie tussen de percepties van coaches en spelers tot een minimum worden beperkt. Tijdens hoog intensieve wedstrijdperiodes hebben coaches de neiging om de trainingsbelasting te overcompenseren. Belastingindicatoren van een wedstrijd, zoals hardlopen op hoge intensiteit en fysiek contact, beïnvloeden respectievelijk vermoeidheid en algemene spierpijn en kunnen daarom worden gebruikt als feedbackparameters. Bovendien zijn vermoeidheid en totale kwaliteit van herstel zeer bruikbaar door de responsieve reactie op acute verhoogde belasting.

Chapter 1

General introduction

In elite team sports, players have to cope with the delicate balance between physical and psychosocial load, capacity and recovery in order to optimize performance and prevent injuries and illnesses (Figure 1).[1,2]

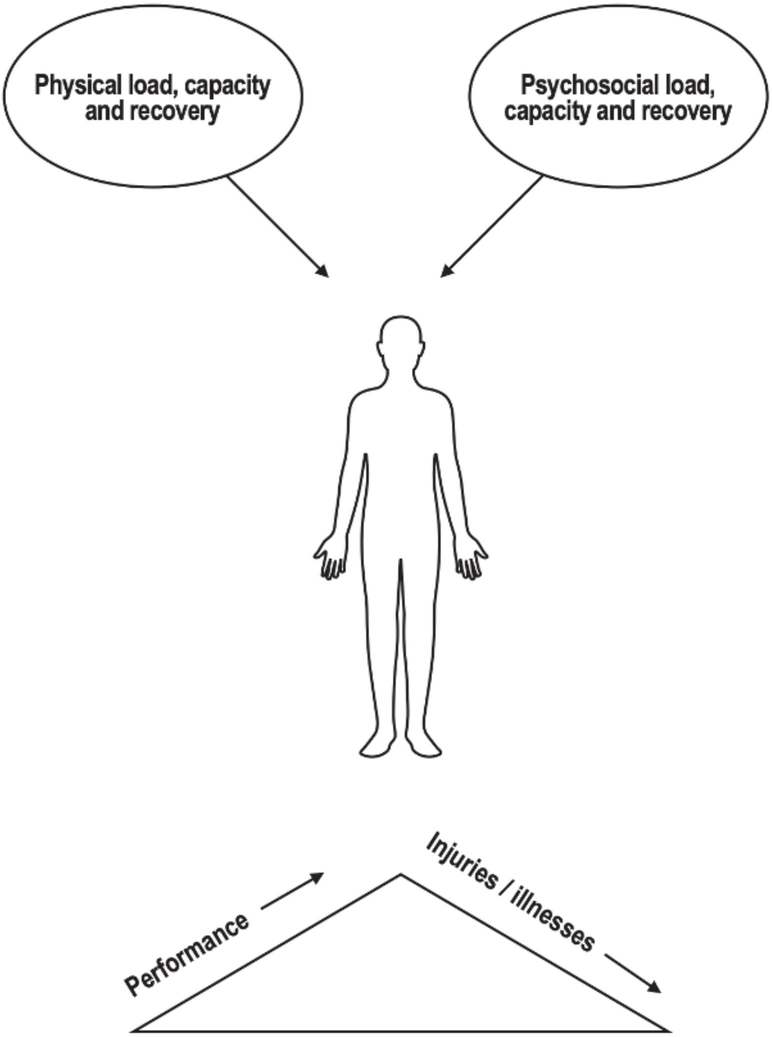

Figure 1 — Theoretical framework of load, capacity and recovery for physical and psychosocial domains. Adapted from050Henttä and Hassmén.[1]

PHYSICAL LOAD, CAPACITY AND RECOVERY

Performance at an elite level coincides with exposure to high physical load caused by the frequency, intensity and duration of training and matches.[3] Elite players train for many years to excel in their sport. On top of training, official matches create even more physical load. The real context of a match evokes that physical, technical and tactical performance is simultaneously stressed.[4] Therefore, matches are played at even higher intensity leading to more load.

The load of training and matches depends on capacities of players and may result in large interindividual differences. For example, players with large physical capacities, such as strength and endurance, better cope with the same absolute load compared to players with lower capacities. Thus, the absolute load is relative to the capacities of each individual player.

In addition to the load that players are exposed to, sufficient recovery is needed to perform at the highest possible level in the next match and to prevent health problems (Figure 1).[1,2,5] Recovery can be defined as the phase between consecutive training sessions or matches (Figure 2).[5] But, recovery not only depends on the time between sessions to allow adaptations to occur, but also depend on potential strategies applied to enhance the process of recovery. So, recovery is related to previous loads and those loads depend on the individual capacity of players, but recovery also depends on the time between sessions and the activities undertaken in that period.

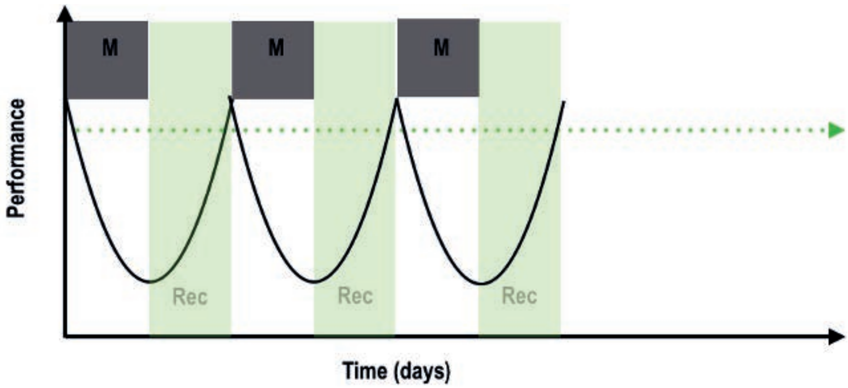

Figure 2 — Schematic overview of performance and recovery over time in days. Abbreviations: M, match; Rec, recovery.

PSYCHOSOCIAL LOAD, CAPACITY AND RECOVERY

Next to physical load, players are exposed to on- and off-field psychosocial load as a result of team dynamics, spectators and media. As a result of playing competitive matches, individual deteriorations in psychological state are demonstrated.[6,7] Moreover, increased perceived stress and reduction in general well-being are previously reported.[8,9] This is due to the disturbed balance between psychosocial load and recovery.

The degree of psychosocial load depends on the player's individual capacities such as level of self-confidence, anxiety control, positive mental health and the ability to form sustainable relationships.[1] These capacities together determine the extent to which a player can deal with the imposed psychosocial load. Players responses to the same psychosocial load differ and consequently, susceptibility to an increased risk of injuries, illnesses and non-functional overreaching may vary.

Finally, to cope with psychosocial stressors there is an urgency for sufficiently planned psychosocial recovery afterwards. Activities such as hanging out with friends, relaxing and visiting family and friends might contribute to psychosocial recovery.[10,11]

It is likely that physical and psychosocial load interact, depend on physical and psychosocial capacities and have their influence on the degree of recovery. If a player is well rested physically and psychosocially (good recovery), imposed load might be less high compared with a prior period of insufficient recovery (poor recovery). Poor recovery occurs if players have to cope with overload. This is the case if periods between consecutive matches become too short to recover properly.[12] As argued, the load-capacity-recovery balance should be approached by a multidimensional view as illustrated in figure 2.[1]

FIXTURE CONGESTION

In elite team sports, the balance between load and recovery is especially challenged with fixture congestion, both from a physical and psychosocial perspective.[13] Next to domestic league competition and CUP- matches, players have to perform in mid-week international competitions (i.g. Champions league, Euro league). During tournaments playing schedules are even denser with multiple matches played within several days. Density of match schedules brings the challenge to the table to anticipate on acute increases of too much load. Sufficient recovery time between successive matches for the individual player is no longer guaranteed and has its consequences on the short- and long-term.

For the short term, players might underperform the next training session or match. For the long term, one can think of negative consequences through cumulated load over several weeks or a full season. Indeed, such congested schedules have negative consequences for team performance,[14,15] increase injury risk or lead to non-functional overreaching.[16] Even more than regular match phases with one match per week.

Time courses of recovery for official matches during fixture congestion are not determined yet, and therefore, potentially not appropriate anticipated for. Therefore, it is very important to have insight in load and recovery for each session by monitoring and to anticipate on the outcomes by for example team management or player rotation strategies.[17]

MONITORING LOAD AND RECOVERY

Several ways of monitoring can be applied in elite team sports to study the interaction between load and recovery.[2,18,19] Monitoring load is crucial to understand individual responses of the applied frequency, intensity and duration of training sessions or matches and to assess fatigue and associated need for recovery.[20] External training or match load can be derived from for example, time-motion analysis from global positioning system (GPS) parameters.[21] To assess internal load, ratings of perceived exertion (RPE) and heart rate are commonly used. Advantage of making use of both, external and internal load measures, is that it helps assessing whether a player is fit or fatigued.[22] For example, if imposed external load is the same between training sessions or matches but coincide with higher internal load, it can be assumed that the player is more fatigued.

To identify time-courses of recovery, performance tests, biochemical markers or self-reported measures are used. These markers, tests and measures are then usually applied multiple times in the hours after exercise and compared to pre-exercise levels. To ensure recovery the value should be at least the same as baseline values (Figure 2).[5]

Biochemical markers such as creatine kinase, cortisol or testosterone are widely used as measures in sports.[23-26] Disadvantage of these variables is that they show large variations between players. Next to that, invasive measurements are unpleasant and hard to apply in elite team sports players. Further, performance tests such as jumping and sprinting tests are frequently used.[27-30] Though, these have limitations in the practical implementation around matches or competitions because of the extra physical strain applied.

Self-reported measures to assess well-being or perceived recovery such as total quality of recovery, is widely and easily used around training and competitions.[1,31-35] These measures are less time consuming compared with performance tests or biochemical testing and do not add to physical strain. In addition, players showed to be very capable of expressing perceptions of their actual physical or psychosocial state.[1] Even with superior sensitivity and consistency in reference to performance tests or biochemical testing, and especially when used to assess within subject changes.[18] Acute (i.e., less than 3 h post-match) and residual (up to 72 h post-match) fatigue leading to alterations in performance and to perturbations in biochemical markers correspond to impaired mood, perceived stress and recovery as self-reported measures.[35,36,37] On the other hand, the literature also shows a lack of association between performance or biochemical and self-reported measures and, therefore, support to use them complementary to give a representative picture of the actual recovery state.[18,38]

In summary, in elite team sports it is essential to determine physical and psychosocial recovery in relation to previous load and individual capacities. Furthermore, it is important to understand how training and match load correspond with recovery during fixture congestion. To study this relation, the complementary use of performance tests and self-reported measures is strongly recommended in the monitoring process. Considering the high demands in elite team sports with the potential of performance decline and increased injury risk, it is of utmost importance to gain more insight in how this affects players. There is a great need for more knowledge on match exertion and recovery kinetics during intensified competition. Moreover, weekly load distribution and subsequent time-courses of recovery during match congestion and regular competition should be studied. Finally, knowledge is lacking on the most extreme example of match congestion, an elite tournament. Therefore, studying the influence of multiple matches in several days on time-courses of recovery and the influence of match load indicators aid in a better understanding of the recovery process within this context.

THESIS AIM AND OUTLINE

The thesis' main aim is to gain insight into the determinants of recovery and the time course of recovery during intensive competition periods (i.g. fixture congestion) within elite team sports. Therefore, imposed load, individual capacities and subsequently recovery are investigated in elite team sport players.

To better understand recovery kinetics after matches, time courses of physical performance tests and biochemical markers in team ball sports were evaluated in **Chapter 2**. Twenty-eight studies are included in qualitative synthesis for this systematic review. Recovery time course changes in creatine kinase, countermovement jump height and sprint time from pre-match to 144 hours post-match were demonstrated. Role of type of sport, exertion and playing level were discussed for variability for recovery kinetics in performance tests and biochemical markers.

In **Chapter 3**, match exertion and subsequent recovery are determined in elite basketball players in order to understand how players perceive load and recovery during an in-season intensified competition period. Players' match exertion and total quality of recovery are compared with estimates by the coach during an in-season intensified competition period.

Chapter 4 we continue to assess consequences of fixture congestion in basketball, but now focus on training load in between matches for phases with and without dense schedules of play during a full season. Furthermore, differences in well-being, total quality of recovery, neuromuscular performance and injuries and illnesses are explored.

In **Chapter 5**, the unique context of an elite rugby sevens tournament during the Women's World Rugby Sevens Series is studied. Tournaments are characterized by a multitude of matches in a very short period of time. Due to the very busy schedules, one could argue that players are likely insufficiently recovered for the next match. However, the consequences for recovery and well-being are currently unknown and tournament studies in elite team sports are scarce. Therefore, time courses of well-being, total quality of recovery, and neuromuscular performance within and after an elite women's rugby sevens tournament are determined. Subsequently, the influence of match load indicators is assessed. Next to internal match load, external match load was measured. Global positioning system (GPS)-based time–motion analysis and video-based notational analysis were performed for the matches to determine individual performance during the Women's World Rugby Sevens Series.

Finally, in **Chapter 6**, this thesis concludes with a general discussion on the main outcomes, strengths and limitations of the individual studies and future directions in research on recovery in team sports. On the basis of the findings, practical applications are presented that can guide training and coaching staff.

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Chapter 2

Post-match recovery of physical performance and biochemical markers in team ball sports: a systematic review

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ABSTRACT

Background: Insufficient post-match recovery in elite players may cause an increased risk of injuries, illnesses and non-functional overreaching. ***Objective:*** To evaluate post-match recovery time courses of physical performance and biochemical markers in team ball sport players. ***Study Design:*** Systematic review. ***Data sources:*** PubMed and Web of Science. ***Eligibility criteria for selecting studies:*** This systematic review was conducted according to PRISMA guidelines. The Critical Review Form for Quantitative Studies was used to evaluate quality. Studies were included if they met the following criteria: (1) original research evaluated players' physical recovery post-match; (2) team/intermittent sports; and (3) at least two post measurements were compared to baseline values. ***Results:*** Twenty-eight studies were eligible. Mean methodological quality was 11.2 ± 1.11. Most used performance tests and biochemical markers were the counter movement jump (CMJ) test, sprint tests and creatine kinase (CK), cortisol (C) and testosterone (T), respectively. ***Summary/conclusions:*** The current evidence demonstrates that underlying mechanisms of muscle recovery are still in progress while performance recovery is already reached. CK-recovery time courses are up to ≥72 hours. Soccer and rugby players need more time to recover for sprint performance, CK and C in comparison with other team ball sports. There are more high-quality studies needed regarding recovery in various team sports and recovery strategies on an individual level should be evaluated. ***Clinical relevance:*** Ongoing insufficient recovery can be prevented by the use of the presented recovery time courses as specific practical recovery guidelines.

INTRODUCTION

Elite team sports players are exposed to busy schedules of training and matches. During the competitive season, players have a match every week and sometimes even twice a week due to international competitions and domestic CUP-league matches. In elite soccer, players participate in approximately 60 matches during a season, which equates 5.5 matches per month.[1] These highly congested match schedules put a lot of strain on these players. In addition, studies reveal the high intensity and variable character of intermittent team ball sports of which the time course of match recovery is unknown.[2-4] To be able to prevent health problems and to perform at the highest possible level, sufficient recovery is crucial in this matter.[5]

In order to plan subsequent training sessions or prepare for upcoming matches, knowledge is needed about time courses of recovery.[6-8] Although match performance is highly variable and depends on several contextual factors, it is assumed that the intensity during matches is maximal and most strain is placed on players. Profiles of physical performance and biochemical markers after a match in team ball sports (e.g. soccer, rugby, handball, basketball, Australian rules football) are needed in order to get a realistic view of recovery and underlying mechanisms.[6,9,10] These different types of sport have likely unique recovery profiles caused by the diversity of game demands such as number of jumps, sprints and collisions.[4,11,12] By comparing profiles within and between different team ball sports, all of which are characterized by high intensity and intermittent activities, the recovery process will be better understood.

Different tests and measurements can be used for monitoring recovery and performance.[9] There are multiple physical performance tests (e.g. jump, sprint, strength, agility, flexibility, technical and aerobic tests) which could be used. Furthermore, biochemical markers (e.g. creatine kinase (CK), cortisol (C) and testosterone (T)) in blood and saliva samples could identify the underlying physiology of the recovery process[9] after playing a match and contribute in the determination of the time course of match recovery. Finally, self-reported measures (e.g. Profile of Mood States (POMS) or Recovery Stress Questionnaire for Athletes (RESTQ-S)) are demonstrated to be highly relevant to monitor the training response.[13]

In order to get a better understanding of post-match recovery kinetics this systematic review focuses on performance tests and biochemical markers in team ball sports. Indeed self-reported measures showed to be sensitive and evaluate multiple constructs in one single measure for monitoring. Although this can be seen as an advantage in daily practice it also limits understanding of which factors play an important role in recovery kinetics after matches. Therefore, we systematically reviewed recovery profiles post-match of objectively measured indicators in team ball sports.

Knowledge of physical performance tests and biochemical markers that reflect the magnitude of change in volume and or intensity of the preceding match[14] is needed for creating balanced training schedules. Appropriate time between the match and the next training impulse should be applied to prevent injuries, illnesses and non-functional overreaching and achieve optimal performance.

Johnston *et al*[15] recently investigated performance and biochemical responses after training. Although, immediately post-training a decrease in performance together with an increase in CK was reported, performance was at pre-training level after two hours while CK continues to increase. This suggest that performance again may be normal, but that underlying systems are still recovering. To date, there is no review available that compares objective recovery measures after matches. Therefore, the aim of this review is to synthesise recovery time courses for matches. Based on the variation in match load in different team ball sports typical recovery patterns are expected and therefore require planning. Furthermore, the course of recovery of performance might deviates of biochemical markers. So, in sum, the main aim of this systematic review is to evaluate post-match recovery time courses of physical performance tests and biochemical markers in team ball sports.

