International Journal of Sports Physiology and Performance, (Ahead of Print)
https://doi.org/10.1123/ijspp.2021-0455

First Published Online: Mar. 7, 2022

Human Kinetics
ORIGINAL INVESTIGATION

Effects of Long-Haul Travel and the Olympic Games on Heart-Rate Variability in Rugby Sevens Medalists

Andrew A. Flatt and Daniel Howells

Purpose: To report the impact of long-haul travel and the Olympic tournament on heart-rate variability and subjective well-being in a rugby sevens team. ***Methods:*** Players (N = 12 men) recorded daily root mean square of successive differences (LnRMSSD) and brief subjective well-being assessments before and throughout the Olympic tournament. Following a 7-day baseline involving a tournament simulation, 2 flights were taken to Brazil (20-h travel and 4-h time gain) on day 1. Matches occurred on days 13 to 15. Undefeated, the team advanced to the gold-medal final. Team staff used a combination of proactive and reactive strategies to support training adaptations, mitigate negative effects of travel, and facilitate recovery from competition. ***Results:*** Peak LnRMSSD values from the preceding preparatory period were observed at baseline. Perceived recovery was impaired on day 1 following tournament simulation ($P < .05$). Lower and less stable LnRMSSD trends were observed in players within the first week following long-haul travel ($P < .05$), evident primarily in nonstarters (effect size = *unclear* to *very large*) versus starters (effect size = *unclear*). Status markers were subsequently maintained at baseline or improved prior to the tournament and were minimally affected by competition ($P > .05$). Changes in LnRMSSD were associated ($P < .05$) with changes in perceived recovery (day 14, $\rho = .64$) and sleep quality (day 15, $\rho = .69$) during the tournament. ***Conclusions:*** Attentiveness to player health and well-being throughout preparation, travel, and the Olympic tournament potentially mitigated decrements in status markers, thereby reducing potential for fatigue or stress-related performance impairment.

Keywords: autonomic, parasympathetic, cardiovascular, elite athletes, sport science

Peaking for Olympic competition at an international venue is among the greatest challenges faced by sport teams. Excess stress and fatigue in the lead-up to competition may increase injury or illness risk and negatively impact performance outcomes.[1] To maintain player health and well-being, coaching and support staff are tasked with managing training loads, travel itineraries, and the acclimation process to changes in time zone and environmental conditions in a foreign location. Heterogeneous responses among a mixed roster of players adds further challenge.[2] Strategies that minimize risk and support adaptations are therefore critical for facilitating a high level of competition readiness at the worlds premier sporting event.

Rugby sevens debuted at the 2016 Olympic games in Rio de Janeiro with one of the highest injury rates of all sports.[3] Physical demands of rugby sevens necessitate high levels of aerobic fitness and musculoskeletal strength and power to endure continuous high-intensity activity with frequent collisions.[4] The tournament format in which rugby sevens is played during the Olympics involves ~6 matches within a 72-hour period, which may provide inadequate recovery for a variety of physiological and performance parameters.[5] Though a limited number of previous studies have addressed short-[6,7] and long-term[8] preparation strategies for Olympic rugby sevens competition, none have addressed the final key events leading up to and including the tournament.

Vagal-mediated heart rate variability (HRV) and perceptual well-being questionnaires provide objective and subjective indicators of stress and recovery, respectively.[1,9] These noninvasive status markers are sensitive to a variety of stressors likely to be experienced by some athletes before or during the Olympics, including: travel fatigue,[7] illness,[10] training and match fatigue,[7,10] and precompetitive anxiety.[11] Daily HRV and well-being tracking enables tailoring of training and recovery interventions based on individual responses.[6] Moreover, important feedback regarding intervention effectiveness can be gained by observing changes in status markers following implementation.[12] Though guidelines exist for supporting players in various training- and travel-related contexts,[1,9,13] a detailed report of implementation methods and their impact on status markers in elite athletes may benefit practitioners. Therefore, the purpose of this investigation was to report the impact of long-haul travel and Olympic competition on HRV and well-being markers in a rugby sevens team. Strategies and interventions aimed at facilitating training adaptations, mitigating negative effects of long-haul travel, and supporting recovery are discussed.

Methods

Subjects

Players (n = 12 men) selected to represent Great Britain at the 2016 Olympic Summer Games were included in the analysis (reported as mean [SD]: height = 185 [7] cm; weight = 91 [7] kg; maximum aerobic speed = 4.60 [0.15] $m \cdot s^{-1}$). Data were collected as part of routine player monitoring by staff. Ethical approval for retrospective analysis of deidentified data was obtained from the Georgia Southern University institutional review board.

