In-Season Training Load Variation - Heart Rate Recovery, Perceived Recovery Status, and Performance in Elite Male Water Polo Players: A Pilot Study

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Background: Increased training and competition demands of the in-season period may disturb athlete fatigue and recovery balance. The aim of this study was to describe the training load distribution applied in a competitive period and the training adaptations and fatigue/recovery status of elite water polo players.

Hypothesis: Effective workload management during tapering (TAP) would restore player recovery and enhance performance.

Study Design: Case series.

Level of Evidence: Level 4.

Methods: Training load, perceived recovery, maximal speed in 100- and 200-meter swim, heart rate (HR) during submaximal swimming (HRsubmax) and HR recovery (HRR) were assessed in 7 outfield water polo players a week before starting a normal training microcycle (NM), after NM, and after congested (CON) and TAP training blocks in the lead-up to the Final Eight of the European Champions League.

Results: Training load was higher in NM compared with CON and TAP by 28.9 ± 2.6% and 42.8 ± 2.1% ($P < 0.01$, d = 11.54, and d = 13.45, respectively) and higher in CON than TAP by 19.4 ± 4.2% ($P < 0.01$, d = 3.78). Perceived recovery was lower in CON compared with NM and TAP ($P < 0.01$, d = 1.26 and d = 3.11, respectively) but not different between NM and TAP (P = 0.13, d = 0.62). Both 100- and 200-meter swim performance was improved in TAP compared with baseline ($P <$ 0.01, d = 1.34 and d = 1.12, respectively). No differences were detected among other training blocks. HRsubmax and most HRR were similar among the training periods.

Conclusion: Effective management of training load at TAP can restore recovery and improve swimming performance without affecting HR responses.

Clinical Relevance: Despite lower workloads, CON training impairs perceived recovery without affecting performance; however, a short-term training load reduction after a CON fixture restores recovery and improves performance.

Keywords: fatigue and recovery; tapering; team sports; training periodization

Elite water polo players are frequently exposed to high competition and training loads.[3,5] In fact, along with training sessions, an elite European water polo team may play >40 competitive matches within an 8-month in-season period. Within the prolonged in-season period, and according to the importance of a match, players often follow differential training periodization models to achieve competitive readiness.

So far, it has been documented that the increased training and nontraining stressors, along with the competition demands of a prolonged in-season period followed by a congested (CON)

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schedule of elite competition, may disturb the fatigue and recovery balance of team sport players, thus resulting in overreaching. In such cases, underperformance or excessive fatigue due to successive matches may occur.[21] However, data describing workload distribution in elite water polo training setting during the in-season period are currently scarce. Accordingly, from a practical standpoint, training monitoring using noninvasive, time-efficient, and accurate training tools is indispensable in tracking water polo players' fitness, fatigue, and recovery status.[4]

Heart rate (HR) during submaximal exercise (HRsubmax) and HR recovery (HRR) have been used extensively to monitor athletic training.[1,19] In particular, HRsubmax has been used to measure cardiorespiratory changes over training periods in team sport athletes.[17] Accordingly, the timecourse of cardiac autonomic recovery after exercise appears to be a useful tool to monitor the overall recovery of an athlete. In this regard, HRR immediately after exercise has been used as an indicator of fitness,[11] as well as an index of cardiac autonomic recovery after training in elite athletes.[2] In particular, Lamberts et al[11] showed that a decrease in HRR was associated with blunted endurance performance and suggested that a decrease in HRR may predict an inability to cope with training load and the accumulation of fatigue. In this regard, Botonis et al[2] observed that acute changes in training load (ie, from low-load to heavy-load training) suppressed HRR of elite water polo players. Nonetheless, it is currently unclear whether HRR is also sensitive to chronic training involving different training mesocycles.

Alongside objective measures, subjective feelings are used frequently in training monitoring. For instance, the application of perceived recovery scale (PRS) is a simple and effective questionnaire, which can be used effectively for recording the recovery process of football and water polo players.[3,16] Thus, the systematic recording of objective and subjective responses could provide important information regarding the fitness and fatigue/recovery status of water polo players.