METHODS

This systematic review was reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses: the PRISMA statement.[16]

Literature search

A systematic literature search was performed in the databases of PubMed and Web of Science for relevant articles. The search included all available articles which were written in English or Dutch from the period between January 1985 and October 2016. Both databases were searched with the following terms (1 AND 2 AND 3):

1. Match (OR Game OR Competition OR Post-Match)
2. Recovery (OR Countermovement Jump OR Counter Movement Jump OR Repeated Sprint Ability OR Creatine Kinase OR Cortisol OR Testosterone)
3. Team (OR Intermittent OR Player OR *Sport* OR *Baseball* OR *Basketball* OR *Football* OR *Hockey* OR *Soccer* OR *Volleyball* OR Rugby OR Handball)

Term 1 was restricted to the title to prevent the inclusion of clinical papers. Also, the cursive terms were used as MeSH terms in PubMed (e.g. Medical Subject Headings). In PubMed, a preselection was set on text availability (full text), species (human) and language (English and Dutch). All studies found in both databases were taken together after which duplicates were removed.

Literature selection

The first selection of the articles for potential relevance was determined based on title and afterwards on abstract. Of the residuals full texts were obtained and read. Two authors (S.H.D. and S.J.K.) analyzed the articles independently. The included articles' reference lists were searched for relevant articles which were not found by using the initial search strategy. Original research articles were included if they investigated physical recovery of players (mean age ≥ 18 years) after a match in intermittent sports. An important condition was that at least two post measurements were compared to a baseline measurement. Intermittent sport was defined as a sport in which players stop and start often and for short periods. As a result, all team sports were included. Studies were excluded if: (1) full text was not available; (2) the article was not published in English or Dutch; (3) data was not reported in numbers in tables and/or text; (4) recovery strategies were used; (5) the study was an intervention; (6) participants were injured, ill, disabled, overtrained or recovering from injury, illness, disability or overtraining; (7) only one post measurement was reported; and (8) there was no baseline measurement. If the two authors disagreed on inclusion, a third author (MSB) decided whether the article was included or not.

Data extraction

Data were extracted from all included articles when statistical significance or a meaningful effect size (ES) across repeated measurements were presented in a result table and/or text. Effect sizes (Hedges' *g*) were calculated when not reported by the authors and mean, standard deviation and number of participants were reported in absolute numbers. Effect size ranges were presented for performance tests and biochemical markers using the following criteria: <0.2 = trivial, 0.2-0.6 = small, 0.6-1.2 = moderate, 1.2-2.0 = large, and >2.0 = very large.[17] The characteristics of the subjects were extracted from the articles, as well as the sport and type, intensity and duration of the exertion. Furthermore, times of measurements and tests which were used to measure recovery were extracted. All values were converted to percentages, so the reported values of different studies could be compared. Also, protocols were checked and compared to see whether there were large differences between the protocols of the different studies.

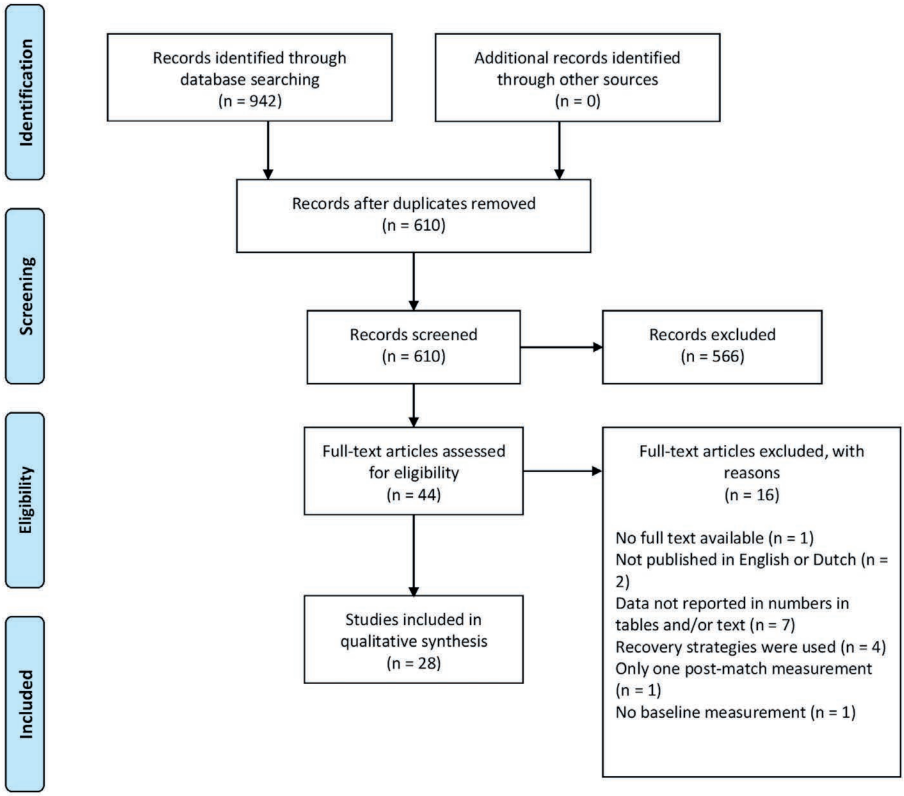

Figure 1 — Eligibility flow diagram

Methodological quality

Two authors (SHD and SJK) assessed the methodological quality of the included articles based on The Critical Review Form for Quantitative Studies.[18] These guidelines consisted of 14 criteria: (1) Was the study purpose stated clearly? (2) Was relevant background literature reviewed? (3) Was the design appropriate for the research question? (4) Was the sample described in detail? (5) Was the sample size justified? (6) Was informed consent obtained? (7) Were the outcomes measures reliable? (8) Were the outcome measures valid? (9) Were results reported in terms of statistical significance? (10) Were the analysis methods appropriate? (11) Was clinical importance reported? (12) Were conclusions appropriate given the study methods? (13) Are there any implications for clinical practice given the results of the study? (14) Were limitations of the study acknowledged and described by the authors? In line with the scope of this systematic review criteria 13 was also positively assessed when a 'practical applications' section was included in the article.

The different criteria were scored with '1' if it was met and it was scored with '0' if it was not met. This resulted in quality scores ranging from 0 to 14. Articles with a score below 7 were considered to have a poor methodological quality. Articles with scores between 7 and 10 were considered to have a good methodological quality. If an article scored over 10 it was considered to have a high methodological quality.[18]

RESULTS

Figure 1 shows the eligibility flow diagram. The initial search yielded a result of 321 studies in PubMed and 621 studies in Web of Science. After removing duplicates and application of the in- and exclusion criteria, 28 articles were included in this study. The supplementary table shows the characteristics and main findings of the included studies. In total, 59 physical performance tests and biochemical markers were used to measure recovery. The mean score for the methodological quality of the studies included was 11.2 ± 1.11 which indicates good to high methodological quality. Twenty-six out of 28 studies scored at least 10 points or higher. None of the studies scored below 7.

Supplementary table Study characteristics of the included studies.

Reference	Subjects[a]	Sport	Type of Exertion Duration Intensity	Performance test and Biochemical marker	Time	Main Findings
Andersson *et al*[95]	Female Elite 23 ± 4	Soccer	Simulated Match 2x 45 min, 15 min rest HR: 162 ± 2 bpm	Blood samples (Glucose, leukocytes, lymphocytes, neutrophils, cytokines)	Pre, 15 min, 21, 45 and 69h post	Increased leukocytes and cytokines for 21h. Neutrophils increased at post-measurement.
Chatzinikolaou *et al*[19]	- Elite 22.8 ± 1.4	Handball	Simulated Match 2x 30 min HR: 163.4 ± 7.6 and 168.7 ± 8.1 bpm	Blood samples (La, glycerol, C, T, MDA, PC, CK, UA, NEFA, ammonia, leukocytes, IL-1β, IL-6, GSH, sVCAM-1, GSSG, GPX), jumping, sprint ability, agility, line-drill testing and strength	Pre-match, post and daily during following 6 days	La, glycerol, NEFA, ammonia, leukocytes, IL-1β, IL-6, C, MDA and PC increased at post-measurement. Jumping, speed, agility, line-drill testing, strength, knee ROM and GSH decreased for 24h. CK, CRP, UA, sVCAM-1, GSSG and GPX increased for 24h.
Coad *et al*[43]	Male Elite 21.8 ± 2.4	Australian Rules Football	3 Matches 4x 30 min Player load: 1095.97 ± 90.44 1081.96 ± 115.05 1266.00 ± 124.57	s-IgA	24 and 1h pre, 1, 12, 36 and 60h post	Main effects between 24-hour pre-match and post-match [s-IgA] were found in matches 2 and 3.
Cormack *et al*[20]	- Elite 23.3 ± 2.7	Australian Rules Football	Match 80.0 ± 12.0 min -	CMJ1, CMJ5, saliva samples (C, T and T:C)	48h pre, pre-match, post and 24, 72, 96 and 120h post	CMJ1 Flight time:Contraction time decreased substantially post-match and appears most useful monitoring neuromuscular status.

Supplementary table Study characteristics of the included studies.

Reference	Subjects[a]	Sport	Type of Exertion Duration Intensity	Performance test and Biochemical marker	Time	Main Findings
Cunniffe *et al*[33]	- Elite 26.4 ± 0.7	Rugby	Match 69 ± 0.9 min -	Blood samples (C, T:C, CK, CRP, IL-6, circulating T lymphocytes, NK cells and neutrophils)	Camp entry, morning of the match, post, 14 and 38 post	C and IL-6 increased immediately post. CK and CRP increased for 14 and 38h. Circulating T lymphocytes, NK cells and neutrophils decreased immediately post. T:C decreased for 14h.
Djaoui *et al*[34]	Male Elite 26.0 ± 2.0	Soccer	2 Matches 2x 45 min per match	CK and La	Pre, 24 and 48h post	CK increased for 24h.
Duffield *et al*[21]	Male Amateur 20.3 ± 2.3	Rugby	Match - RPE: 6 ± 2	CMJ, MVC, Voluntary activation, Pt, RTD, RR	Pre, post and 2h post	Pt, RTD and RR decreased immediately post. MVC decreased for 2h.
Elloumi *et al*[42]	Elite 25.2 ± 4.2	Rugby	Match - -	C, T and T:C ratio	Pre and during 6 days post-match	C increased for 4h. T:C increased for 120h.
Fatouros *et al*[22]	Male Elite 20.3 ± 0.3	Soccer	Match 2x 45 min HR: 168.6 ± 8.2 bpm	Blood samples (leukocytes, CK, UA, PC, MDA, GSH, GSSG, GSH/GSSG, TAC, TBARS, Catalase, GPX), CMJ and sprint ability	Pre, 24, 48 and 72h post	Performance deteriorated throughout recovery. Leukocytes increased for 24h, CK for 48 h. TBARS, PC, UA, GPX and TAC increased throughout recovery.

Supplementary table Study characteristics of the included studies.

Reference	Subjects[a]	Sport	Type of Exertion Duration Intensity	Performance test and Biochemical marker	Time	Main Findings
Gravina *et al*[35]	Female Elite and sub-elite Elite: 25 ± 5 Sub-Elite: 18.3 ± 1.5	Soccer	Match - -	Blood samples (LDH, UA, T, CK, CRP, neutrophils, albumin, TAS, leukocytes, lymphocytes, eosinophils, monocytes and basophils).	24h pre, post and 18h post	Leukocytes, neutrophils, LDH, UA, albumin, TAS and T increased immediately post. Lymphocytes, eosinophils, monocytes and basophils decreased immediately post. CK increased for 18h.
Hoffman *et al*[30]	Female NCAA Division 3 Starters: 20.0 ± 1.0 Non-Starters: 18.2 ± 0.4	Soccer	Match - -	Squat jump and CMJ	24h pre, post and 24h post	Squat jump and CMJ decreased for 24h.
Ispirlidis *et al*[23]	Male Elite 21.1 ± 1.2	Soccer	Match 68 min HR: 159.7 ± 4.1 bpm	Performance and blood samples (C, T, CK, CRP, LDH, PC, UA, IL-6, leukocytes, cytokines and TBARS)	Pre, post and during 6 following days	Performance decreased for 24-96h. Leukocytes, cytokines and C increased immediately post. CRP, TBARS increased for 48h. CK, LDH and PC increased for 72h and UA for 96h.
Kraemer *et al*[36]	- NCAA Division 1 20 ± 1	American Football	Game - -	Blood samples (CK, C, T, T:C, Mb and LDH)	Pre, 18-20h and 42-44h post	CK and Mb increased for 18h. LDH increased for 42h.

Supplementary table Study characteristics of the included studies.

Reference	Subjects[a]	Sport	Type of Exertion Duration Intensity	Performance test and Biochemical marker	Time	Main Findings
McLellan *et al*[37]	Male Elite 24.2 ± 7.3	Rugby	Match 60-80 min -	Blood samples (CK and C)	24h pre, 30 min pre, 30 min post and 24, 48, 72, 96 and 120h post	C increased for 96h. CK increased through complete recovery period.
McLellan *et al*[38]	Male Elite 19.0 ± 1.3	Rugby	Match 60-80 min Covered Distances: Backs: 5747 ± 1095m Forwards: 4774 ± 1186m	Blood samples (CK, C, T and T:C)	24h pre, 30 min pre, 30 min post and daily during the 5 following days	T decreased immediately post. C increased for 24h. CK increased through complete recovery period.
McLellan *et al*[31]	Male Elite 24.2 ± 7.3	Rugby	Match 60-80 min Covered Distances: Backs: 7886 ± 1695m Forwards: 7462 ± 1566m	PRFD, peak power, peak force of CMJ	24h and 30 min pre, 30 min post and 24, 48, 72, 96 and 120h post	RFD and peak power decreased to 24h post. Peak force decreased to 30 min post.
Nédélec *et al*[24]	- Elite 21.8 ± 3.2	Soccer	Match 2x 45 min -	CMJ, MVC and blood samples (CK)	Pre, 24, 48 and 72h post	CMJ, MVC and CK decreased through complete recovery period.
Pliauga *et al*[25]	Male College level 21.5 ± 1.7	Basketball	Simulated Match 4x 10 min -	Blood samples (CK), CMJ, sprint ability and body temperature	Pre, 20 min post, 24 and 48h post	CMJ decreased at 24h post. CK increased through complete recovery period.

Supplementary table Study characteristics of the included studies.

Reference	Subjects[a]	Sport	Type of Exertion Duration Intensity	Performance test and Biochemical marker	Time	Main Findings
Rampinini *et al*[32]	Male Elite 19 ± 1	Soccer	Match 2x 45 min 88.0 ± 4.1% and 96.3 ± 2.8% of HRmax	MVC and sprint ability.	Pre, post, 24 and 48h post	MVC and sprint ability decreased immediately post.
Romagnoli *et al*[26]	Male Professional 17-20	Soccer	Match 2x 45 min 88 ± 4% and 82 ± 4% of HRmax	Blood samples (WBC, lymphocytes, neutrophils, monocytes, CK, CRP, C, T, IL-6) and CMJ	Pre, 30 min post, 24 and 48h post	CMJ decreased and CK increased for 48h. C and T decreased for 48h.
Russel *et al*[39]	Male Professional Under-21	Soccer	4 matches 2x 45 min per match -	CK and CMJ	Pre, 24 and 48h post	CK increased and peak power output decreased for 48h.
Russel *et al*[6]	Male Professional 20 ± 1	Soccer	5 matches 2x 45 min per match -	CK and CMJ	Pre, 24 and 48h post	CK increased and peak power output decreased for 48h.
Silva *et al*[10]	Male High-Level 22-31	Soccer	Match 94 min -	Sprint ability, CMJ and blood samples (Mb, CRP, UA, C, T, T:C, CK, MDA, SH, GR, GPX, TAS and SOD)	72h pre, 24, 48 and 72h post	Mb, CRP, -SH and GR increased for 24h. GPX decreased for 24h. C, CK, TAS, SOD and MDA increased for 48h. T decreased for 48h.
Souglis *et al*[40]	Male and Female Elite Male:23.1 ± 3.0 Female: 22.9 ± 2.4	Soccer	3 matches 2x 45 min per match Male: 86.9 ±4.3% of HRmax Female: 85.6 ± 2.3% of HRmax	Blood samples (IL-6, TNF-α, CRP, CK)	Pre, post, 24h and 48h post	IL-6 and TNF-α increased and returned to baseline within 24h. CRP decreased within 48h. CK increased for 48h.

Supplementary table Study characteristics of the included studies.

Reference	Subjects[a]	Sport	Type of Exertion Duration Intensity	Performance test and Biochemical marker	Time	Main Findings
Takarada[41]	- Elite-Amateur 26.6 ± 0.7	Rugby	Match - -	Blood samples (CK and Mb)	Pre, post and 24h post	Mb increased for 24h. CK increased through complete recovery period.
Twist & Sykes[27]	Male Club Level 23.5 ± 2.3	Rugby	Simulated match 2x 43 min 87 ± 3 and 83 ± 4 % of HRmax	Knee torque, CMJ and CK	Pre, post, 24 and 48h post	CK increased for 24h. Peak knee flexor torque decreased for 24h. Peak knee extensor torque and CMJ decreased for 48h.
Twist *et al*[28]	Male Professional 25.9 ± 5.1	Rugby	Match Backs: 80 min and Forwards: 50.7 min -	CMJ and CK	Pre, 24 and 48h post	CMJ decreased for 14h. CK increased through complete recovery period.
West *et al*[29]	Male Elite 24.9 ± 4.4	Rugby	Match - -	CMJ, blood samples (C, T and T:C)	36h pre, 12, 36 and 76h post	CMJ, T and T:C decreased for 36h. C increased for 36h.