Schedule

Mean and median values from 7 days immediately predeparture for Brazil were used to establish baseline for HRV and wellness parameters, respectively. The baseline week involved routine

Flatt is with the Dept of Health Sciences and Kinesiology, Biodynamics and Human Performance Center, Georgia Southern University (Armstrong Campus), Savannah, GA, USA. Howells is with Rugby Football Union, Rugby House, Twickenham Stadium, Twickenham, United Kingdom. Flatt (aflatt@georgiasouthern.edu) is corresponding author.

training for 3 days, a rest day, and finished with a 3-day Olympic tournament simulation. Day 1 of the observation period involved 2 southwestward flights to Belo Horizonte, Brazil (~9000 km) for a 6-day training camp. Departure and arrival times were 1220 Greenwich Mean Time^{+1}(GMT) and 0130 GMT^{-3}, respectively. Total time spent in airports or transit was ~20 hours. HRV recordings were omitted on day 2 due to an altered wake time. Rugby training progressively resumed on day 4 (40-min AM session of skills and mobility, 40-min PM session of single phase, unopposed rugby), day 5 (60-min PM session of noncontact, multiphase rugby), and day 7 (AM session of multiphase rugby and contact drills). Pool-based active recovery sessions (~20 min) occurred on mornings of days 3 and 5, and following training on days 7, 10, and 12. One flight was taken to the Olympic Village in Rio de Janeiro (~442 km) on day 8. Opening ceremonies were attended on day 9. Tournament matches occurred on days 13 to 15. Brief priming sessions consisting of warm-up and mobility (10 min) followed by highintensity running intervals (10 min, work:rest = 1:3) were performed ~3 hours before kick-off. Undefeated, the team advanced to the gold medal final. Various strategies and interventions were implemented by team staff to minimize the physiological and psychological impact of the events leading up to and including the Games (described further in the "Discussion" section). A calendar of events is displayed in Figure 1.

Monitoring Variables

Postwaking HRV and subjective well-being were obtained as described previously.[6,7] In brief, the natural logarithm of the root mean square of successive RR interval differences (LnRMSSD) was derived from seated 60-second recordings using an H7 chest strap (Polar Electro, Kempele, Finland) paired with a smartphone application (Elite HRV, Asheville, NC). RR filtering was performed by the applications proprietary algorithm. Compliance with daily HRV was 97% (1%). HRV data were assessed as daily LnRMSSD values, 7-day rolling LnRMSSD averages, and 7-day rolling coefficient of variation (LnRMSSDcv, calculated as [SD/mean] × 100). Daily values represent short-term effects, the rolling average reflects cumulative effects from the preceding 7-day period, and the rolling LnRMSSDcv reflects the magnitude of fluctuation in values from the preceding 7-day period. Higher and more stable values are generally desirable in athletes,[6,14] whereas fluctuations and sustained reductions are associated with stress and fatigue.[10,15] Following HRV recordings, players submitted 1 to 10 well-being subscale ratings of sleep quality, energy levels, muscle soreness, perceived recovery, and mood, via e-mail (higher numbers reflected better ratings).[1] Compliance with questionnaires was 99 (1%).

Training Load

Session rating of perceived exertion was used to quantify loads from conditioning, resistance training, rugby training, and competitions, as previously described.[6,7] Following sessions, players reported their 1 to 10 RPE, which was multiplied by the session duration in minutes. The daily session rating of perceived exertion sum was recorded for analysis.

Statistical Analyses

The HRV data are reported as mean and 95% confidence interval, and wellness data are reported as median and 95% confidence interval. Mixed effects linear models were used to examine variation in HRV parameters. Time was included as a fixed effect and subject identification was included as a random effect. Dunnet tests were used for post hoc comparisons to baseline. Hedges effect size (ES) was used to calculate standardized differences.[16] ES values of <0.2, <0.6, <1.2, <2.0, and >2.0 were qualitatively interpreted as *trivial, small, moderate, large*, and *very large*, respectively.[17] ES were deemed *unclear* if the 95% confidence interval of the ES overlapped the trivial zone (0.2 to −0.2). Due to differences in match loads, data for starters (n = 7) and nonstarters (n = 5) were compared with ESs. Friedman test was used to examine variation in wellness parameters across time. Post hoc comparisons to baseline were performed with Dunn tests. Associations between changes in (Δ) daily LnRMSSD and Δ subjective parameters following travel, and throughout the Olympic tournament were quantified with Spearman ρ. Correlation <.1, <.3, <.5, <.7, <.9, and >.9 were interpreted as *trivial*, *small*, *moderate*, *large*, *very large*, and *nearly perfect*, respectively.[17] P values < .05 were considered statistically significant. All analyses were performed using Prism 9.1.0 (GraphPad, San Diego, CA).