To date, the chronic workload undertaken by elite water polo players has not been described. Moreover, whereas most of the aforementioned training monitoring tools have been proven sensitive within short training periods, it is currently unknown whether these objective and subjective methods of training monitoring are also sensitive in the assessment of fitness and fatigue/recovery status of elite players within a prolonged in-season training. Therefore, the purpose of this study was to describe the training load distribution over 3 distinct training phases (ie, normal training microcycle [NM], CON, and tapering [TAP]) applied within the competitive period and to evaluate the use of objective and subjective measures in detecting training adaptations and changes in fatigue/recovery status of elite water polo players. We hypothesized that a CON period of training and competition would result in diminished recovery and performance deterioration and that the effective management of workload distribution in the TAP phase before the Final Eight of the European Champions League would restore player fatigue and recovery status and enhance swimming performance.

METHODS

Subjects

A total of 11 male elite water polo players (age, 26.4 ± 5.2 years; body mass, 101.6 ± 16.1 kg; stature, 192.3 ± 7.9 cm) took part in the study. Of these 11 players, 4 did not participate in all measurements due to illness or injury, and were excluded from data analysis. As a result, 7 players completed all training and testing sessions and were considered for the study (age, 26.0 ± 5.0 years; body mass, 100.5 ± 17.1 kg; stature, 192.6 ± 8.4 cm). The study was conducted during the competitive period, during which players participated in National League games as well as in the European Champions league tournament. Written informed consent was obtained from all participants. The experimental protocol was approved by the faculty review board (1107/13-03-2019) and conformed to the Declaration of Helsinki for human subjects.

Design

The training phases of the current study were designed with the aim to improve competitive readiness and performance of elite water polo players in the lead-up to the Final Eight of the European Champions League. Internal training load (ITL) and perceived recovery were assessed daily. Maximal (100- and 200-meter swim) and submaximal intermittent 4 × 100-meter constant swimming speed tests were applied at the beginning of normal training (baseline) as well as at the end of CON and TAP training phases to evaluate training-induced performance and recovery alterations. In this regard, HRsubmax and HRR measures were recorded during and after the intermittent swimming test to assess physiological adaptations to training as well as to provide an index of players' cardiac autonomic recovery.

Procedures

Training Schedule

Each training block consisted of different training microcycles. In particular, NM was divided into 2 consecutive training microcycles (10 and 8 days: NM-1 and NM-2, respectively). During NM, all players participated in 23 training sessions and competed in 2 domestic and 1 international match played at home (Table 1). The CON block was divided into 3 consecutive microcycles (4, 10, and 10 days: CON-1, CON-2, CON-3, respectively). During CON, players participated in 20 training sessions, 1 domestic match played for the National League, 1 international tournament (2 matches played within 2 days), and 2 international matches played away for the European Champions League (Table 1). The TAP block was divided into 2 consecutive training microcycles (6 and 7 days: TAP-1 and TAP-2, respectively), during which all players participated in 10 training sessions and 1 European Champions League match played at home (Table 1).

Measurements

A week before NM (baseline) and at the end of NM, CON, and TAP training blocks, maximum effort tests in 100- and 200-meter freestyle swimming were applied to assess performance. During the same periods, and 1 or 2 days later, an intermittent 4 ×

Table 1. Training content across 3 distinct training blocks: NM, CON, and TAP

Training Block	Strength Training (Gym Sessions)	In-water Conditioning, Technical and Tactical Training	National League Matches	Champions League Matches/ International Matches	Rest Days	Travel Days	s-RPE, AU
NM-1 (10 days)	2	10	1	1	2	0	5.89 ± 0.22
NM-2 (8 days)	2	9	1	0	2	0	4.96 ± 0.19
CON-1 (4 days)	0	2	0	1	0	2	5.43 ± 0.42
CON-2 (10 days)	1	9	0	2	1	2	5.51 ± 0.28
CON-3 (10 days)	0	8	1	1	1	2	6.04 ± 0.35
TAP-1 (6 days)	1	5	0	1	1	0	6.70 ± 0.19
TAP-2 (7 days)	0	4	0	0	4	0	6.05 ± 0.30

AU, arbitrary units; CON, congested training microcycle; NM, normal training microcycle; s-RPE, session rating of perceived exertion; TAP, tapering microcycle.