C cortisol, *CK* creatine kinase, *CMJ* counter movement jump, *CRP* c-reactive protein, *GPX* glutathione peroxidase activity, *GR* reductase, *GSH* reduced glutathione, *GSSG* oxidized glutathione, *HR* hearth rate, *HRmax* maximum heart rate, *IL-1*β interleukin-1β, *IL-6* interleukin-6, *La* lactate, *LDH* lactate dehydrogenase, *Mb* myoglobin, *MDA* malondialdehyde, *MVC* maximum voluntary contraction, *NEFA* nonesterified fatty acids, *PC* protein carbonyls, *Pt* evoked twitch contractile properties of peak twitch force, *PT* maximal isometric peak torque, *PRFD* peak rate of force development, *RR* contraction duration and relaxation rate, *RTD* rate of torque development, *SH* sulfhydryl, *SOD* superoxide dismutase, *sVCAM-1* soluble vascular adhesion molecule 1, *T* testosterone, *TAC* total antioxidant capacity, *TAS* total antioxidant status, *TBARS* thioburbituric acid-reactive substances, *TNF*-α tumor necrosis factor alpha, *UA* uric acid, *s-IgA* Salivary Immunoglobulin A, *WBC* white blood cell count.
[a] Ages are presented in Mean ± SD, actual or range

PHYSICAL PERFORMANCE TESTS

Twelve studies used the CMJ as performance test to assess changes in jump height.[10,19-29] Reduced jump height indicated that the player was not yet fully recovered. However, there were also studies which used CMJ for different outcomes, such as peak power,[6,30,31] peak force,[30,31] mean power, mean force, flight time, contraction time or flight time:contraction time.[20] The reported results for CMJ height can be found in Figure 2 (ES range 0.24-1.22). The decrease in CMJ height ranged from 1.6 to 6 cm. Two studies show that CMJ height was decreased most immediately[21,27] or 30 min post-match.[26] Other studies did not measure immediately post-match except for one study.[25] These studies showed strongest decrease for CMJ height at 12[29] or 24[10,19,22-25] hours post-match. In one study, CMJ height was returned to baseline after 2 hours.[21] In the other studies CMJ height returned to baseline after 48[10,22,23,27] and 60[29] hours. There were three studies in which CMJ height did not increase to baseline values within the last measurement at 48[25,26] or 72[24] hours post-match of that study.

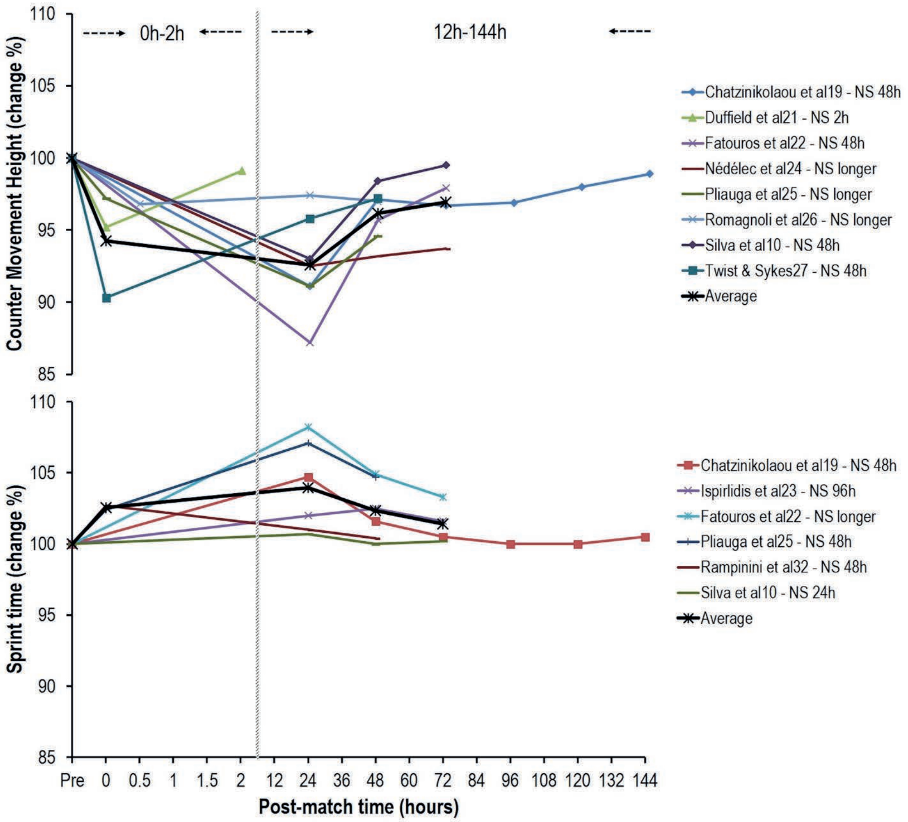

Figure 2 — Recovery time course changes (%) in countermovement jump height and sprint time from pre-match to 144 hours post-match. All studies were set on 100% pre-match. NS, non-significant from baseline values.

Six studies used sprint time to asses recovery, measured over the following distances: 5,[10] 10,[19,25] 20,[22,23] 30[10] and 40[32] meters(m). Figure 2 shows the reported results for sprint time over different distances, the results of 5m sprints are not displayed (ES range 0.30-1.10). All studies, except for one,[23] showed the strongest increase in sprint time at the first measurement after the match. This was immediately post-match[25,32] or at 24[10,19,22] hours post-match. Sprint time was returned to baseline values after, respectively, 48[10,19,32] or 96[23] hours. There were two studies in which sprint time did not decrease to baseline values within the last measurement at 48[25] or 72[22] hours post-match of that study. In one study none of the values was significantly different from premeasurement.[10]

Other performance tests which were used are for example, the maximum voluntary contraction test,[21,24,32] muscle function tests,[19,27] squat jump[30] and line drill test[19] (Supplementary table).

BIOCHEMICAL MARKERS

CK was the most frequently used biochemical marker and assessed in 19 studies.[6,10,19,22-28,33-41] The extent of increase of CK concentration differed among the studies (ES range 0.54-7.80) (Figure 3). In seven studies, peak values ranging from 100 to 500U/L were reported.[19,25-28,35,36] Twelve studies reported peak values which were strongly increased in comparison to their pre- measurement; values that were six or seven times higher were presented. These values ranged from 671 to 1411U/L.[6,10,22-24,33,34,37-41] Fourteen studies found peak values 24 hours post-match.[6,10,19,24-28,34,37-41] In the other studies peak values were reported after 14,[33] 18[35,36] or 48[22,23] hours. In 12 studies, CK concentration did not decrease to baseline within the times of measurement.[6,22,24-26,28,33,35,37-40] In the other studies, CK concentration returned to baseline after 42,[36] 48,[19,27,34,41] 72[10] or 120 hours.[23]

Other biochemical markers which were often used were C and T (Supplementary table). Eleven studies used C[10,19,20,23,26,29,33,36-38,42] and T.[10,19,20,23,26,29,33,35,36,38,42] T:C ratio as anabolic/catabolic balance was calculated in eight studies.[10,20,26,29,33,36,38,42]

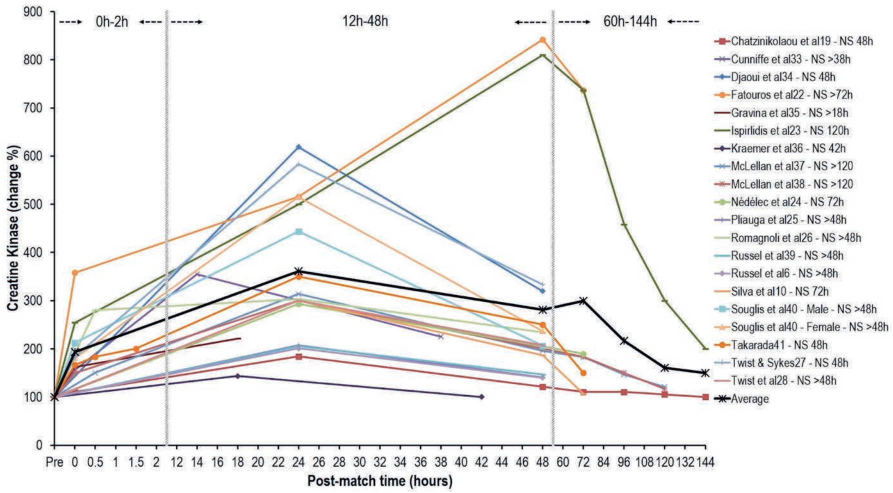

Figure 3 — Recovery time course changes (%) in creatine kinase from pre-match to 144 hours post-match. All studies were set on 100% pre-match. NS, non-significant from baseline values.

There were six studies which measured the concentration of C from blood samples[10,19,23,26,33,36] and five studies measured it from saliva samples.[20,29,37,38,42] Peak values measured from blood samples ranged from 219 to 662nmol/L, whereas peak values measured from saliva samples ranged from 16.3 to 80nmol/L. All studies reported peak values immediately after the match, except for one study[20] and the ones that did not measure immediately after.[10,29,36] These studies reported peak values at 14,[29] 18-20,[36] 24[20] and 48[10] hours post-match. In two studies, C was decreased to baseline values after 24 hours.[19,23] In the other studies this was at 14,[33] 48,[37,38] 60[29] or 72[10] hours. In three studies values became significantly different again at 38[33] and 96[37,38] hours post-match. In one study C was decreased for 48 hours post-match.[26] However, there were also two studies in which none of the values were reported as significantly different from baseline.[20,36] One study did not compare values with baseline measurements.[42]

Seven studies measured the concentration of T from blood samples,[10,19,23,26,33,35,36] the other four studies used saliva samples.[20,29,38,42] In four studies T concentration did not clearly increase or decrease pre-match or post-match.[10,19,23,36] One study reported a strong decrease pre-match[38] followed by an increase post-match with two other studies.[35,38,42] In four studies T concentration decreased post-match.[20,26,29,33] T concentration increased again to baseline values within 24[29,33] or 48[20] hours or stayed significantly different after 48[26] hours.

Finally, the supplementary table shows that six and five studies measured leukocytes[7,19,22,23,33,35] and uric acid,[10,19,22,23,35] respectively. C-reactive protein[10,19,23,26,33,35,40] and interleukin-6[7,19,23,26,33,40] were respectively used in seven and six studies. Other biochemical markers that were used are, for example, myoglobin,[10,36,41] lactate dehydrogenase,[23,35,36] protein carbonyls,[19,22,23] and salivary immunoglobulin A.[43]

DISCUSSION

The main purpose of this systematic review was to synthesize post-match recovery time courses of physical performance tests and relevant biochemical markers in team ball sports. The main finding is that physical test performance (e.g. CMJ height and sprint time) returned to baseline after 48 hours in most studies.[10,19,22,23,27,32] For the biochemical tests, higher variability within and between studies and tests is shown. In 14 out of 19 studies, CK returned to baseline after ≥72 hours[10,22-24,37,38] or did not decrease to baseline within the times of measurement.[6,22,24-26,28,33,35,37-40]

PERFORMANCE TESTS: ROLE OF TYPE OF SPORT, EXERTION AND PLAYING LEVEL

CMJ height was the most used performance test amongst the included studies. Players needed at least 48 hours to return to pre-match values on this test, with the exception of one study.[21] Sprint time was also used often as an indicator of recovery. Recovery time of sprint ranged between 24 and 96 hours. CMJ height and sprint time was measured only in male players in the included studies and effect sizes were small to moderate. In the literature, the validity, reliability and sensitivity of performance test was subject of debate.[44] For example, the value of jump height for measuring recovery is limited. Rowell *et al*[14] recently showed that flight time:contraction time is a more sensitive measure of recovery. Although, small within-player variation (CV<5%) and high intra-class correlation coefficient (ICC) are reported for the

CMJ and sprint tests,[45-52] the included studies showed CV's up to 12.8% and 8.2%, respectively. Changes exceed normal variation and thus are relevant.

For CMJ height, one explanation for the length of recovery time courses can be type of sport. Our results indicate relatively longer recovery time courses for basketball in comparison to other team ball sports. One basketball study needed more than 48 hours to reach non-significant values.[25] This can be confirmed by another basketball study that reported 96 hours.[53] The longer recovery time courses can be explained by the high number of jumps performed during basketball matches.[12,25,54,55]

For sprint time, duration of recovery time courses can be explained by type of sport, duration of exercise, and type of exertion. Two out of four soccer studies reported that more than 72 hours was needed to recover to baseline values.[22,23] The other type of sports, basketball[25] and handball,[19] showed shorter recovery time courses (i.g. between 48 and 72 hours). Variability in the duration of total playing time between soccer (2x45min), basketball (4x12min) and handball (2x30min) is evident. It might be expected that longer duration of exercise causes longer sprint recovery time courses. Furthermore, in contrast with soccer, basketball and handball are influenced by interruptions (e.g. time-outs, time between quarters, match stops) and the use of substitutions. More short-term recovery in sprint time can be expected when performing these intermittent sports compared to soccer.

Finally, for both CMJ height and sprint time, physical fitness indicated by differences in competition level might explain variability between study results.[56] One study with non-elite players showed a strong decrease in CMJ height directly post-match.[27] This is in accordance with Magalhães *et al*'s[57] that showed a strong decrease followed by a long recovery period (>72 hours) in 2nd and 3rd division soccer players. The sharp drop in jump height and subsequent longer recovery time may indicate that lack of physical fitness in these amateur players affects recovery. A similar pattern is seen in sprint time. This was relatively high at the lower in comparison to the elite level.[57,58] Players played second and third divisions[57] and secondary division,[58] respectively. In these studies, sprint time also needed to recover longer.

Biochemical markers and variability of recovery kinetics

The most used biochemical markers to monitor recovery were CK, C and T. Except for one study,[35] strict protocols were set up for measuring these biochemical markers. Players followed a controlled diet, were measured at exactly the same times of the day and were excluded from heavy exercise other than the match during the measurements. Although CK (effect sizes were large to very large) shows high variability (CV>25%) between individual players and poor sensitivity,[52,59-62] the included studies showed CVs up to >700%. This exceeds normal variation which makes it relevant to discuss. For C and T high ICCs are reported in standardized conditions.[63]

CK helps with the synthesis of ATP in muscles and increases after a match as a result of muscle damage.[64-66] All studies that investigated CK took blood samples after a match. Interestingly, 11 studies reported much higher peak values for CK concentration,[6,10,22-24,33,34,37-39,41] than other included studies.[19,25,27,28,35,36] A possible explanation for this might be type of sport. High peak values of CK were all found in soccer or rugby studies. The other studies represent more variation in type of sport. This suggests that soccer and rugby may be physically more demanding and muscle damage caused by for example, distance covered, accelerations and high impacts is higher.[38,67-69] According the literature this cannot be concluded unambiguously.[70] However, taking competition level, position on the field[21,71,72] and type of methodology (e.g. global positioning system, time-motion analyses)[73,74] into account, it complements studies investigating player load or recovery in these sports.[4,11,70,75-79]

Three studies in soccer and rugby reported lower peak values.[27,28,35] Deviation in one of these studies[27] might be explained by the fact that samples were taken after a simulated match, while in all studies that reported high peak values, samples were taken after an official match. Possibly, next to lower physical exertion during simulated matches,[80] lower peak values of CK can be expected.

C is an important catabolic stress response hormone and is considered to be increased as a result of playing a match.[64,81] The results of the included studies showed a high variance in time needed for C concentrations to decrease to baseline values. However, most soccer or rugby studies needed at least 48 hours to recover.[10,29,37,38] So, it seems that in line with CK also C is responsive to higher loads in soccer and rugby and this causes longer recovery times. This is in accordance with previous studies reporting a greater C response in higher intensity and longer duration.[82,83]

T is an anabolic hormone that stimulates glycogen synthesis and protein signaling which is needed for tissue repair.[64,84,85] In general, an unclear pattern of T-responses is demonstrated by the included studies. This is in line with previous reported differences between rugby and other sports by Cormack *et al*[20] that supports the high demands of this sport. In our systematic review one soccer one rugby study reported higher T-levels directly post-match and returned to baseline within 18-24 hours.[35,38] Another two studies showed a decrease immediately post-match followed by an increase to baseline within 14 hours[33] or delayed higher T-levels in the following days[42] in rugby players. Three studies showed a prolonged decrease that was interpreted as unclear and trivial by the authors,[20] increased to baseline after 60 hours[29] or deviation still 48 hours post-match.[26] Finally, in four studies no significant change in T concentration was found.[10,19,23,36] Individual variability in T-responses might explain the differences found in the studies.

Practical perspective

Overall, results of this systematic review suggest that team ball sports players need, in most cases, at least 48 hours to perform at the same level as pre-match. Some biochemical markers needed even longer to return to baseline values. Especially, CK is increased for ≥72 hours post-match. This is the case for all team ball sports. However, CK reached higher values in soccer and rugby. In addition, for soccer and rugby it took longer to return to baseline for sprint performance, CK and C in comparison with other team ball sports.

The slow decrease of CK suggests that, although performance is already at pre-match values, the muscles need more time to recover. This is an important finding that should be kept in mind working as a practitioner or support staff in daily practice with team ball sport players. In the decisions making process of determining adequate recovery, coaches should distinguish short term and long term under recovery and consider context such as stage of season. If for example performance is unaffected during a tournament, but biochemical indicators are, one can still decide to play in optimal formation. This is especially true when full recovery is possible after the tournament and cumulative fatigue is avoided. However, if biochemical markers indicate poor recovery without upcoming phases of rest, then coaches could implement recovery strategies or prescribe rest within the training schedule. This seems important to avoid the ongoing process of insufficient recovery that is not directly demonstrated by performance tests. Based on practical perspective and cost-benefit arguments, one could decide to only perform biochemical analyses with clear indication of ongoing insufficient recovery during for example, fixture congestion. Commonly used performance tests with their recovery time courses, will then, in all likelihood, deviate of biochemical markers that could indicate more precise muscle damage.

Finally, there is a need to understand individual players and their recovery profiles. Recovery is highly dependent on both variation in load that players are exposed during matches (e.g. position dependent and variation of time during matches) and individual capacities (e.g. aerobic and anaerobic).[24,32] These capacities determine how players respond to the match load and play an important role in their ability to recover from that load. Therefore, it is crucial to monitor individual match load and recovery.

STRENGTHS AND LIMITATIONS

This systematic review provides extensive insight in post-match physical recovery in team ball sports with at least two post-match measurements compared to pre-match values. This satisfies the lack of a valuable overview of post-match recovery time courses. Despite studies that not reported data in numbers in tables and/or text were excluded, results of these studies are affirmative with the results found.[53,57,58,79,86-88]

A limitation of this review is that it not provide information on the available tests and processes of psychological recovery. It has been stated that a disturbed balance between both, physiological and psychological, stress and recovery can lead to maladaptation and performance can be directly influenced by a poor mental state.[89,90] However, the aim of this systematic review was to understand and compare objective, single-construct, recovery measures after matches.