Results

The HRV values and ESs are presented in Figures 2 and 3, respectively. Significant model effects were observed for the rolling LnRMSSD average ($F_{14,154} = 2.787$, $P = .001$) and LnRMSSDcv ($F_{14,154} = 2.388$, $P = .005$). The rolling LnRMSSD average was lower than baseline on days 4 to 7 ($P = .005$–$.035$), though corresponding ESs were *unclear* (−0.33 to −0.42). Starters demonstrated smaller ES changes in the rolling LnRMSSD average (−0.26 to 0.05, *unclear*) than nonstarters (−0.56 to −0.07, *unclear*). The rolling LnRMSSDcv was greater than baseline on day 6 ($P = .047$), while ES increases were *moderate* (0.69 to 0.89) on days 5 to 7. Starters demonstrated smaller increases and greater reductions in LnRMSSDcv (−0.56 to 0.33, *unclear*) relative to baseline than nonstarters, who only showed increases (0.13 to 2.03, *unclear–very large*). No model effect was observed for daily LnRMSSD ($F_{14,148} = 1.644$, $P = .074$). Though ES were *unclear*, changes in daily LnRMSSD were smaller for starters (−0.44 to 0.21) than nonstarters (−1.08 to 0.41).

Wellness data are presented in Figure 4. Significant model effects were observed for sleep ($\chi^2_{15} = 41.03$ $P = .0003$), energy ($\chi^2_{15} = 62.79$, $P < .0001$), soreness ($\chi^2_{15} = 65.50$, $P < .0001$), and recovery ($\chi^2_{15} = 84.44$, $P < .0001$). No model effect was observed for mood ($\chi^2_{15} = 13.87$, $P = .54$). Recovery was below baseline on day 1 ($P = .028$) and greater than baseline on day 13 ($P = .028$). Energy was greater than baseline on day 13 ($P < .009$). No post hoc differences were observed for sleep ($P = .13$–$.99$), or soreness ($P = .17$–$.99$).

No associations were observed between Δ variables on day 1 or 3 ($P > .05$). On day 14, Δ LnRMSSD (relative to the 7-d rolling average on day 13) was *largely* associated ($\rho = .64$, $P = .035$) with Δ recovery (relative to day 13). Subsequently on day 15, Δ LnRMSSD (relative to the 7-d rolling average on day 13) was *largely* associated ($\rho = .69$, $P = .018$) with Δ sleep (relative to day 13). Scatterplots are displayed in Figure 5.

Discussion

Herein, we report cardiac-autonomic and perceptual responses of rugby sevens players to the events leading up to and including the 2016 Olympic Games. HRV and subjective parameters were negatively affected by tournament simulation and travel-related

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
			BL 1. -Rest	BL 2. -Light conditioning -Light weights	BL 3. -Rest	BL 4. -Rest
BL 5. Tournament simulation -Speed -Weights -Rugby -Cryotherapy	BL 6. Tournament simulation -Speed -Weights -Rugby -Cryotherapy	BL 7. Tournament simulation -Speed -Weights -Rugby	1. London → Belo Horizonte (9006 km, 4 h time gain)	2. -Mobility/stretch	3. -Pool recovery -Weights	4. -Pool recovery -AM rugby -PM rugby
5. -Pool recovery -Rugby -Weights	6. -Rest	7. -Rugby -Pool recovery	8. Belo Horizonte → Rio (440 km)	9. -Rugby -Opening ceremony	10. -Weights -Rugby -Pool recovery	11. -Rest
12. -Rugby -Pool recovery	13. -Priming (0900) -Match 1 (1200) -Match 2 (1700)	14. -Priming (0930) -Match 3 (1230) -Quarter-final (1800)	15. -Priming (1200) -Semi-final (1500) -Final (1900)			

Figure 1 — Calendar of events during the observational BL and Olympic period. BL indicates baseline.