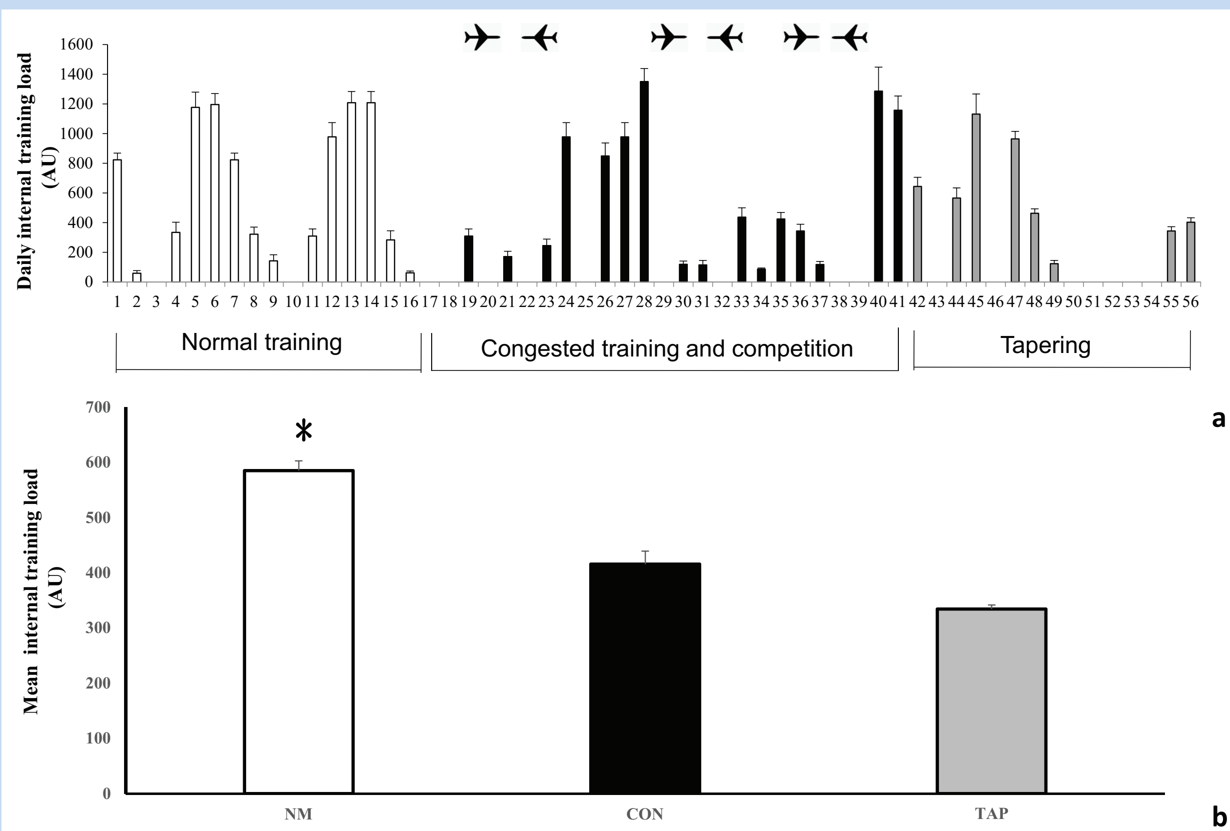

Figure 1. (a) Daily and (b) mean ITL applied within NM, CON, and TAP training; ✈ indicates airline travel for an away match. AU, arbitrary units; CON, congested training microcycle; ITL, internal training load; NM, normal training microcycle; TAP, tapering microcycle. *The asterisk depicts significant difference ($p < 0.01$) between NM and CON as well as between NM and TAP.

100-meters with 10 seconds passive resting interval swimming test was completed with intensity corresponding to 85% of the maximum speed attained during the 100-meter maximum intensity freestyle swim test.