FUTURE RESEARCH

Twenty-three out of 28 included studies investigated recovery in soccer or rugby. Unfortunately, studies in other sports were not as extensive as the soccer or rugby studies. Therefore, it is more difficult to get an indication of recovery of players from these sports. High-level original research is needed to get more insight in post-match recovery in these sports. Furthermore, studies using recovery strategies or interventions, were excluded from this review. Future studies should also evaluate the effects of these recovery strategies (e.g. active recovery, sleep, mental recovery) on an individual level in the practical setting of team ball sports.

Key messages

What is already known on this subject?

- ► The recovery process is challenging to manage in team ball sports and depends on several contextual factors.
- ► Multiple performance tests and biochemical markers are used to monitor the time course of recovery after training and matches.
- ► Physical performance recovery takes up to ≥48 hours after regular training.

What are the new findings?

- ► After matches, underlying mechanisms of muscle recovery last up to ≥72 hours, despite recovery of physical performance after ≥48 hours.
- ► For soccer and rugby the time course of recovery is longer in comparison with other team ball sports for performance tests (sprint) and biochemical markers (CK and C).
- ► Clinical vigilance on 'hidden' recovery may prevent ongoing insufficient recovery in elite team sport players.

CONCLUSIONS

This systematic review has demonstrated high variability in post-match recovery time courses for various team ball sports within and between physical performance tests and biochemical markers. In addition, it is determined that CMJ height and sprint time recovers faster than CK. For the short-term, this suggest that on the basis of performance recovery players might be physically ready from 48 hours post-match for a subsequent training or match. However, on the long run, demonstrated by the longer time course of recovery of CK (≥72 hours), there might be the risk of ongoing insufficient recovery. For practitioners and support staff it is important to have clear and complete insight in these recovery processes for different type of sports. Imposing load without sufficient recovery might lead to injuries, illnesses, and non-functional overreaching.[91-93] Therefore, especially during fixture congestion with less than 48 hours of rest between consecutive matches, it is crucial to monitor match load and subsequent recovery closely based on recovery profiles.[94]

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Chapter 3

Impaired player-coach perceptions of exertion and recovery during match congestion

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ABSTRACT

During intensified phases of competition, attunement of exertion and recovery is crucial to maintain performance. Although a mismatch between coach' and players' perceptions of training load is demonstrated, it is unknown if these discrepancies also exist for match exertion and recovery. ***Purpose:*** The aims of this study are to determine match exertion, subsequent recovery and to investigate to what extent the coach is able to estimate players' match exertion and recovery. ***Methods:*** Rate of perceived exertion (RPE) and Total quality of recovery (TQR) of 14 professional basketball players (age 26.7±3.8 y, height 197.2±9.1 cm, weight 100.3±15.2 kg, body fat 10.3±3.6 %) were compared with observations of the coach. During an in-season phase of 15 matches within 6 weeks, players gave RPE after each match. TQR scores were filled out before the first training session after the match. The coach rated observed exertion (ROE) and recovery (TQ-OR) of the players. ***Results:*** RPE was lower than ROE (15.6±2.3 and 16.1±1.4; $p=0.029$). Furthermore, TQR was lower than TQ-OR (12.7±3.0 and 15.3±1.3; $p<0.001$). Correlations between coach' and players' exertion and recovery were $r=.25$ and $r=.21$, respectively. For recovery within 1 day the correlation was $r=.68$ but for recovery after 1-2 days no association existed. ***Conclusion:*** Players perceive match exertion hard to very hard and subsequent recovery reasonable. The coach overestimates match exertion and underestimates degree of recovery. Correspondence between coach and players is thus not optimal. This mismatch potentially leads to inadequate planning of training sessions and performance decrease during fixture congestion in basketball.

Keywords

RPE, intensity, regeneration, competition, performance, basketball.

INTRODUCTION

In elite team sports, players have to cope with extremely high physical and psychosocial demands to achieve success. Frequency, duration and intensity of training and matches are high and players have to adapt to dense playing schedules with short recovery periods between consecutive matches.[1] Next to domestic league championships and CUP-matches, players have to perform in mid-week international competitions like the Europa League in soccer or Euro league in basketball. Such congested schedules can have negative consequences for team performance[2-4] and increasing injury risk.[5]

For training and coaching staff it is imperative to monitor and control the load to optimize the recovery between matches and performance for the next one, which can be done through appropriate prescription of training. This requires an individual approach, that takes variability in playing time caused by disruptions and substitutions into account.[6] For an optimal planning of training sessions between matches, it is vital that the intended loads match the actual load of players.[7] In general, a poor relationship between planned and actual training load is reported with a general tendency of coaches to overestimate training load.[8-10] More specific, it appears that coaches underestimate player load in low intensity training and overestimate in high intensity training sessions.[10,11]

Knowledge of match exertion can help plan the training sessions but this is not yet known. Furthermore, it is unclear if coaches can accurately estimate these match loads for the planning of subsequent training. Mainly for practical reasons (e.g. no time, unresponsive players immediately after the match, match location) it is harder to gather this information in the real-match-context instead of the training context.[12] In order to guide the training process following these matches, a realistic view of the match exertion is needed for each individual player, especially during fixture congestion. Coaches that are well informed about players' match exertion are thus crucial to find the optimal balance between exertion and recovery and to subsequently prevent underperformance.

Next to specific match and training exertion, coaches need to know effects of ensuing fatigue and ability of individual players to recover for an upcoming match or training to optimize periodization plans. To illustrate, insufficient recovery time could lead to performance decrement. Moreover, accumulative effects from both matches and training have the potential to decrease performance even further.[13]

To indicate recovery performance tests (e.g. sprinting, jumping), biochemical markers (e.g. creatine kinase) and self-reported instruments are used to give more insight in recovery processes.[14] Kenttä & Hassmén[15] introduced The Total Quality of Recovery scale to measure psychophysiological recovery. This self-report measure is a promising tool because it measures the total recovery state of a player, similar to RPE for exertion.

In sum, no studies have yet examined match exertion and subsequent recovery during fixture congestion in professional basketball. Furthermore, the ability of the coach to observe player match exertion is not investigated yet. Finally, no information is currently available to what extent coaches are able to estimate players' quality of recovery before the first post-match training session by observation. Yet, to carefully plan succeeding training sessions it is of high importance to acquire more insight and knowledge in this particular matter. Hence, the aim of this study is to determine match exertion, recovery and to investigate to what extent the coach is able to estimate players' match exertion and total quality of recovery within an in-season intensified competition period.

METHODS

Subjects

Fourteen elite basketball players playing at the highest competition level of the Dutch Basketball Association participated in this study. Characteristics of the players are mean (±*SD*) age (years) 26.7±3.8, height (cm) 197.2±9.1, weight (kg) 100.3±15.2, body fat (%) 10.3±3.6. The head coach, assistant coach and strength & conditioning coach were responsible for the training program. The head coach is licensed and certified to coach at the highest level nationally and internationally and has more than 10 years of experience in elite basketball as a professional coach. Players underwent different types of training (e.g. technical basketball drills, tactical, specific strength and conditioning with intermittent character) during the intensive training and match period within the competitive season (Table 1). The ethical committee of the Center for Human Movement Sciences of the University of Groningen approved the study and written informed consent was obtained from the subjects.

Table 1 — Overview of weekly player activities during the study.

Day	Morning activities	Afternoon activities
Monday	Technical/Tactical training	Travelling
Tuesday	Shooting/video	Euro league match
Wednesday	Travelling	Shooting
Thursday	Shooting/video	Dutch league match
Friday	Strength and conditioning	Technical/Tactical training
Saturday	Shooting/video	Dutch league match
Sunday	Rest	Rest

Experimental protocol and procedures

During an intensive competition period of 15 matches (8 domestic league, 1 CUP-league and 6 Euro league) within 6 weeks (2.5 matches per week) rating of perceived exertion (RPE) on a 6 (no exertion) to 20 (extreme exertion) scale was obtained of the players thirty minutes after each match individually. Each player was asked to provide his subjective perception of the match by pointing his finger to the 6-20 scale.[16] Session-RPE is a valid method to assess individual exertion including disruptions and substitutions in professional elite-standard basketball players.[4] Playing time of each player was noted from start to end of the match excluding all interruptions in the match (e.g. time-outs, time between quarters, match stops, injury time) to calculate match load (intensity × duration, warming-up excluded).[16] Players pointed with their finger to their total quality of recovery score (TQR) on a 6 (no recovery) to 20 (maximal recovery) scale[15] before the first post-match training session. These scores were individually assessed before the morning training session (between 8-10 a.m.) of that day. It is assumed that the TQR measures individual characteristics of player recovery.[15] The coach gave his rating of observed exertion (ROE) for each individual player within the same time course (30 minutes) after the match like the players. Furthermore, the coach was instructed to provide total quality of observed recovery (TQ-OR) scores for each individual player on the same scale as the players did directly before the start of the first post-match training session. A familiarization trial of players and coach took place four weeks before data collection started. They were informed verbally on the procedures and were supervised on a daily basis during the whole period. One investigator collected all data.

Statistical analysis

Means and standard deviations were calculated for duration, RPE, ROE, match load, TQR and TQ-OR. One player was excluded in the analysis because of an injury and two players for being a non-starter/reserve with no playing time over the whole observation period. Players had to meet ≥10 minutes of actual playing time per match to include obtained scores in the analysis. Paired sample T-tests were used to analyze differences between RPE and ROE and TQR and TQ-OR. Effect sizes (ESs, Cohen's *d*) and 90% confidence intervals (CI) for effect sizes were calculated for all comparisons. Criteria for Cohen's *d* values are $0.2 \leq d \leq 0.5$, $0.5 \leq d \leq 0.8$ and $d \geq 0.8$ representing small, moderate and large effect, respectively.[17] Bivariate Pearson correlation coefficients were calculated to evaluate the relationship between RPE and ROE and TQR and TQ-OR. Recovery scores obtained within 1 day (12-24 hours) post-match and after 1-2 days (24-48 hours) post-match were separated in the analysis. Bland Altman plots were used in analyzing the agreement between the measurements and for detecting outliers. Criteria for the interpretation of correlations were set on: 0-0.3 negligible association, 0.3-0.5 low association, 0.5-0.7 moderate association, 0.7-0.9 high association and 0.9-1.0 very high association.[18] Statistical analyses were performed using SPSS software (version 23.0; SPSS Inc., Chicago IL). P-values lower than .05 were considered as statistically significant.

RESULTS

RPE and ROE of 15 matches and TQR and TQ-OR before 14 post-match training sessions were obtained. Mean actual playing time was 25.6±6.9 (min). Match load was 403±135 (arbitrary units [AU]) and 418±130 (AU) for players and coach respectively. Mean RPE was 15.6±2.3 and ROE was 16.1±1.4. ROE (t=-2.21, df=112, p=0.029, ES=-0.26, CI=-0.48 to -0.04) was significantly higher than RPE. Mean TQR was 12.7±3.0 and TQ-OR was 15.3±1.3. TQ-OR (t=-8.36, df=87, p<0.001, ES=-1.12, CI=-1.39 to -0.85) was significantly higher than TQR.

Mean time between the match played and next planned training session was 28.0±11.4 (hours). After 7 matches was the next training within 1 day (12-24 hours) and after another 7 matches after 1to 2 days (24-48 hours). TQR and TQ-OR scores within 1 day were respectively mean 13.1±2.8 and 15.4±0.8 and TQR (t=-6,61, df=42, p<0.001, ES=-1.12, CI=-1.49 to -0.73) was significantly lower than TQ-OR. After 1-2 days TQR was lower (12.3±3.2) compared to TQ-OR (15.3 ± 1.7) (t=-5,73, df=44, p<0.001, ES=-1.17, CI=-1.54 to -0.79) (Figure 1).

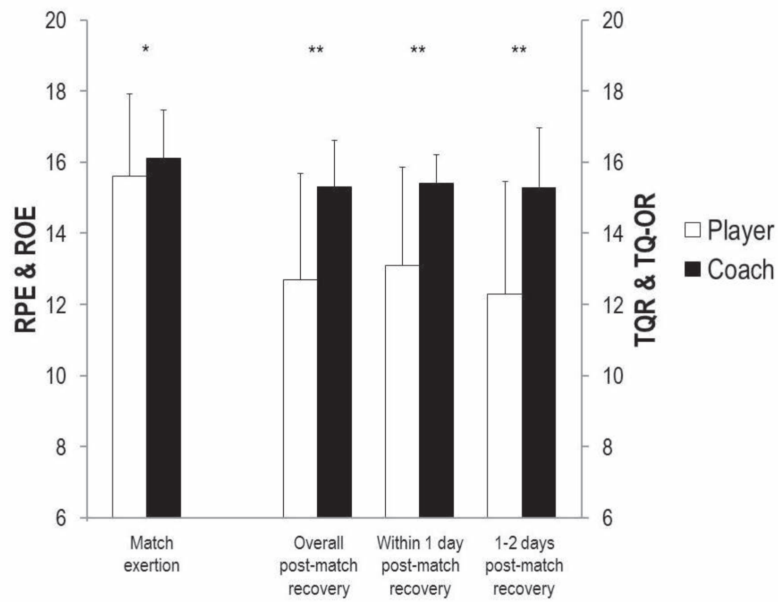

Figure 1 — Comparison between players and coach on match exertion (n = 113), overall post-match recovery (n = 88), within-1-day post-match recovery (n = 43), and after 1 to 2 days post-match recovery (n = 45). Abbreviations: RPE, rating of perceived exertion; ROE, rating of observed exertion; TQR, total quality of recovery; TQ-OR, total quality of observed recovery. **P* < .05; ***P* < .001.

Figure 2 shows the Pearson correlation coefficients for RPE and ROE and TQR and TQ-OR. Correlation between RPE and ROE was r=.25 (p<0.01) and between TQR and TQ-OR r=.21 (p<0.05). Data points above the lines of equality indicate overestimation of match exertion and post-match recovery by the coach.

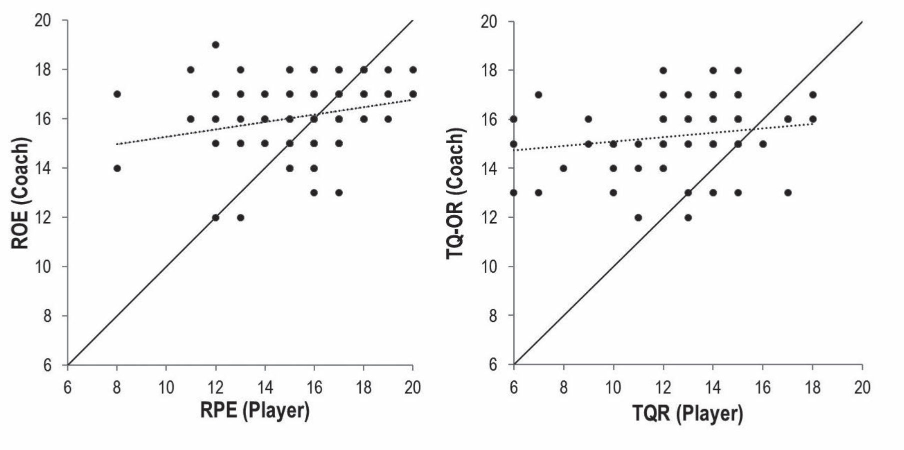

Figure 2 — Relationships of rating of perceived exertion (RPE) and rating of observed exertion (ROE) (n = 113) and of total quality of recovery (TQR) and total quality of observed recovery (TQ-OR) (n = 88). Solid line indicates equality; dotted line, regression.

Pearson correlation coefficients for TQR and TQ-OR within 1 day and after 1-2 days are presented in Figure 3. The association was r=.68 ($p<0.001$) and no correlation respectively. Data points above the lines of equality indicate underestimation of post-match recovery by the coach.

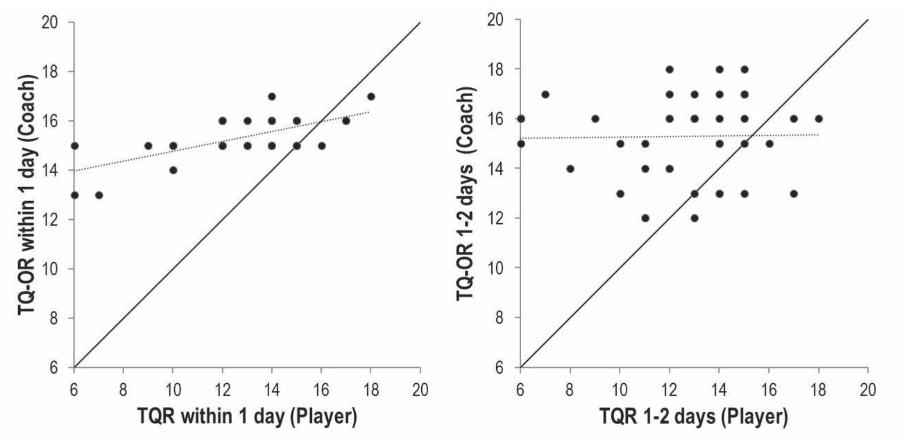

Figure 3 — Relationships of total quality of recovery (TQR) and total quality of observed recovery (TQ-OR) for within 1 day (n = 43) and after 1 to 2 days (n = 45). Solid line indicates equality; dotted line, regression.

DISCUSSION

The aims of the present study were to determine match exertion, subsequent recovery and investigate to what extent the coach is able to estimate players' match exertion and total quality of recovery within an in-season intensive game phase (i.e. 2.5 matches per week over several weeks).