HR Parameters

Throughout the 4 × 100-meter test, HR was recorded continuously using telemetry (Hosand, Aqua). Immediately after completion of the test, players remained passive in an upright position and HRR was assessed for 60 seconds. The average HRsubmax value was calculated during the last 30 seconds of the 4 × 100-meter swimming test. HRpeak was the maximum HR value recorded during the test. HRend was the mean HR value over the last 5 seconds of the test; Δ60 was the absolute difference between HRend and mean HR recorded over 15 seconds after 60 seconds of upright recovery (HR60). HRR10s% was the percent change in HR during the first 10 seconds of recovery from HRend.[22] The Δ60peak was the difference between the HRpeak during the test and the mean HR over a 5 second period that occurred 60 seconds after the test.[20]

ITL and Perceived Recovery

Throughout the 3 distinct training blocks, ITL was measured daily at 30 minutes posttraining or postmatch by multiplying the rating of perceived exertion by training or playing time duration.[12] Perceived recovery was obtained from each player every morning upon awakening (8:00-8:30 AM) and assessed on a scale of 0 (very poorly recovered) to 10 (very well recovered) when players were asked "how do you feel?"[3,16] Daily ITL and perceived recovery were averaged for the NM (NM-1 and NM-2), CON (CON-1, CON-2, and CON-3), and TAP (TAP-1 and TAP-2) blocks and used in the analysis.

Statistical Analysis

All results are expressed as means, and standard deviations and 95% confidence limits (CL) were also calculated. One-way analysis of variance with repeated measures was used to detect differences in HR indices, ITL, perceived recovery, and swimming performance across timepoints. A Tukey's Honest Significant Difference post hoc test was applied to detect specific differences among testing points. The magnitude of difference of all variables between testing points was determined using Cohen's *d*. Values of 0.20, 0.50, and >0.80 were considered small, medium, and large, respectively.[8] Significance level was set at $P \leq 0.05$.

RESULTS

Daily and mean ITL distribution are depicted in Figure 1. Training load was higher in NM compared with CON and TAP by 28.9 ± 2.6% and 42.8 ± 2.1% ($P < 0.01$, $d = 11.54$, and $p < 0.001$, $d = 13.45$, respectively). In addition, it was higher in CON than TAP by 19.4 ± 4.2% ($P < 0.01$, $d = 3.78$). Regarding the specific loading patterns applied within microcycles, it was revealed that training loads were higher in NM-1 and NM-2 compared with the others ($P < 0.01$). Furthermore, in CON the peak training load was recorded in CON-2, which was higher than CON-1, CON-3, and TAP-2 ($P < 0.01$) but similar to TAP-1 ($P = 0.12$).

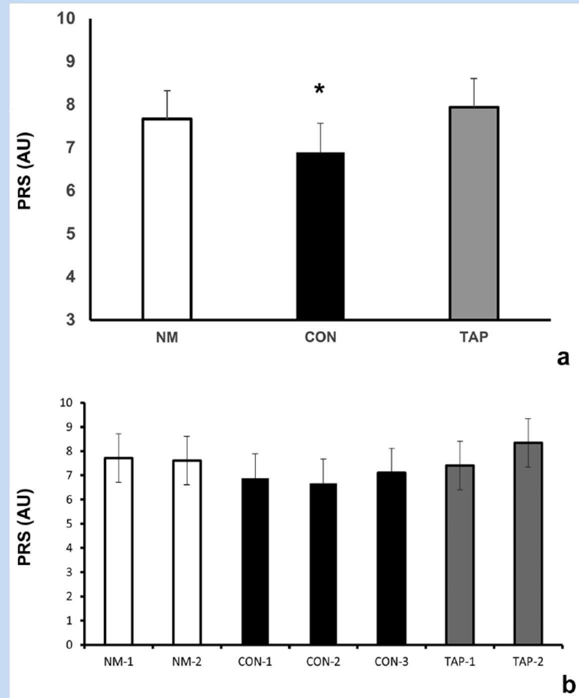

Figure 2. PRS across (a) training blocks and (b) microcycles. *Significant difference between CON and NM ($P < 0.01$) and CON and TAP ($P < 0.01$). AU, arbitrary units; CON, congested training microcycle; NM, normal training microcycle; PRS, perceived recovery scale; TAP, tapering microcycle.

Figure 2 presents PRS across training blocks and microcycles. PRS was different among training blocks ($P < 0.01$). In particular, PRS was lower in CON compared with both NM and TAP training ($P = 0.00$ and $P = 0.00$, $d = 1.26$ and $d = 3.11$, respectively), while no differences were found between NM and TAP ($P = 0.13$, $d = 0.62$). With respect to the PRS observed within microcycles, it was lower in CON-1 and CON-2 compared with NM-1 and NM-2 and reversed progressively toward TAP-2.

Swimming speed in 100- and 200-meter tests was improved in TAP compared with baseline ($P = 0.00$, $d = 1.34$ and $P = 0.00$, $d = 1.12$, respectively), whereas no differences were detected among the other training blocks ($P > 0.05$; Table 2). The swimming pace during the 4 × 100-meter test was similar ($P = 0.31$) among testing days and corresponded to 86.8 ± 1.9%, 86.3 ± 3.3%, 85.8 ± 2.7%, and 85.1 ± 0.9% of the maximum 100-meter speed at baseline, as well as after the completion of NM, CON, and TAP, respectively ($P = 0.83$; Table 2). HRsubmax was similar among the training periods ($P = 0.60$; Table 2). Most HRR indices remained unaltered among training blocks (Table 2).

Table 2. Exercise performance and HR measurements performed at the beginning (baseline), and after NM, CON, and TAP training[a]

	Variable	Baseline	NM	CON	TAP	Time Effect
Exercise performance	100-meter swim test, m/s	1.65 ± 0.05 1.59; 1.75	1.67 ± 0.05 1.62; 1.71	1.67 ± 0.04 1.63; 1.70	1.69 ± 0.03* 1.66; 1.75	0.01
	200-meter swim test, m/s	1.50 ± 0.04 1.46; 1.54	1.51 ± 0.04 1.47; 1.55	1.52 ± 0.05 1.47; 1.56	1.54 ± 0.06* 1.49; 1.60	0.00
	Mean swimming speed in 4 × 100-meter test, m/s	1.46 ± 0.05 1.41; 1.50	1.47 ± 0.05 1.42; 1.52	1.46 ± 0.04 1.43; 1.49	1.47 ± 0.03 1.44; 1.50	0.42
HRR	Δ60, beats/min	38 ± 17 21.91; 54.18	30 ± 12 19.43;41.13	35 ± 5 30.11; 39.89	34 ± 12 22.60; 45.02	0.31
	HRR10s%	1.90 ± 1.90 0.14; 3.65	1.18 ± 0.80 0.44; 1.92	4.07 ± 2.64** 1.63; 6.51	2.50 ± 1.35 1.25; 3.76	0.05
	HR60, beats/min	140 ± 18 123; 156	141 ± 13 130; 153	135 ± 10 126; 144	136 ± 13 124; 148	0.75
Exercise HR measures	HRsubmax	171 ± 9 163; 180	170 ± 12 159; 182	169 ± 11 160; 179	167 ± 10 158; 176	0.60
	HRpeak (beats·min^{-1})	174 ± 9 166; 182	173 ± 12 162; 184	171 ± 12 160; 182	173 ± 12 162; 184	0.82
	HRend (beats·min^{-1})	176 ± 5 170; 181	171 ± 11 161; 182	170 ± 11 160; 181	170 ± 9 161; 178	0.21

Δ60, difference in HR at end of exercise and after 60 seconds rest; Δ60peak, difference in peak HR and HR after 60 seconds rest; CL, confidence limits; CON, congested training microcycle; HR, heart rate; HRsubmax, submaximal HR; HR60, HR after 60 seconds rest; HRend, HR at end of exercise; HRR10s%, percent change in HR during the first 10 seconds of recovery from HRend; HRpeak, maximum HR recorded during exercise; NM, normal training microcycle; TAP, tapering microcycle.

[a]Data presented as mean ± SD and 95% CL.

*$P < 0.05$ compared with baseline; **$P < 0.05$ compared with NM.

HRR10s%, however, was higher after congested training compared with normal training ($P = 0.04$, $d = 0.97$; Table 2).