The first finding was that the Mean Rate of Perceived Exertion of players was between hard and very hard and mean Total Quality of Recovery was reasonable. This is the first study presenting player match exertion and subsequent recovery in elite basketball during congested fixtures. For match exertion in elite team sports no reference values are available. However, extreme exertion might be expected in this intensive phase of competition. Relatively poor recovery scores by players after 1 to 2 days post-match could be explained by the delayed onset of muscle soreness (DOMS).[19] It is shown in elite team sports that peak scores of DOMS are reported at 24 [20] and 48 hours.[21] Results of performance tests are congruent and also report these recovery time courses.[20-25]

The second finding was that coach' and players' perceptions show variability for match exertion and recovery. This variability can partly be explained by individual differences in playing time. Divergence in perceptions highlights the need to track exertion and post-match recovery individually, regularly and accurately during the training process.[14]

For match exertion, Rate of Observed Exertion of the coach was higher than the Rate of Perceived Exertion of players. In addition, results suggested a weak relationship between observed exertion of the coach and experienced exertion of players. Overestimation by the coach is in contrast with previous findings during training sessions in other sports.[26,27] In elite junior tennis players and volleyball players, coaches underestimated session-RPE after they observed training sessions.[26,27] However, it is known that when training sessions are designed to be hard by the coach, these sessions are perceived less intense by the players.[10,11,28] This suggests that the high imposed intensity levels planned by the coach might not be reached during training.[10] This may also be true for matches where coaches expect maximal exertion. During matches other contextual factors (e.g. atmosphere, crowd, motivation, match result, sponsors) may further explain the differences in perceptions. This remains to be determined.

For recovery, the coach significantly overestimated post-match recovery of the players. Moreover, results indicated a weak relationship (r=.21) of post-match recovery between coach estimates and players' perceptions. So, the coach expects good recovery before the next training session even though previous match exertion is overestimated. Along with overestimation of match exertion and underestimation of recovery in general, a remarkable difference was shown between player-coach recovery scores within 1 day and after 1-2 days. Results indicated a reasonable relationship between estimated coach recovery and players' perceived recovery within 1 day post-match (r=.68). However, no correlation was found for a recovery time after 1-2 days.

An explanation for the deviation of post-match recovery scores can be that players are out of sight of the coach after the match until the following training session. As a result, the coach has little insight in the activities that players may undertake in the days between the match and the first training session. These activities could either enhance recovery (e.g. active recovery, sleeping, compression garments, etc.)[29,30] or reduce recovery (e.g. individual training in private time or stress full events in personal life of players). The longer the player is out of sight of the coach the more activities may have happened. Moreover, because recovery time courses of 1-2 days are associated with better recovery,[30] higher coach estimates are expected after 1-2 days post-match. Finally, individual differences in recovery curves between players may be more pronounced after 1-2 days instead of within 1 day. The recovery process of players varies naturally due to individual characteristics of the player, i.e. one recovers faster than the other depending for example on physical fitness.[7] Because the coach showed a greater variation in recovery scores after 1-2 days (Figure 3), it indicates that he might take this into account. For recovery, other contextual factors like for example the potential impact of travel-induced fatigue when playing away (especially Euro league matches) may further explain differences in perceptions.

This is the first study that collected players' and coach responses of matches. Subsequent post-match recovery of players' perceptions and coach estimates are presented. Furthermore, this study adds interpretation of different recovery times to the current body of knowledge, emphasized by the strong deviation between players' perceptions and coach estimates after 1-2 days post-match recovery and its potential negative consequences for performance. Finally, our study design with 2.5 matches per week periodization accounting for within match substitutions and between successive matches player rotation is scarce and warranted.[6]

Limitations and future research

Limitation of the study is that data of one team and one coach is observed. In addition, no data on recovery activities is collected. The first limitation might affect the generalizability of the outcomes. However, it is likely that the number of players and coaches diverges in player-coach studies in team sports.[8,10,27] This observational study design meets the real practical context of a professional basketball team playing at the highest national competition level and Euro league during fixture congestion. It is important not to interfere in this process. The present study demonstrated that with simple tests for monitoring individual match exertion and post-match recovery is obtained from players and coach.[14]

The recovery process must be approached as a complex mechanism in which both physical and psychosocial processes are involved. Future research should aim to track psychophysiological recovery after matches continuously. Moreover, it is recommended to identify and apply player recovery enhancing activities during time-off. Next to physical recovery strategies (e.g. active recovery) are sleep and mental recovery strategies like debriefing an interesting field of research to apply in elite team sports. Study designs should meet congested playing schedules in elite team sports to understand its consequences on performance.

CONCLUSION

In conclusion, results showed that players perceived match exertion between hard and very hard and subsequent recovery was reasonable. The coach overestimated match exertion of players with poor correspondence. Overall post-match recovery was underestimated by the coach. Furthermore, for recovery within 1 day moderate association and after 1-2 days negligible association was demonstrated. The coach overestimated the ability of players to recover and adapt well after 1-2 days before a consecutive training stimulus is introduced. It can be concluded that in this in-season intensive game phase the coach was not able to give an optimal estimation of players' match exertion and total quality of recovery of professional basketball players.

PRACTICAL APPLICATIONS

For training and coaching staff of team sports, it is very important to have clear insight in individual match exertion and subsequent recovery of players. Tools like RPE and TQR improves understanding of players' perceptions of exertion and recovery and are therefore recommended in daily practice. When doing this, coaches should be aware of potential automatic player responses. A discrepancy between players' and coaches' perceptions might have negative consequences on the subsequent training content. Overestimation of match exertion by the coach might lead to too easy training sessions. On the other hand, underestimation of the degree of recovery for a subsequent training session potentially imposes too hard training sessions. Communication between coach, support staff and player is crucial to track exertion and post-match recovery over time. Subsequently, players can be supported with adequate recovery time and evidence-based effective recovery strategies.[30] Furthermore, coaches should adapt to congested playing schedules within their training plans. Short recovery times between successive matches are likely not to meet sufficient recovery and therefore recovery-enhancing activities are even more important to strive for optimal performance.

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Chapter 4

Managing load to optimize well-being and recovery during short-term match congestion in elite basketball

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ABSTRACT

In elite basketball, players are exposed to intensified competition periods, when participating in both national and international competitions. How coaches manage training in between matches and in reference to match scheduling for a full season is not yet known. ***Purpose:*** Firstly, to compare load during short-term match congestion (i.g. ≥2-match weeks) with regular competition (i.g. 1-match weeks) in elite male professional basketball players. Secondly, to determine changes in well-being, recovery, neuromuscular performance and injuries and illnesses between short-term match congestion and regular competition. ***Methods:*** Sixteen basketball players (age 24.8±2.0 years, height 195.8±7.5 cm, weight 94.8±14.0 kg, body fat 11.9±5.0 %, VO_{2max} 51.9±5.3 $mL·kg^{-1}·min^{-1}$) were monitored during a full season. Session rating of perceived exertion (s-RPE) was obtained and load was calculated (s-RPE x duration) for each training session or match. Perceived well-being (fatigue, sleep quality, general muscle soreness, stress levels and mood) and total quality of recovery (TQR) were assessed each training day. Countermovement-jump (CMJ) height was measured and injuries and illnesses were collected weekly using the adapted Oslo Sports Trauma Research Center (OSTRC) Questionnaire on Health Problems. ***Results:*** Total load (training sessions and matches) ($p<.001$) and training load ($p<.001$) were significantly lower for ≥2-match weeks. Significantly higher well-being ($p=.011$) and less fatigue ($p=.001$) were found during ≥2-match weeks compared to 1-match weeks. ***Conclusion:*** Total load and training load were lower during short-term match congestion compared to regular competition. Furthermore, better well-being and less fatigue were demonstrated within short-term match congestion. This might indicate that coaches tend to overcompensate training load within intensified competition.

Keywords

RPE, regeneration, wellness, performance, overuse.

INTRODUCTION

In elite basketball, players are subject to the delicate balance between load and recovery during in-season intensified competition periods, participating in both national and international competitions. This leads to a high match frequency and subsequently to a high physical and psychosocial load.[1,2]

Density in match schedules is often referred to as fixture congestion and may influence performance.[1,3-5] It is known that playing two competitive matches per week impairs players' capacity to sprint, jump and perform repeated intensive activities compared to one match per week.[2]

Aside from the physical consequences in reference to dense match schedules, it may also lead to psychosocial stress, given the consequences of for example team dynamics, pressure of spectators and coach-athlete relationship. Results of previous studies have shown deteriorations in psychological state after competitive matches.[6,7] This might negatively influence subsequent performance along injury occurrence.[8]

Training and coaching staff may anticipate on short-term match congestion by squad rotation management.[9] Furthermore, training sessions in between can be adjusted in load by decreasing frequency, intensity or duration. When planning subsequent training sessions, coaches ideally take the individual ability to recover into account and determine personalized training regimes.[10,11]

Sufficient recovery time between successive matches is assumed key in fixture congestion. To understand possible performance decrements, it is crucial to have clear insight in players' recovery during short-term match congestion (i.g. ≥2-match weeks) compared with regular competition (i.g. 1-match weeks).[12] Furthermore, it is imperative for training and coaching staff to manage players' fatigue by monitoring to avoid maladaptive responses throughout the competitive season.[13]

To understand the complex mechanisms of recovery kinetics in elite basketball, especially during match congestion, multidimensional monitoring of player' recovery is recommended.[10,14] It is previously demonstrated that self-reported well-being and recovery are sensitive to an acute increase in load and are impaired during periods of intensified competition.[15,16] Next to that, neuromuscular recovery as complementary objective measure is used.[16] If there is inadequate recovery while load remains high, it is assumed that injury occurrence increases.[16] Moreover, rapid increases of load are likely to increase the risk for injuries and illnesses.[18]

In summary, considering potentially negative consequences of multiple matches per week, it is important to gain more insight in training load periodization. How coaches are dealing with this matter is unclear. Moreover, its consequences on the recovery kinetics over an entire season in elite basketball remains to be determined to maintain performance and prevent injuries and illnesses. Hence, the aim of this study is to compare load during short-term match congestion (i.g. ≥2-match weeks) with regular competition (i.g. 1-match weeks) over a full season in elite male professional basketball players. Subsequently, to gain more insight in recovery kinetics, differences in well-being (i.g. fatigue, sleep quality, general muscle soreness, stress levels and mood), total quality of recovery, neuromuscular performance and injuries and illnesses will be compared between the two conditions.

METHODS

Subjects

Sixteen elite basketball players playing at the highest level of the Dutch Basketball Association of two professional basketball teams participated in this study. Characteristics of the players are mean ± SD age 24.8 ± 2.0 years, height 195.8 ± 7.5 cm, weight 94.8 ± 14.0 kg, body fat 11.9 ± 5.0 % and VO_{2max} 51.9 ± 5.3 $mL \cdot kg^{-1} \cdot min^{-1}$.

All training sessions and matches were executed as prescribed by the head coaches, assistant coaches and strength and conditioning staff without any interference or manipulation. Training sessions consisted of strength training, technical training, tactical training, shooting practice, drills, intermittent exercise sessions and recovery training. Measurements were organized in a way that minimized impact on the normal preparation and structure of training sessions and matches. During pre-season players were familiarized with the experimental protocol, procedures and measurements. The ethical committee of the Center for Human Movement Sciences of the University of

Groningen approved the study protocol, and written informed consent was obtained from the subjects.

Experimental protocol and procedures

During this prospective observational study, players were monitored during a full season. Figure 1 shows an overview of measurements during an intensified competition week (i.g. ≥2-match week) within the study. Next to daily training and match load, well-being, total quality of recovery, neuromuscular performance and injuries and illnesses were measured.

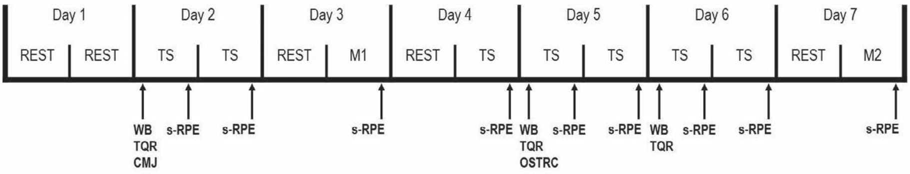

Figure 1 — Overview and time points of measurements during ≥2-match weeks in the study. CMJ indicates countermovement jump; M1, match1; M2, match 2; OSTRC, Oslo Sports Trauma Research Center Questionnaire on Health Problems; s-RPE, session rating of perceived exertion; TS, training session; TQR, total quality of recovery; WB, well-being.

Session Rating of Perceived Exertion (s-RPE) was obtained individually thirty minutes after each training session or match. Intensity was rated on a 6 (no exertion) to 20 (extreme exertion) scale. Training and match load were calculated by multiplying s-RPE with training or match duration (excluding warming-up, interruptions, time-outs, time between quarters, match stops, injury time) and expressed in arbitrary units (AU).[19] Session RPE is a valid method to monitor exercise intensity including disruptions and substitutions in professional elite-standard basketball players.[20]

Well-being and Total Quality of Recovery (TQR) were assessed individually thirty minutes before the first training session on training days between 8.00 and 10.00 AM. The 'Well-being Questionnaire'[21] consists of five items (fatigue, sleep quality, general muscle soreness, stress levels and mood) and was rated on a scale from 1 (most negative) to 5 (most positive) with 0.5 intervals. The overall well-being was calculated by summarizing the scores on the five items.

The ‘Well-being Questionnaire’ is based on previous recommendations[22] and showed sensitivity for changes of preceding load.[21] TQR was rated on a 6 (no recovery) to 20 (maximal recovery) scale. The TQR-scale was designed to monitor individual characteristics of player recovery.[23]

Neuromuscular performance (NMP) was assessed by performing countermovement jumps (CMJ) between 8.00 and 10.00 AM of that day. CMJ is a reliable and valid indicator of NMP in team sports.[24] CMJ height was measured using a portable contact platform (ProJump, Lode BV, Groningen, the Netherlands). Players were instructed and demonstrated to perform 5 maximal vertical jumps with ~3 seconds rest between each jump.[25] The jump began with the player standing in upright position, followed by bending the knees to a self-selected depth, before jumping with maximal vertical height. Hands were placed on the hips during the whole procedure to exclude arm swing influence on CMJ performance. The mean CMJ height of 5 jumps was calculated and used for analysis since it provided the most reliable performance measure for repeated CMJ’s (CV 1,9% in elite athletes).[24]

Acute and overuse injuries and illnesses were collected weekly using the adapted Oslo Sports Trauma Research Center (OSTRC) Questionnaire on Health Problems.[26] The questionnaire contains four key questions on the consequences of health problems on sports participation, training volume and sports performance as well as the degree to which athletes have experienced symptoms. Each of these questions has four possible answers, in which answering the minimum score on all of them finishes the questionnaire. However, if athletes reported anything other than the minimum value for any question, subsequent questions followed. The remaining questions provided additional information about the problem. Most importantly, they specify whether the problem was an injury or illness, and the number of days of time loss caused by it. The OSTRC Questionnaire on Health Problems, based on the OSTRC Overuse Injury Questionnaire, which is validated in elite team sports, enables reliable registration of all type of problems including illness, acute injury and overuse injury.[26]

Statistical analysis

Individual player data were analysed per week. Means and standard deviations were calculated for total load (training sessions and matches), duration, and s-RPE and training load, training duration and training s-RPE for ≥2-match weeks and 1-match weeks. Subsequently, well-being, fatigue, sleep quality, general muscle soreness, stress levels, mood, TQR, CMJ, prevalence of injuries and illnesses, severity scores and time loss were calculated for ≥2-match weeks and 1-match weeks over the season. Matchless weeks were excluded from the analysis and players had to have ≥10 minutes of playing time in 90% of all matches to be included in the analysis. To investigate changes for well-being, fatigue, sleep quality, general muscle soreness, stress levels, mood, TQR, CMJ, prevalence of injuries and illnesses, severity scores and time loss the data were analyzed using multi-level modeling with MLwiN (version 2.35 for Windows).[27] Multi-level analysis is able to include dependent data and can handle a varying number of measurements between players, which is inevitable in a repeated measures design. The actual data does have missing values. Multi-level analysis can make use of all available data in the prediction of model parameters due to its flexible treatment of the time predictor. Missing values in the dataset were at random.

Separate multilevel models were created for the following outcome measures: well-being, fatigue, sleep quality, general muscle soreness, stress levels, mood, TQR, CMJ, injuries and illnesses. The multilevel model was created with repeated measures within players (level 1), differences between players (level 2) and between teams (level 3). First step was to create an empty model predicting the averages of the players on the outcome measures. The second step was to create a 2-level model indicating possible differences between measurements, therefore time points were added to the intercept model. Finally, a 3-level model was created to indicate possible differences between teams. The model fit was evaluated by comparing the -2Log Likelihood of the empty model with the final model. Furthermore, differences between ≥2 match weeks and 1-match weeks were evaluated by comparing the mean of the coefficient and its standard error (SE) (coefficient/SE >1.96 = significant). The possible differences were calculated for well-being, fatigue, sleep quality, general muscle soreness, stress levels, mood, TQR, CMJ, injuries and illnesses.

Effect sizes were calculated by f^2.[28] Guidelines for interpretation of f^2 indicate that 0.02 is a small effect, 0.15 is a medium effect, and 0.35 is a large effect.[29] P-values lower than .05 were considered as statistically significant.

RESULTS

Table 1 shows total load (training sessions and matches) and training load, which displays duration, s-RPE and training duration, training s-RPE, respectively, for ≥2-match weeks compared to 1-match weeks. Furthermore, perceived well-being, fatigue, sleep quality, general muscle soreness, stress levels, mood, TQR and CMJ height and, as outcome measures for injuries and illnesses severity scores and time loss are presented. The prevalence of injuries and illnesses are 17.2% and 3.3% for ≥2-match weeks and 18.1% and 4.6% for 1-match weeks, respectively.

Table 1 — Total load (training sessions and matches) and training load displays duration and s-RPE for ≥2-match weeks and 1-match weeks. Perceived well-being, TQR and CMJ height, severity score and time loss for ≥2-match weeks and 1-match weeks. Abbreviations: s-RPE, Session Rating of Perceived Exertion; AU, arbitrary units; TQR, Total Quality of Recovery; CMJ, countermovement jump. All data are displayed as mean±se.