DISCUSSION

The present study described training load distribution within the competitive period and evaluated the use of objective and subjective responses as training surveillance tools in elite water polo players. The principal findings are as follows: (1) during the extended CON period, training load was significantly lower compared with NM. However, the perceived recovery was worse in CON than both NM and TAP; (2) in TAP, the perceived recovery was restored and both 100- and 200-meter swim times were significantly improved compared with baseline; and (3) HRsubmax and most HRR indices remained unaltered across training blocks.

The present ITL values are much greater compared with values reported during the in-season phase in other team sports.[15] Nonetheless, in comparison with other team sports, the match loads appear to be lower in water polo; this might be due to the shorter match duration as well as to the frequent rotation applied among players during competition.[2] In addition, since competition in water polo occurs in an aquatic environment, it is plausible that less eccentric load is imposed on players compared with other team sports.

Of note also, the distribution of workloads demonstrates that, as in other team sports,[18] strategic periodization is also used in elite water polo. This suggests that elite teams choose to intentionally peak for matches of perceived greatest priority or difficulty.[18] Herein, we observed significantly different workloads among the different microcycles, with the highest workloads being observed during NM-1 and NM-2. During CON training, the available time for training was relatively limited due to the multiple matches in which the team planned to participate and, as a result, we observed lower workloads during CON training compared with the other training blocks. The lower workloads reported in CON training most likely led to a greater reduction in HRR after the standardized swim test, as reflected by the pronounced decrease in HRR10s% compared with NM, probably denoting greater parasympathetic reactivation.[7,9] Conversely, we observed that, despite the lower workloads during CON fixtures, perceived recovery deteriorated compared with NM training, indicating an accumulation of fatigue and a residual stress induced by successive travels and matches. This finding corroborates previous observations in professional Australian football players, who were found to demonstrate reduced wellness scores and prolonged time of recovery in the late competition phase compared with the early competition phase of a prolonged in-season period comprised of matches and travel.[10]

In addition, workloads were considerably reduced during TAP-2. Similar strategies have been also applied in other team sports as well as in water polo.[5,13,14] During this period, Easter break intervened, and the staff decided on a 4-day training cessation. In this context, Buchheit et al[6] demonstrated that the Christmas break allowed Australian football players to return well recovered with their physical qualities preserved. Similarly, we showed here that the perceived recovery of the players was restored compared with CON fixture and that swimming performance improved significantly in a test applied 2 days after the termination of training cessation.

Despite the significance of the present results, there are some limitations that have to be considered. First, only a small number of players (N = 7) participated in the study, which likely makes the generalization of our findings difficult. Second, the present training program was applied in elite water polo players and, as such, it would be difficult to apply a similar training program and/or periodization model in lower-level players with different training experience. Third, the absence of biological markers (other than HR) is definitely another limitation, since it is currently unknown whether such a periodization, together with perceived recovery, affects objective indices of recovery.

CONCLUSION

This study describes training periodization and testing procedures in a real training and competition setting adopted by an elite water polo team during a long-term competitive period leading up to the Final Eight of the European Champions League. Our findings demonstrate that the high training load, competition, and travel demands impair the perceived recovery status of the players. However, effective management of training load during TAP-2 can restore recovery and improve swimming performance.

CLINICAL RECOMMENDATIONS

Despite the lower workloads, a CON period of training impairs perceived recovery without affecting swimming performance. The worse perceived recovery is likely due to fatigue accumulation induced by consecutive travel and matches. During the same period, and despite the lower training load, swimming performance also remained unaltered, indicating that the exercise stimulus from successive matches was high enough to preserve players' physical qualities. However, a short-term, abrupt reduction of workload due to training cessation after a CON fixture restores recovery and helps elite players to improve swimming performance.