	≥2-match weeks	**1-match weeks**	**P-value**
Total load (s-RPE x duration) (AU)	7730.5 ± 2499.27	9307.8 ± 3028.63	< 0.001
s-RPE	13.1 ± 1.84	13.7 ± 1.59	< 0.001
Duration (min)	592.1 ± 171.93	671.7 ± 201.00	0.001
Training load (s-RPE x duration) (AU)	5651.8 ± 2259.72	8155.11 ± 2870.41	< 0.001
Training s-RPE	12.2 ± 2.24	13.3 ± 1.70	< 0.001
Training duration (min)	446.2 ± 159.49	596.8 ± 194.04	< 0.001
Well-being	18.5 ± 1.36	18.2 ± 1.60	0.011
Fatigue	3.5 ± 0.44	3.4 ± 0.51	0.001
Sleep quality	3.8 ± 0.30	3.8 ± 0.35	0.183
General muscle soreness	3.4 ± 0.50	3.3 ± 0.56	0.081
Stress levels	3.9 ± 0.33	3.8 ± 0.38	0.265
Mood	4.0 ± 0.30	4.0 ± 0.35	0.116
TQR	14.0 ± 1.03	13.9 ± 1.06	0.163
CMJ height (cm)	36.5 ± 1.35	36.4 ± 1.39	0.907
Severity score (0-100)	13.5 ± 29.11	16.4 ± 30.46	0.335
Time loss (number of days)	2.5 ± 2.70	2.5 ± 2.93	0.528

To indicate load distribution over the season for ≥2-match weeks and 1-match weeks, for one team (*N*=9) total load (training sessions and matches) and training load are presented (Figure 2). Note that matchless weeks 12, 13 (winter break) and 20 were excluded in the analysis and therefore not presented.

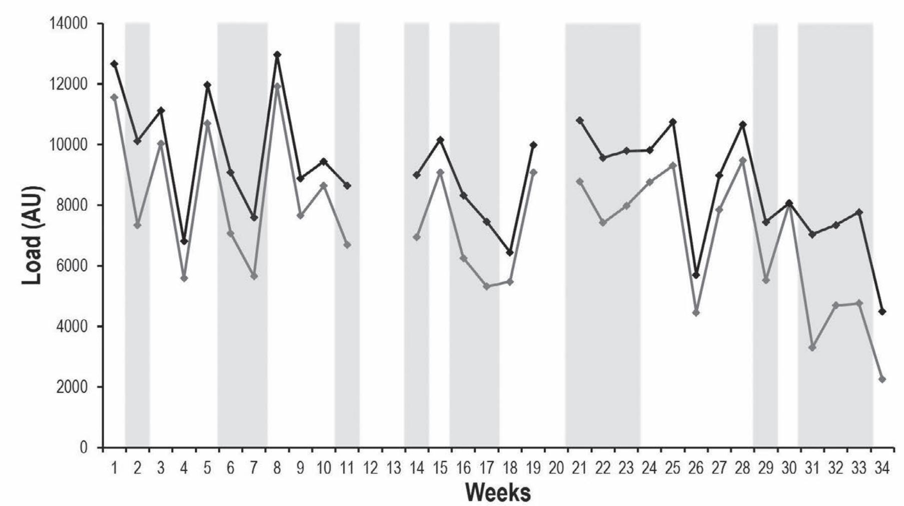

Figure 2 — Total load (training sessions and matches; black line) and training load (gray line) for 1 team (N=9) per week over the season. Gray vertical blocks indicate ≥2-match weeks.

Table 2 presents predicted total well-being and fatigue. Adding level-2 (measurements between players) to the empty model significantly increased the model fit. No increased model fit was found for differences between teams (level 3). Therefore, a 2-level model is used. Well-being (f^2 =.0001; CI: 17.72 – 18.78) and fatigue (f^2 = .04; CI: 3.16 – 3.52) are significantly improved in ≥2-match weeks compared to 1-match weeks. Sleep quality, general muscle soreness, stress levels, mood, TQR, CMJ height (individual CV's 1.1% to 5.9%), severity score and time loss are not significantly different for ≥2-match weeks compared to 1-match weeks.

Table 2 — Multi-level models for predicted well-being and fatigue and the difference between 1-match weeks and ≥2-match weeks.

N=427	Model	Intercept (constant)	Estimate (s.e)	Level 2 between players	Level 1 within players	Log likelihood (χ2)
Well-being	Empty model	18.37 (0.26)	-	1.05 (0.39)	1.26 (0.09)	1361.68
		18.25 (0.27)	0.28 (0.11)	1.05 (0.39)	1.24 (0.09)	1355.20*
Fatigue	Empty model	3.41 (0.09)	-	0.18 (0.04)	0.12 (0.01)	353.31
		3.34 (0.09)	0.11 (0.03)	0.12 (0.04)	0.12 (0.01)	342.75**

*p = 0.011 **p = 0.001

DISCUSSION

The aim of this study was to compare load during short-term match congestion (i.g. ≥2-match weeks) with regular competition (i.g. 1-match weeks) in elite male professional basketball players over a full season. The second aim was to investigate differences in well-being (i.g. fatigue, sleep quality, general muscle soreness, stress levels and mood), total quality of recovery, neuromuscular performance and injuries and illnesses for both conditions.

The first main finding was that total load (training sessions and matches) and training load were significantly lower during short-term match congestion compared to regular competition. Although, this is the first study that captured a full season in basketball, this has been reported previously.[30] More specifically, players reported significantly lower total s-RPE and training s-RPE during short-term match congestion compared to regular competition. Their s-RPE corresponded with *fairly light* for short-term match congestion and *somewhat hard* for regular competition. Next to a lower s-RPE, total and training duration were significantly lower during short-term match congestion. Interestingly, a large standard deviation was seen in duration of training which suggest that programs were tailored to the needs of the individual player.

A lower training load during short-term congestion, indicate that coaches focused on maintenance of fitness and prevention of overload.[30] Fairly light perceived exertion and relatively short training duration are likely a result of a carefully managed training program, including effective recovery strategies.[23] Although, this might be interpreted as beneficial, it could also result in underload and suboptimal performance. Our results suggest that the training and coaching staff considered the number of matches being played per week when planning training,[20] but tended to overcompensate. One explanation for this is, that coaches may overestimate exertion of players during matches[1] and more carefully planned pre- and post-match training sessions. This not only affect training adaptations on the short-term, but could also have consequences on the long-term leading to suboptimal performance.[31]

Our second finding was higher well-being and less fatigue reported by players during short-term match congestion compared to regular weeks. Well-being and fatigue scores during regular competition were 18.2 ± 1.60 and 3.4 ± 0.51, respectively, which is relatively high compared to other research,[30,33] Fatigue corresponded with *normal* and *fresh* and can thus be considered as ready to perform. The fact that players' well-being was higher (18.5 ± 1.36) and that they reported less fatigue (3.5 ± 0.44) during congested weeks may indicate that players could train harder. In our study we captured a full competitive season that included irregular weeks of short-term match congestion. Certain phases of the season consisted of more dense weeks compared to other. While our analysis did not discriminate between these phases it is important to realize that within season variation may exist. Indeed, Conte et al.[30] showed lower well-being during short term match congestion during the initial 10 weeks of the season. This could also be caused by relatively poor fitness after the summer break. Although, the present study also shows high variability in load during the initial phase of the season, also periods of unloading (matchless weeks or winter break) within a full season were included. It is recognized that this has clearly beneficial consequences for psychological and physical recovery.[32]

Next to well-being and fatigue, no changes in sleep quality, general muscle soreness, stress levels, mood and TQR were found between short-term match congestion and regular competition. These findings are partly in line with previous research that found no changes in sleep quality, stress levels and mood after increased load.[33] Associations between changes in training load and general muscle soreness[34] and TQR[35] are previously demonstrated, though depending on weekly training load exposure. For the current study, lack of association is likely explained by the relatively low total load and training load.[35]

Our third finding was that neuromuscular performance did not significantly change between short-term match congestion and regular competition. This means that the players maintained jump performance. Since players reported less fatigue during congested weeks, one could expect that players would jump even higher. However, ~48 hours of recovery prior CMJ testing may have washed out this influence.

Finally, prevalence of injuries and illnesses were 17.2% and 3.3% for short-term match congestion and 18.1% and 4.6% for regular weeks, respectively. The prevalence and days of time-loss in our study are in line with previous research in other team sports at professional level.[26] It is known that the risk for injuries and illnesses is higher with increases in load.[36] However, no significant differences for severity scores and time-loss were observed between short-term match congestion and regular competition. This is likely because of reduced training load to compensate for multiple matches during the congested schedule.

To our knowledge, this is the first study that demonstrated that coaches intend to manage load in reference to match scheduling in elite male professional basketball for an entire season. Moreover, multilevel modeling was used for data analysis to assess associations at individual level. Finally, next to insight in total load (training sessions and matches) and training load, the study provides outcomes for well-being, recovery, neuromuscular performance and injuries and illnesses.

Limitations and future research

A limitation of the study is that with 2 participating teams only 2 coaches were involved. This is a well-known issue for studies in team sports.[1] Furthermore, no insight was gained into recovery activities outside the field or other stressors in life (e.g. life events, family situation, daily hassles). This may provide additional insight on well-being and recovery state.

Future research should aim at finding the optimal balance between load and recovery for the competitions involved in within team sports including recovery activities and other stressors. Next to training guidelines (e.g. intensity, duration), type of training should be examined in quasi-experimental designs. For example, intensity, duration and type of training can be adjusted intermediate via feedback loops in one team, but not for the other. Thereafter, results could be integrated in the macro-periodization schedule of the season. Consequently, training potential for the individual player is used utmost while well-being and recovery are maintained.

CONCLUSION

In conclusion, results demonstrated that total load (training sessions and matches) and training load were lower during short-term match congestion compared to regular competition in elite basketball players. Furthermore, better well-being and less fatigue were seen within short-term match congestion. This may indicate on unused training potential to improve performance during short-term match congestion.

PRACTICAL APPLICATIONS

For short-term match congestion (i.g. ≥2-match weeks) and regular competition (i.g. 1-match weeks), total load (training sessions and matches) and training load were presented. Results suggest that the coaches overcompensate training load during congested weeks. An explanation for this is that coaches often apply tapering off towards pre-match[20] and tend to overestimate match intensity.[1] The latter could result in lower intensity during post-match training sessions. If more matches are played within a week, this overcompensation effect is expected to become larger. Therefore, training and coaching staff are advised to closely monitor training load and perceived fatigue of players. This may help them to guide the training process and increase training load when possible. Absence of evidence was found for the use of the other well-being items, with TQR and neuromuscular performance.

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Chapter 5

High match load's relation to decreased well-being during an elite women's Rugby Sevens tournament

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ABSTRACT

During rugby sevens tournaments it is crucial to balance match load and recovery to strive for optimal performance. ***Purpose:*** To determine changes in well-being, recovery and neuromuscular performance during and after an elite women's rugby sevens tournament and assess the influence of match load indicators. ***Methods:*** Twelve elite women rugby sevens players (age 25.3±4.1 y, height 169.0±4.0 cm, weight 63.9±4.9 kg, body fat 18.6±2.7 %) performed 5 matches during a two-day tournament of the Women's Rugby Sevens World Series. Perceived well-being (fatigue, sleep quality, general muscle soreness, stress levels, mood), total quality of recovery (TQR), and countermovement-jump flight time (CMJ) were measured on match day 1 (MD1), match day 2 (MD2), 1 day post-tournament (D+1) and 2 days post-tournament (D+2). Total distance, low-, moderate- and high-intensity-running (HIR) and physical contacts (PC) during matches were derived of GPS based time-motion analysis and video-based notational analysis, respectively. Internal match load was calculated by session-rating of perceived exertion (RPE) and playing time (RPE x duration). ***Results:*** Well-being ($p<.001$), fatigue ($p<.001$), general muscle soreness ($p<.001$), stress levels ($p<.001$), mood ($p=.005$) and TQR ($p<.001$) were significantly impaired after match day 1 and did not return to baseline values until D+2. More HIR was related to more fatigue ($r=-.60$; $p=.049$) and a larger number of PC with more general muscle soreness ($r=-.69$; $p=.013$). ***Conclusion:*** Perceived well-being and TQR were already impaired after match day 1 while performance was maintained. HIR and PC were predominantly related to fatigue and general muscle soreness, respectively.

Keywords

Regeneration, wellness, time-motion, load indicators, performance.

INTRODUCTION

Match analysis of elite women's rugby sevens shows that players cover average distances of 1066m per match, with on average 37% of total distance at speeds above 3.5 $m \cdot s^{-1}$ and 14% above 5 $m \cdot s^{-1}$.[1] In addition, players spent for over 75% of the game above 80% of their heart rate maximum.[2-4] A high number of collisions and tackles during matches are likely to contribute to these high-intensity demands.[4] Moreover, these moments of direct impact lead to increased muscle damage, which has been associated with decreased muscle power.[5]

During rugby sevens tournaments these impacts accumulate over multiple matches per day and cause high perceived stress.[3,6] Moreover, players have to cope with only ~3 hours of rest between the consecutive matches for multiple days. So, high match intensity, physical contacts and congested schedules result in extremely high levels of physical and psychological load in rugby sevens.

As a consequence of insufficient recovery time and residual fatigue during and after women's rugby sevens tournaments, decreased well-being and neuromuscular function are expected in line with the literature.[7,8] Subsequently, this might lead to decreased performance and an increased injury risk.[2,9,10] For subsequent training prescription or consecutive tournaments it is, therefore, highly relevant to determine recovery time courses and to identify influencing factors.

Currently, recovery time courses of women's rugby sevens tournaments are unknown. In addition, load indicators that influence recovery time courses the most are not described yet. In football, it is demonstrated that impacts at high intensity, total distance covered and accelerations and decelerations correlate moderate to very large with creatine kinase levels and countermovement jump performance.[11] These results contribute to the growing body of evidence to indicate more specific time-motion parameters and their influence on objective recovery and performance outcomes. However, it is also necessary to integrate self-reported well-being and recovery as sensitive and responsive monitoring tools.[12] Furthermore, assessment during and after elite tournaments might provide crucial information for player rotation strategies within and between consecutive tournaments for optimal performance.

In summary, recovery time courses of both, objective and self-reported measures during and after an elite women's rugby sevens tournament are not examined yet. Furthermore, there is no information about which match load indicators subsequently correspond with well-being, recovery or neuromuscular performance in a women's rugby sevens tournament. Considering the high demands of rugby sevens, with the potential for performance decline and increased risk of injuries within the time course of one tournament, there is a high need to gain more insight into how this affects the overall athlete. Therefore, the aims of this study are to determine time courses of well-being, total quality of recovery and neuromuscular performance within and after an elite women's rugby sevens tournament and to assess the influence of match load indicators.

METHODS

Subjects

Twelve elite women rugby sevens players (mean ± SD; age (years) 25.3±4.1; height (cm) 169.0±4.0; weight (kg) 63.9±4.9; body fat (%) 18.6±2.7; rugby experience (years) 8.8±5.7) of a national team participated in this study. The head coach, assistant coach and strength & conditioning coach were responsible for the training program in preparation for this tournament study which was conducted within the Women's World Rugby Sevens Series. All participants were informed about the experimental protocol and procedures of the study and written informed consents were obtained. The total study protocol was approved by the ethical committee of the Center for Human Movement Sciences of the University of Groningen. Before the start of the tournament all participants were familiarized with the experimental protocols, procedures and measurements.

Experimental protocol and procedures

During and after an elite women's rugby sevens tournament self-reported well-being and recovery, and neuromuscular performance were monitored. Figure 1 shows the single group repeated measures design with measurements in the morning (between 8.00-9.00 AM) on match day 1 (MD1), match day 2 (MD2), 1 day post-tournament (D+1) and 2 days post-tournament (D+2). In total, participants played 5 matches of which 3 on MD1 and 2 on MD2 according the Rugby Union Laws of the Game. Participants did not have to travel and, therefore, no time-zones needed to be covered. During the tournament, players did not undergo recovery-enhancing strategies (e.g. massages, garments, cold water immersion) and were instructed to avoid sun exposure between matches and to remain sufficiently hydrated. Players participated 3 days pre-tournament in one training session a day with an average rating of perceived exertion of mean ± SD 11.7±1.9 indicating fairly light exercise.

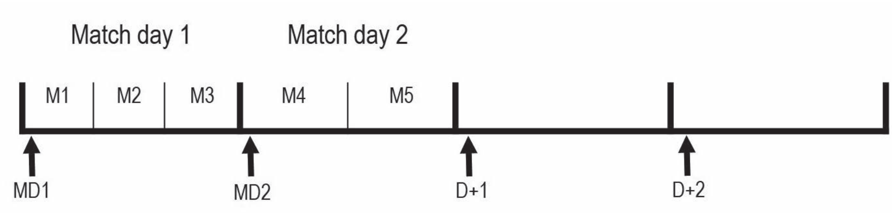

Figure 1 — Measurement time course of the study. M1 through M5 indicate match 1 through match 5; MD1, match day 1; MD2, match day 2; D+1, 1 day post-tournament; D+2, 2 days post-tournament.

External match load was measured with GPS based time-motion analysis (JOHAN Sports, Noordwijk, the Netherlands)[13] and video-based notational analysis. For time-motion analysis, GPS trackers were worn in a custom-made vest under regular match clothing. Navigation technology from the European Space Agency with a sample rate of 10 Hz was used. This appears to be most valid and reliable to measure distance for varying speeds across linear and team sport simulated running.[14] The GPS device used in this study was tested with a (error ± deviation) 2.5 ± 0.41 % reliability for total distance covered. This can be considered as a good reliability.[14] Each player wore the same tracker during all matches to limit error and to foster reliability of the measurements conducted. The time-motion parameters assessed were total distance and total distance covered during low ($<2 m\cdot s^{-1}$), moderate ($2\text{-}3.5 m\cdot s^{-1}$) and high ($>3.5 m\cdot s^{-1}$) intensity.[1] For notational analysis, a video camera placed on the middle of the long side of the field provided video recordings. Two analysts independently executed the notational analysis. In case of disagreement a third analyst was asked for his observation.[15] The number of times a player was involved in physical contact (PC) with other players was used for analysis.

PC included the following actions: player securing a ruck, player clearing a ruck, player pushing a maul, player carrying the ball in a maul, player involved in a scrum, player involved in other physical contact.

To calculate internal match load (intensity x duration, warming-up excluded)[16] rating of perceived exertion (RPE) on a 6 (no exertion) to 20 (extreme exertion) scale was obtained of each individual player thirty minutes after each match. The player was asked to provide her subjective perception of the match by pointing out her finger to the 6-20 scale with verbal anchors. Playing time (minutes) of each player was noted from start to end of the match excluding all interruptions in the match (e.g. time between the two halves or extra time periods, match stops, injury time). Session RPE is a valid method to assess individual exertion including disruptions and substitutions for the perception of global intensity in rugby sevens.[17] To assess self-reported well-being the Well-being questionnaire[7] was individually assessed between 8.00 and 9.00 AM of that day. This questionnaire consists of five items (fatigue, sleep quality, general muscle soreness, stress levels and mood), which are rated on a scale from 1 (most negative) to 5 (most positive) with 0.5 intervals. The overall well-being was calculated by summarizing the scores on the five items. The well-being questionnaire was based on previous recommendations[18] and shown to be sensitive to changes of preceding load.[7]

To measure individual characteristics of player recovery Total Quality of Recovery (TQR)[19] and neuromuscular performance (NMP) were individually assessed between 8.00 and 9.00 AM of that day. Players rated their TQR on a scale from 6 (no recovery) to 20 (maximal recovery). It is assumed that recovery is strongly related to load and therefore, TQR has been structured around the concept of RPE to emphasize the interrelationship between load and recovery.[19] NMP was assessed by performing countermovement jumps (CMJ) between 8.00 and 9.00 AM of that day. It has been concluded that CMJ is a reliable and valid indicator of NMP in team sports.[20] CMJ flight time was measured using a portable contact platform (ProJump, Lode BV, Groningen, the Netherlands). Players were instructed and demonstrated to perform 5 maximal vertical jumps with ~3 seconds rest between each jump.[21] The jump began with the player standing in upright position, followed by bending the knees to a self-selected depth, before jumping with maximal vertical height.

Hands were placed on the hips during the whole procedure to exclude arm swing influence on CMJ performance. The mean CMJ flight time of 5 jumps was calculated and used for analysis since it provided the most reliable performance measure for repeated CMJ's (CV 1,9% in elite athletes).[20]

Statistical analysis

Means and standard deviations were calculated for total distance, low-, moderate- and high-intensity-running, physical contact, internal match load (RPE x duration), well-being, TQR and CMJ. One player was excluded in the time-motion analysis because of missing GPS data and one player did not participate in the 5th match because of an injury. For the purpose of investigating changes on well-being, TQR and CMJ, the data were analyzed using multi-level modeling with MLwiN (version 2.35 for Windows).[22] Multi-level analysis is able to include dependent data and can handle a varying number of measurements between players, which is inevitable in a repeated measures design. Missing values in the dataset were at random. Multilevel models were created for well-being, fatigue, sleep quality, general muscle soreness, stress levels, mood, TQR and CMJ with repeated measures *within* players (level 1) and differences *between* players (level 2). First step was to create an intercept model with MD1 as reference value. The second step was to create a model indicating possible differences between measurements (MD1, MD2, D+1 and D+2), therefore time points were added to the intercept model. The model fit was evaluated by comparing the -2Log Likelihood of the intercept model with the second model. Furthermore differences between measurements were evaluated by comparing the mean of the coefficient and its standard error (SE) (coefficient/SE >1.96 = significant). The possible difference between measurements were calculated for well-being, fatigue, sleep quality, general muscle soreness, stress levels, mood, TQR and CMJ. For both match days difference scores were used between measurements (∆MD1_MD2 and ∆MD2_D+1) to calculate bivariate Pearson correlation coefficients to evaluate the relationship between load indicators and recovery parameters. Criteria for the interpretation of correlations were set on: 0-0.3 negligible association, 0.3-0.5 low association, 0.5-0.7 moderate association, 0.7-0.9 high association and 0.9-1.0 very high association.[23] Correlation coefficients were performed using SPSS software (version 23.0; SPSS Inc., Chicago IL). P-values lower than .05 were considered as statistically significant.

RESULTS

Mean actual playing times for the 5 matches were 10.8±5.98; 9.9±4.70; 9.6±5.61; 9.2±5.02 and 10.4±4.64 (min) respectively. Table 1 presents descriptive results of match load.

Table 1 — External and internal match load. External match load (n=11 for match 1-4; n=10 for match 5) displays total distance and distance covered at low-, moderate- and high-intensity-running during the five matches. Internal match load (n=12 for match 1-4; n=11 for match 5) displays session RPE x duration. Abbreviations: EML, external match load; IML, internal match load; RPE, Rate of Perceived Exertion; AU, arbitrary units. All data are displayed as mean±sd.

		Day 1			**Day 2**	
		Match 1	**Match 2**	**Match 3**	**Match 4**	**Match 5**
EML	Total distance (m)	1450.9 ± 533.89	1434.6 ± 376.12	1320.2 ± 455.83	1651.7 ± 350.15	1471.1 ± 444.92
	Low Intensity (m)	630.9 ± 152.90	651.4 ± 135.79	561.9 ± 146.90	859.4 ± 204.08	581.7 ± 117.99
	Moderate Intensity (m)	486.1 ± 249.04	433.9 ± 148.88	402.8 ± 144.12	402.9 ± 134.99	443.1 ± 190.70
	High Intensity (m)	333.6 ± 143.02	351.9 ± 148.39	355.3 ± 190.18	344.5 ± 113.50	446.2 ± 170.69
	Number of physical contact with others	7.5 ± 4.80	5.8 ± 4.18	6.4 ± 5.09	6.8 ± 6.58	5.5 ± 3.99
IML	Session RPE x duration (AU)	196.3 ± 116.77	165.1 ± 83.51	171.1 ± 114.78	158.5 ± 92.17	177.5 ± 89.36

Figure 2 shows the predicted time course of recovery for total well-being, fatigue, sleep quality, general muscle soreness, stress levels, mood, TQR and CMJ flight time. Adding time to the intercept model significantly increased the model fit. Well-being ($p<.001$), fatigue ($p<.001$), general muscle soreness ($p<.001$), stress levels ($p<.001$), mood ($p=.005$) and TQR ($p<.001$) were significantly impaired after match day 1 and did not return to baseline values up to D+2 post-tournament. Fatigue ($\Delta MD1\_MD2 = -1.2$), general muscle soreness ($\Delta MD1\_MD2 = -1.8$) and TQR ($\Delta MD1\_MD2 = -3.3$) decreased the most after match day 1.

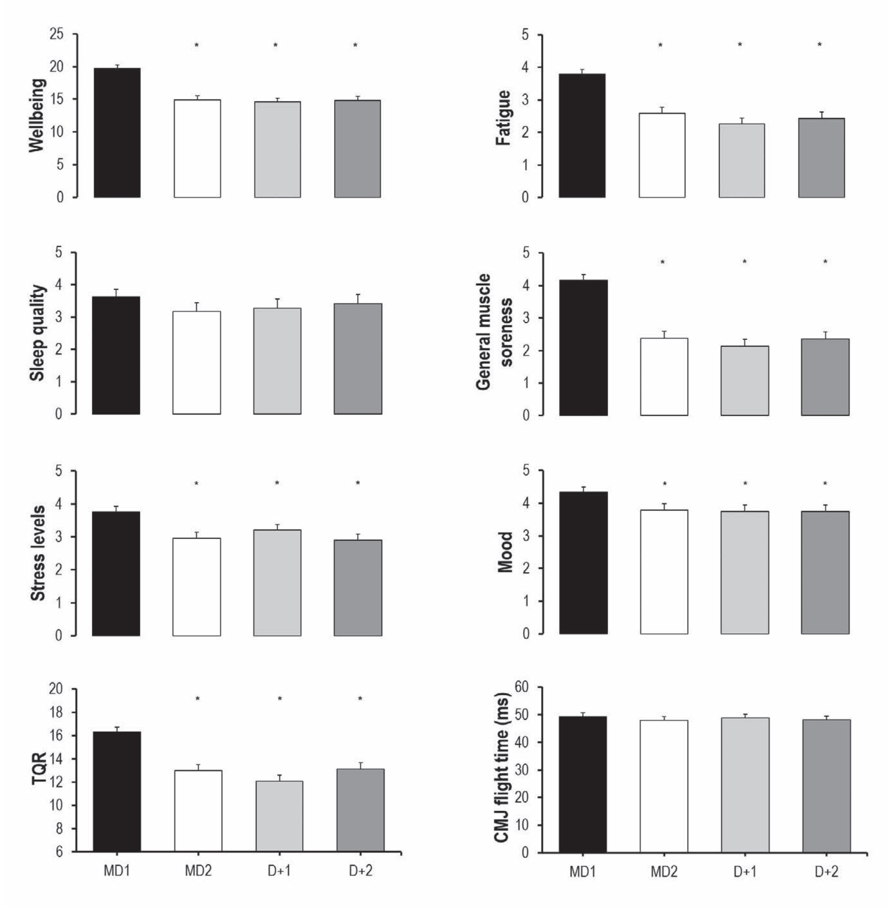

Figure 2 — Time course of self-reported well-being, fatigue, sleep quality, general muscle soreness, stress levels, mood, TQR, and CMJ flight time on MD1, MD2, D+1, and D+2 based on predicted outcomes of the multilevel models. Error bars display SE. CMJ indicates countermovement jump; D+1, 1 day post-tournament; D+2, 2 days post-tournament; MD1, match day 1; MD2, match day 2; TQR, total quality of recovery. *P < .01 compared with MD1.

For match day 1, there was a moderate correlation between high-intensity-running and the increase in fatigue (r=-.60, p=.049, Figure 3). Moreover, there was a moderate correlation between physical contact and the increase in general muscle soreness (r=-.69, p=.013, Figure 3). No associations were found for match day 2 or between other indicators and recovery parameters.

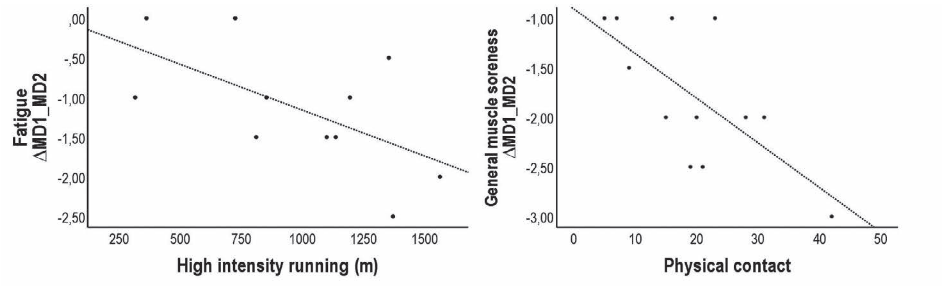

Figure 3 — Relationships of high-intensity running and fatigue and physical contact and general muscle soreness. Dotted line indicates lines of regression. ΔMD1_MD2 indicates difference score between match days 1 and 2.

DISCUSSION

The aims of the present study were to determine time courses of well-being, total quality of recovery and neuromuscular performance within and after an elite women's rugby sevens tournament and to assess the influence of match load indicators. Results showed reduced well-being and recovery profiles after match day 1. Well-being and recovery remained impaired up to 2 days post-tournament (D+2). More high-intensity-running was associated to increased fatigue (r=-.60) and a larger number of physical contact with more general muscle soreness (r=-.69) after match day 1.

Our first main finding was that time courses of well-being, the subscales fatigue, general muscle soreness, stress levels and mood and self-reported recovery (TQR) were significantly impaired already after match day 1. In line with previous research, the largest decreases were seen in total well-being, fatigue, general muscle soreness and TQR and not in stress and mood.[7,24,25] Furthermore, it is known that fatigue and general muscle soreness are especially affected during fixture congestion in rugby.[7,12,25] An explanation for the fact that these changes already became apparent after the first day might be that players' had 3 consecutive matches with high intensity levels on match day 1. After match day 1, no further decrease was demonstrated. However, well-being, fatigue, general muscle soreness, stress levels, mood and TQR remained significant different for match day 2 up to 2 days post-tournament (D+2) compared to baseline levels (MD1). This might suggest that on top of challenges with the match schedule and high match intensity on match day 1, players had insufficient recovery between the matches to improve for match day 2 and thereafter. In addition, other contextual factors (e.g., atmosphere, crowd, sponsors) may play an important role during the tournament. This remains to be determined.

Next to these explanations, one could argue that despite impairment of perceptual measures, physical output in the tournament was not reduced and therefore, not meaningful. It is previously demonstrated that self-reported well-being showed to be more sensitive to acute increase in load compared to objective measures.[12] Even though coaches could ignore this for performance purposes on the short term, they could consider this if for example multiple competitive matches are planned after the tournament. If, for example, players were able to take full recovery and avoid cumulative fatigue by taking rest after the tournament, coaches could neglect reduced scores within the tournament itself. However, if consecutive tournaments or competition are planned without a phase of rest, it does provide information coaches should act on.[8] This to avoid ongoing reduced well-being and insufficient recovery which is not demonstrated by physical output or performance tests. Furthermore, for coaching staff it is imperative to identify in an early stage increased stress and fatigue that may contribute to an increased injury risk.[3]

For neuromuscular performance no changes were found within and post-tournament. This means that players were able to maintain jump performance. According the high demanding characteristics of the rugby game and the intense match schedule it was expected that CMJ performance was reduced.[21,25] It is expected that high exposure to intensified competition causes more accumulated fatigue leading to reduced neuromuscular performance.[21] However, it might be that the way jumping performance (i.e. flight time with a contact plate) was measured in our study is not sensitive enough to determine subtle changes in neuromuscular performance.

The second finding was that for match day 1 more high-intensity-running was related to more fatigue (r=-.60) and larger number of physical contacts with more general muscle soreness (r=-.69). Therewith, relevant match load indicators during an elite women's rugby sevens tournament are identified. It is previously suggested that a reduction in distance covered, although not significant, reflected increased fatigue in a rugby sevens tournament.[2] Our study contributes to existing knowledge in identifying high-intensity-running as influencing load indicator on fatigue responses. In addition, the influence of physical contacts (i.g. rucks, mauls, scrums) on general muscle soreness was expected according previous research,[26] though, not previously investigated yet in elite women's rugby sevens.

No associations were found between match load indicators and stress levels and mood which is consistent with findings of Sawczuk et al[27] investigating the influence of exposure to match play on well-being in youth athletes. Moreover, load did not influence sleep quality in the current study. Consequently, no relationship was found with total well-being, since this parameter is the sum of the separate scales.[12] Furthermore, it may be that higher match load and for a longer period of time, can influence stress levels, mood and sleep quality. This also appears to be true for TQR and neuromuscular performance. To promote readiness to perform, coaches apply player rotation within the tournament itself in order to reduce cumulative load.[21] In addition, the coaching staff reduced training load pre-tournament (i.g. no exhaustive exercise 3 days pre-tournament) in order to prepare players for upcoming matches. These coach interventions may have influenced the relation between the load and the outcome parameters. For match day 2 no significant correlations were found between match load indicators and well-being, TQR or neuromuscular performance. A likely explanation for this result is that well-being and TQR reached a floor effect after match day 1.

This is the first study that demonstrated time courses of well-being, recovery and neuromuscular performance within the unique practical context in which participants performing in the Women's World Rugby Sevens Series. Furthermore, multi-level modeling was used to deal with the data which was most appropriate and accurate in our repeated measures design. Finally, this study provides knowledge about the influence of load indicators on well-being, emphasized by quantifying impact of high-intensity-running and physical contact on fatigue and general muscle soreness, respectively. This is crucial in the prevention of underperformance.

Limitations and future research

Limitation of the present study is that next to total distance, intensity and match load no biomechanical load indicators were measured.[28] Even though we determined the number of physical contacts for each player, it remains unclear what the impact was for each of these contacts. In addition, no psychosocial stressors were identified. It might be argued that psychosocial stress also contributes to the explanation of well-being and recovery profiles and directly influence performance.[19] Finally, CMJ flight time might be not sensitive enough to measure alteration in neuromuscular responses in this particular tournament setting.

Future research should aim to additionally measure biomechanical load (e.g. muscle-tendon forces) and try to quantify to what extent critical values are reached in maintaining well-being and recovery. Moreover, the influence of psychosocial stressors (e.g. general, emotional, social stress) on well-being and recovery during tournaments or in-season intensified competition periods should be investigated. To better understand the recovery process, other measures (e.g. muscle damage) could be of additional value.[29] Finally, studying recovery strategies as interventions within congested playing schedules might prevent players of ongoing fatigue and muscle soreness.

CONCLUSION

In conclusion, within the present elite women's rugby sevens tournament study, total well-being, fatigue, general muscle soreness, stress levels, mood and total quality of recovery showed a diminished recovery profile within match day 1, up to 2 days post-tournament while physical output was maintained. Fatigue, general muscle soreness and total quality of recovery were most diminished after match day 1. Furthermore, it can be concluded that high-intensity-running and physical contact predominantly influenced perceived fatigue and general muscle soreness, respectively.

PRACTICAL APPLICATIONS

For training and coaching staff of women's rugby sevens players, it is of utmost importance to maintain their ability to perform and let them deal with reduced well-being or insufficient recovery between matches during a two-day tournament and on a prolonged timeframe. Therefore, coaches should have clear insight into individual perceived well-being and recovery of players by daily monitoring. Well-being and TQR scores add to a better understanding of recovery profiles in the tournament context because of their responsiveness to acute increased load.[12] Although, no performance decline was demonstrated in the present study, outcomes of the perceived measures can be used as early warning signals of affected players and guide coaching staff in their team management. It enables coaches to directly intervene by evidence based recovery strategies or make adjustments to exposed individual load.