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REFERENCES

1. Bellenger CR, Fuller JT, Thomson RL, Davison K, Robertson EY, Buckley JD. Monitoring athletic training status through autonomic heart rate regulation: a systematic review and meta-analysis. *Sports Med*. 2016;46(10):1461-1486.
2. Botonis PG, Arsoniadis GG, Platanou TI, Toubekis AG. Heart rate recovery responses after acute training load changes in top-class water polo players. *Eur J Sport Sci*. 2021;21(2):158-165.
3. Botonis PG, Smilios I, Platanou TI, Toubekis AG. Effects of an international tournament on heart rate variability and perceived recovery in elite water polo players. *J Strength Cond Res*. 2022;36(8):2313-2317.
4. Botonis PG, Smilios I, Toubekis AG. Supercompensation in elite water polo: heart rate variability and perceived recovery. *Sports Med Int Open*. 2021;5(2):E53-E58.
5. Botonis PG, Toubekis AG, Platanou TI. Training loads, wellness and performance before and during tapering for a water polo tournament. *J Hum Kinet*. 2019;66:131-141.
6. Buchheit M, Morgan M, Wallace J, Bode M, Poulos N. Physiological, psychometric, and performance effects of the Christmas break in Australian football. *J Strength Cond Res*. 2015;10(1):120-123.
7. Buchheit M, Papelier Y, Laursen PB, Ahmaidi S. Noninvasive assessment of cardiac parasympathetic function: postexercise heart rate recovery or heart rate variability? *Am J Physiol Heart Circ Physiol*. 2007;293(1):H8-H10.
8. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. New York: Routledge Academic; 1988.
9. Daanen HA, Lamberts RP, Kallen VL, Jin A, Van Meeteren LUN. A systematic review on heart-rate recovery to monitor changes in training status in athletes. *Int J Sports Physiol Perform*. 2012;7(3):251-260.
10. Fowler P, Duffield R, Waterson A, Vaile J. Effects of regular away travel on training loads, recovery and injury rates in professional Australian soccer players. *Int J Sports Physiol Perform*. 2015;10(5):546-552.
11. Lamberts PR, Swart J, Capostagno B, Noakes TD, Lambert MI. Heart rate recovery as a guide to monitor fatigue and predict changes in performance parameters. *Scand J Med Sci Sports*. 2010;20(3):449-457.
12. Lupo C, Capranica L, Tessitore A. The validity of session-RPE method for quantifying training load in water polo. *Int J Sports Physiol Perform*. 2014;9(4):656-660.
13. Marrier B, Le Meur Y, Leduc C, et al. Training periodization over an elite Rugby Sevens season: from theory to practice. *Int J Sports Physiol Perform*. 2019;14(1):113-121.
14. Marrier B, Robineau J, Piscione J, et al. Supercompensation kinetics of physical qualities during a taper in team-sport athletes. *Int J Sports Physiol Perform*. 2017;12(9):1163-1169.
15. Moreira A, Bilsborough JC, Sullivan CJ, Ciancosi M, Aoki MS, Coutts AJ. Training periodization of professional Australian football players during an entire Australian Football League season. *Int J Sports Physiol Perform*. 2015;10(5):566-571.
16. Paul DJ, Tomazoli G, Nassis GP. Match-related time course of perceived recovery in youth football players. *Int J Sports Physiol Perform*. 2019;14(3):339-342.
17. Rago V, Krustrup P, Martin-Acero R, Rebelo A, Mohr M. Training load and submaximal heart rate testing throughout a competitive period in a top-level male football team. *J Sports Sci*. 2020;38(11-12):1408-1415.
18. Robertson SI, Joyce DG. Informing in-season tactical periodization in team-sport: development of a match difficulty index for super Rugby. *J Sports Sci*. 2015;33(1):99-107.
19. Schneider C, Hanakam F, Wiewelhove T, et al. Heart rate monitoring in team-sports - a conceptual framework for contextualizing heart rate measures for training and recovery prescription. *Front Physiol*. 2018;9:639.
20. Thomson RL, Bellenger CR, Howe PRC, Karavirta L, Buckley JD. Improved heart rate recovery despite reduced exercise performance following heavy training: a within-subject analysis. *J Sci Med Sport*. 2016;19(3):255-259.
21. Twist C, Highton C, Daniels M, Mill M, Close G. Player responses to match and training demands during an intensified fixture schedule in professional rugby league: a case study. *Int J Sports Physiol Perform*. 2017;12(8):1093-1098.
22. Watson AM, Brickson SL, Prawda ER, Sinfilippo JL. Short-term heart rate recovery is related to aerobic fitness in elite intermittent sport athletes. *J Strength Cond Res*. 2017;31(4):1055-1061.