On the basis of our findings, coaches can intervene on fatigue, general muscle soreness, stress and mood within the tournament already. For physical recovery of fatigue and general muscle soreness effective short-term recovery modalities (e.g. cold water immersion, contrast baths, compression garments) might have a beneficial effect.[30] For psychosocial recovery of stress and mood relaxation techniques (e.g. debriefing, power naps, systematic breathing) might be proposed.[31] Finally, perceptual total well-being and perceived recovery can be enhanced by compression garments in combination with electromyostimulation.[30]

Next to recovery modalities, coaches could benefit of sufficient insight into individual high-intensity-running and physical contacts as distinctive match load indicators during women's rugby sevens tournaments. Critical cut-offs can be determined for the individual player of the influence of high-intensity-running and physical contacts on fatigue and general muscle soreness, respectively. Therefore, match load indicators should be monitored constantly and accurately to provide direct feedback about the most important match demands in this population.

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Chapter 6

General discussion

The thesis' main aim was to gain insight into the determinants of recovery and the time course of recovery during intensive competition periods (i.g. fixture congestion) within elite team sports. Therefore, imposed load, individual capacities and subsequently recovery are investigated in elite team sport players.

First, current body of knowledge was systematically reviewed to understand the typical time-courses of recovery after single matches in team sports, without dense schedules of play. Players' physical post-match recovery was evaluated within team/intermittent sports in which at least two post measurements were compared to baseline values. It was found that it requires about 48 hours for performance indicators to return to baseline, but that underlying mechanisms of muscle recovery lasted longer and took up to ≥72 hours to recover to the initial level.

Thereafter, we focused on congested playing schedules in which recovery time between successive matches is limited. First, we took the standpoint of the coach and assessed his observed exertion and recovery of individual players during intensified competition. We then compared these observations with the response of players. It turned out that players' perceived exertion was lower than observed by the coach. On top of that, total quality of recovery of players was worse than observed by the coach. So, even in intensive match periods, although the coach interpreted recovery as good, training load was lowered. This finding was further supported in the following study, where we compared training load, well-being, performance, injuries and illnesses in regular and intensified competition. Here, total load and training load were lower in weeks with multiple matches (e.g. short-term match congestion) compared to one match a week (e.g. regular competition). Thus, it appeared that coaches tended to overcompensate towards lower training load for intensified competition. This consequently led to even better well-being and less fatigue during intensified competition.

We then focussed on a situation with even less time for recovery and players were monitored during a tournament with multiple matches per day. In this rather extreme situation without options to manage training load in between matches, perceived well-being and total quality of recovery were impaired after match day 1. Furthermore, it was demonstrated that in particular, high-intensity running and physical contacts were related to more fatigue and general muscle soreness, respectively.

PHYSICAL AND PSYCHOSOCIAL RECOVERY AND MEASUREMENTS

In the current thesis, we adopted a multidisciplinary approach, meaning that we aimed to capture both physical and psychosocial recovery. In addition, we used various methods and instruments, such as pre- and post-testing, and frequent assessment through self-report.[1-5] We demonstrated that degree of recovery depends on the constructs that were measured and instruments that were used.

Throughout the studies it appears that although in general players' test performance did not decline, self-reported measurements of the same players were negatively affected. In line with recent research, this confirms the need to combine different types of measures to cover the overall concept of recovery including performance tests as well as self-reported measures to complement eachother.[1,6-8]

It is interesting to note, that in this thesis performance tests were not affected, despite impairment of perceptual measures. One could argue that players have sufficient physical recovery and prevent cumulative fatigue by taking rest, and consequently, coaches could ignore reduced self-reported scores for that match week or competition (i.g. tournament) on the short term.[9,10] However, for coaching staff it is important to identify increased stress and fatigue as soon as possible since it may contribute to an increased injury risk.[11,12] With the knowledge that underlying mechanisms of muscle recovery lasted longer and took up to ≥72 hours to recover to the initial level, the coach must take the self-report measures into account as an early warning signal.

These self-reported measures can be criticized,[13,14] but they do have some major advantages.[1,6,15] The measures are simple and easy to use and can be used at high frequency in practice which is of main importance to report fluctuations clearly in our prospective observational longitudinal studies.[1,6] It is previously demonstrated that self-reported well-being, fatigue or quality of recovery are more sensitive to acute increases in load compared to performance tests.[1,4,16] Findings in our studies, in which we focused on congested playing schedules with limited recovery time between successive matches, confirms this. More specific, fatigue, general muscle soreness and overall well-being were negatively affected.

We further noticed inter-individual differences in physical and psychosocial recovery. This can likely be explained by different individual capacities as well as being exposed to various sources of physical and psychosocial load and recovery.[17-19] Players with relatively poor physical capacities (i.e. fitness), have higher internal loads and consequently, recovery is slower.[20,21] The same is true for psychosocial capacities, one player is better able to cope with stressors then another, because of personal characteristics such as trait anxiety.[22,23]

On top of these differences between physical and psychosocial capacities, players are exposed to various stress and recovery related activities in between training and matches. It is known that differences already exist in relatively standardized training and match sessions on field,[24-28] but even larger differences can be expected off-field. Players are exposed to various stressors in their private live, from family, friends, media and travel activities. Possibilities to recover physical and psychosocial may vary as well.

Following this line of reasoning, one could expect that recovery is largely dependent on the capacities of the individual and thus require a personalized approach. This means that individual changes should be assessed and should cover physical and psychosocial load and recovery in a feasible manner.

RECOVERY DURING FIXTURE CONGESTION

To maintain performance, sufficient recovery is needed to cope with fatigue after match play.[29-31] It is shown that this is challenged by the highly congested match schedules which lead to a lot of extra strain on the players.[32-37] In the recent literature, there is a lack of knowledge and interpretation on time courses of recovery after matches during match congestion in elite team sports. The recovery process is hard to manage in elite sports and depends on several contextual factors.[35,36] From training studies in team ball sports, it is revealed that physical performance recovery takes up to ≥48 hours after regular training.[32] However, these study designs are not in line with daily practices of elite team ball sport players with multiple matches in a short period of time. Recovery studies that focus on fixture congestion are scarce, and therefore, for training and coaching staff no reliable guidelines within these situations based on scientific insights.

The present thesis demonstrated how intermittent team ball sports with high intensity and variable characteristics in external and internal load by match congestion, affect the time course of match recovery.[38,39] In order to carefully plan and adjust training sessions and tailor this more individually in between matches, time courses of recovery were monitored and revealed within the studies. Although the generalizability is limited through the different contexts, the studies provide further insight into situations in which recovery time is short due to intensive training and competition periods varying from intensive match periods to a full season, to a micro level, within a tournament.

According to a recent review on the effect of fixture congestion on performance, no impact on physical performance was found and there was a lack on data for tactical or technical performance.[40-45] Unaffected performance is in line with our findings during match congestion in the studies. This can be attributed to that players might compensate within matches on low- and moderate intensity[40] to be able to continue to deliver the high-intensity effort during match congestion. Moreover, muscle damage is greatly caused by alternative movement variables such as accelerations, decelerations and changes in directions.[46] These variables were not further investigated within the studies. However, based on the finding that underlying mechanisms of muscle recovery lasted longer and took up to ≥72 hours to recover to the initial level, muscle damage might have been apparent despite that performance remained unaffected.

Another explanation for no impact on performance can be that in between matches training load was lower as found in our studies. Tapering off training load before a match is common.[47] This effect might be expected to be further enhanced if several matches are played in a week or intensified match period. Consequently, this led to even better well-being and less fatigue during intensified competition. On the contrary, well-being and total quality of recovery were immediately impaired in the extreme situation of playing multiple matches per day such as in a tournament (Figure 1). This can be explained by that time in between matches was that short that options to promote recovery were limited.

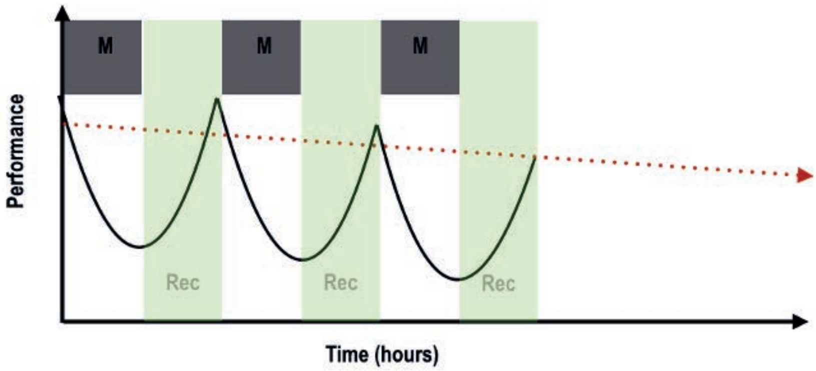

Figure 1 — Schematic overview of insufficient recovery in between matches over time in hours. Abbreviations: M, match; Rec, recovery.

MODIFICATION OF TRAINING

As shown in chapter 4, training and coaching staff anticipate on short-term match congestion with adaptations in training load. Consequently, higher well-being and less fatigue were reported during intensified match weeks. To our knowledge, the current thesis presents the first study in basketball which captured a full season anticipating for short-term match congestion. Inter-individual variability in the duration of training sessions was high which suggest that programs were tailored to the capacities and needs of individual players. A plausible explanation for the lower training load, is that the coaches in this study overestimated exertion of players during matches as previously shown in chapter 3. This mismatch between players and coach is reported before.[48,49] Based on this overestimation of the coach, pre- and post-match training sessions were carefully planned and adjusted accordingly which resulted in lower imposed training load. This means that in between matches, training sessions were less frequent, had lower intensity, and duration was shorter. From a prevention perspective for health, one could interpret this as a positive intervention by the training and coaching staff considering aspects as readiness to perform, maintenance of fitness level and to prevent overload.[50] However, it could also lead to underload, because of lower training intensity, frequency and/or duration which may cause suboptimal training adaptation and thus underperformance. Underload affects training adaptations negatively on the short-term, but also have consequences on the long-term, for example, leading to underperformance within the final phase of the season. We hypothesize that if more matches are played per week this overestimation of exertion by coaches may even increase, and could lead to even stronger detraining effects.[32,47,51,52]

STRENGTHS AND LIMITATIONS

The present thesis provides extensive insight in post-match recovery in team ball sports. Based on the multidimensional model of Kenttä and Hassmén,[30] load, capacity and recovery were included, both physical and psychosocial.

The studies presented in this thesis, reflect the unique practical context of the elite team ball sports player accounting for fixture congestion in the study designs. Elite players were monitored within their professional environment without intervention or manipulation. These methodological approaches are scarce and warranted to understand recovery kinetics in their daily sports practice. The presented studies demonstrated that with relatively simple performance tests and self-reported measures, individual match load and post-match recovery was obtained from players.

Additionally, in chapter 5, the influence of load indicators on well-being were demonstrated. By quantifying impact of high-intensity-running and physical contact on fatigue and general muscle soreness, respectively, the association between load indicators and well-being items were further specified and illustrated.

Limitation of the current thesis might be the number of participants within the single studies. This is a well-known issue for studies in elite team sports[16,48,49,53] and might affect the generalizability of the outcomes. However, we adopted a longitudinal design with repeated measurement on a day-to-day basis in study periods up to one full season. Furthermore, we used multilevel modeling to take individual differences into account.

Another limitation is that although we have accurately defined load with rate of perceived exertion (RPE), duration and GPS based time-motion analysis, biomechanical load has not been made transparent. Potentially, insufficient insight into the load on lower extremities (or ankles, knees and hips) is gained.[54] It remains unclear what the impact was of biomechanical load and it might be argued it also contributes to the explanation of well-being and recovery profiles and influence performance.[1,30]

Finally, no insight was gained into recovery activities (e.g., relaxation, social activities, nutrition), outside the field or other psychosocial stressors in life (e.g., life events, family situation, daily hassles). In addition, sleep has been integrated in the studies, but not as extensive as necessary to provide additional insight on well-being and recovery state.

FUTURE PERSPECTIVES IN RESEARCH ON RECOVERY

In this thesis load and recovery was studied during dense schedules of play in team ball sports. It should be acknowledged that relatively little is known on this topic and therefore several recommendations for future research can be made. First, both physical and psychosocial load and recovery appear important and should be tracked continuously to unravel the dynamic processes in this context. This should preferably be done on an individual level to truly understand personal responses to training and matches. At this point, most studies applied observational designs to describe load and recovery processes. This is understandable, as intervention studies around matches, especially at the elite level, are not easy to incorporate. However, future studies could bring research a step further and use more advanced models to be able to predict sudden changes in the future.[55,56] These models could enable coaches to adjust training schedules, individualize recovery approaches and player rotation strategies at an early stage on the basis of load and recovery data.

Second, it is important to better understand perceptions of players versus perceptions of the training and coaching staff. Results demonstrated differences for both, match exertion and match recovery in player-coach perceptions. Future research should focus on explanations for these differences and strategies to bring perceptions of players and staff more in line. Moreover, it should be monitored more closely what players do outside of the scope of the coach 24-48 hours post-match. Players and coaches work professionally on a daily basis and, therefore, the interaction and interpretation of training and match load and its consequences for recovery should be studied more in-depth.

Finally, future studies should evaluate the effects of different and combined recovery strategies (e.g., active recovery, sleep quantity and quality, mental recovery, nutrition) after (simulated) matches on an individual level in the practical setting of team ball sports. Herewith, the recovery process must be considered as dynamic and multidisciplinary in which both physical and psychosocial processes are involved.

PRACTICAL APPLICATIONS

The results presented in this thesis, have several practical applications. Based on our findings in chapter 2, coaches should consider that recovery kinetics may depend on tools that are used or constructs that these tools capture. For example, performance may already have returned to baseline values while biochemical markers demonstrate a delayed recovery and still remain impaired when the next training load is offered. Lower training load or additional recovery strategies should be prescribed if poor recovery is demonstrated on the basis of biochemical markers over a longer period of time.[52] Since biochemical testing is not conducted on a regular or daily basis for reasons such as feasibility, a training and coaching staff should consider this at specific times during the season, for example during an intensified in-season phase. On the contrary, coaches could decide to neglect ongoing insufficient muscle recovery if performance is maintained while biochemical markers are affected. This could be the case if full recovery is in sight after a tournament or play offs series, for example. The coach and players can take a calculated risk to play with the best players in optimal formation for a short period within the competitive season or a tournament.

Adequate communication between coach and player adds to more insight in match exertion and the process of post-match recovery of the player. For optimal performance, discrepancy between coaches' and players' perceptions should be reduced to a minimum. If coaches overestimate players' recovery, this may lead to prescription of too high loads, while underestimations may lead to lower prescribed loads than necessary for a training stimulus. In both cases, performance is likely suboptimal. It can be expected that overcompensation, in that coaches offer less training load, becomes larger when more matches are played because of tapering off towards pre-match.[47]

It is important to realize that training modification is possible in combination with national and international competition, but not when multiple matches are played per day in a tournament setting. In this case, training and coaching staff can use several tools to detect changes but options to intervene are limited.[17] Physical capacities of players could be optimized before the tournaments to better handle potential fatigue. In addition, training and coaching staff could impose recovery strategies in between successive matches, like psychological debriefing, relaxation techniques or napping.[18,57-59]

Finally, it is of high importance to strive for personalized monitoring of match load and recovery. Individual capacities determine match load responses and the ability to recover. The interaction and balance between variation in load, recovery and individual capacities is crucial in this matter.[60-62] Match load indicators such as high-intensity-running and physical contact in rugby influence fatigue and general muscle soreness, respectively and might, therefore, be used as feedback parameters. Moreover, mainly well-being, fatigue and total quality of recovery scores showed high responsiveness to acute increased load which is in line with previous research and should be used for monitoring purposes.[1,2,30]

CONCLUSION

It can be concluded that, after matches in team ball sports, biochemical recovery trajectories last longer compared to performance recovery trajectories. Therefore, trainers and coaches should be vigilant on hidden recovery processes. Furthermore, during match congestion in basketball impaired player-coach perceptions of exertion and recovery were demonstrated. The coach overestimated players' match exertion and underestimated degree of recovery. For optimal performance, discrepancy between coaches' and players' perceptions should be reduced to a minimum. During short-term match congestion overestimation of load by the coach may lead to overcompensation in training load. This may explain better well-being and less fatigue found during short-term match congestion. Finally, during the densest playing schedule, like a tournament, perceived wellbeing and total quality of recovery were already impaired after match day 1 while match performance was maintained. In rugby, high-intensity running and physical contact were predominantly related to fatigue and general muscle soreness, respectively. Because of their responsiveness to acute increased load, well-being, fatigue and total quality of recovery are most useful as early warning signals of insufficient recovery.

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APPENDICES

About the author
Publications and presentations
Dankwoord

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Steven Doeven was born February 13th 1981, Meppel, the Netherlands. Steven studied both Physical Education at the Hanze University of Applied Sciences and Human Movement Sciences at the University of Groningen. He was a research assistant in the field of "Talent identification and development" in elite sports from 2004 to 2007. Thereafter, he became researcher on running related injuries at the University Medical Center Groningen. Moreover, he did a specialization on cardio pulmonary exercise testing at the School of Sport, Exercise and Nutrition, Massey University, Wellington, New Zealand. In 2009, he started working as a lecturer / researcher at the School of Sport Studies, Hanze University of Applied Sciences. From this position he set up the exercise testing laboratory of the SportsFieldLab, Groningen. Steven was a guest lecturer in the European Master in Health and Physical Activity, Italian University of Sport and Movement, Rome from 2009 to 2016. Furthermore, he was a senior lecturer / researcher in the bachelor's degree Sports Studies and is the coordinator of the bachelor projects. Next to that, he was lecturer in the course Sport Performance Analysis from in the interdisciplinary minor Sport Science. In 2017, he worked for his PhD at the Institute of Sport, Exercise and Active Living (ISEAL), Victoria University, Melbourne, Australia. Steven combined his lecturer position at the Hanze University of Applied Sciences with his PhD at the University of Groningen. Currently, Steven Doeven, is Head of Department for Sportkunde, International Sport Studies and Associate degree Sport within the School of Sport Studies, Hanze University of Applied Sciences, the Netherlands.

PUBLICATIONS AND PRESENTATIONS

International journal

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