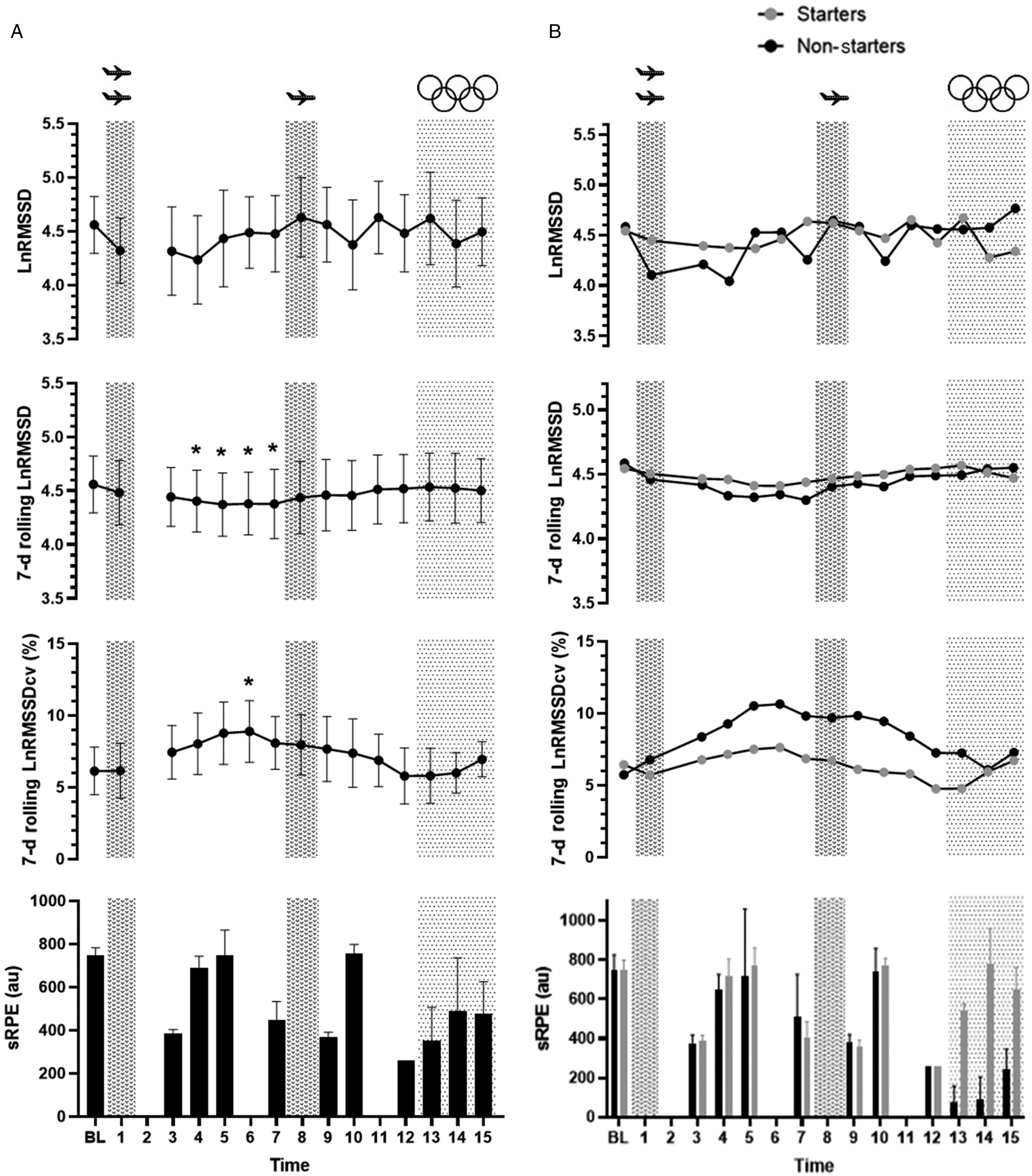

Figure 2 — Mean and 95% confidence interval for daily, 7-day rolling average, and 7-day rolling CV of the LnRMSSD and sRPE for (A) the entire roster (N = 12) and (B) starters (n = 7) versus nonstarters (n = 5). Confidence intervals are not displayed in (B) for clarity. BL indicates baseline; CV, coefficient of variation; LnRMSSD, logarithm of the root mean square of successive differences; sRPE, session rating of perceived exertion. *Different from baseline ($P < .05$).

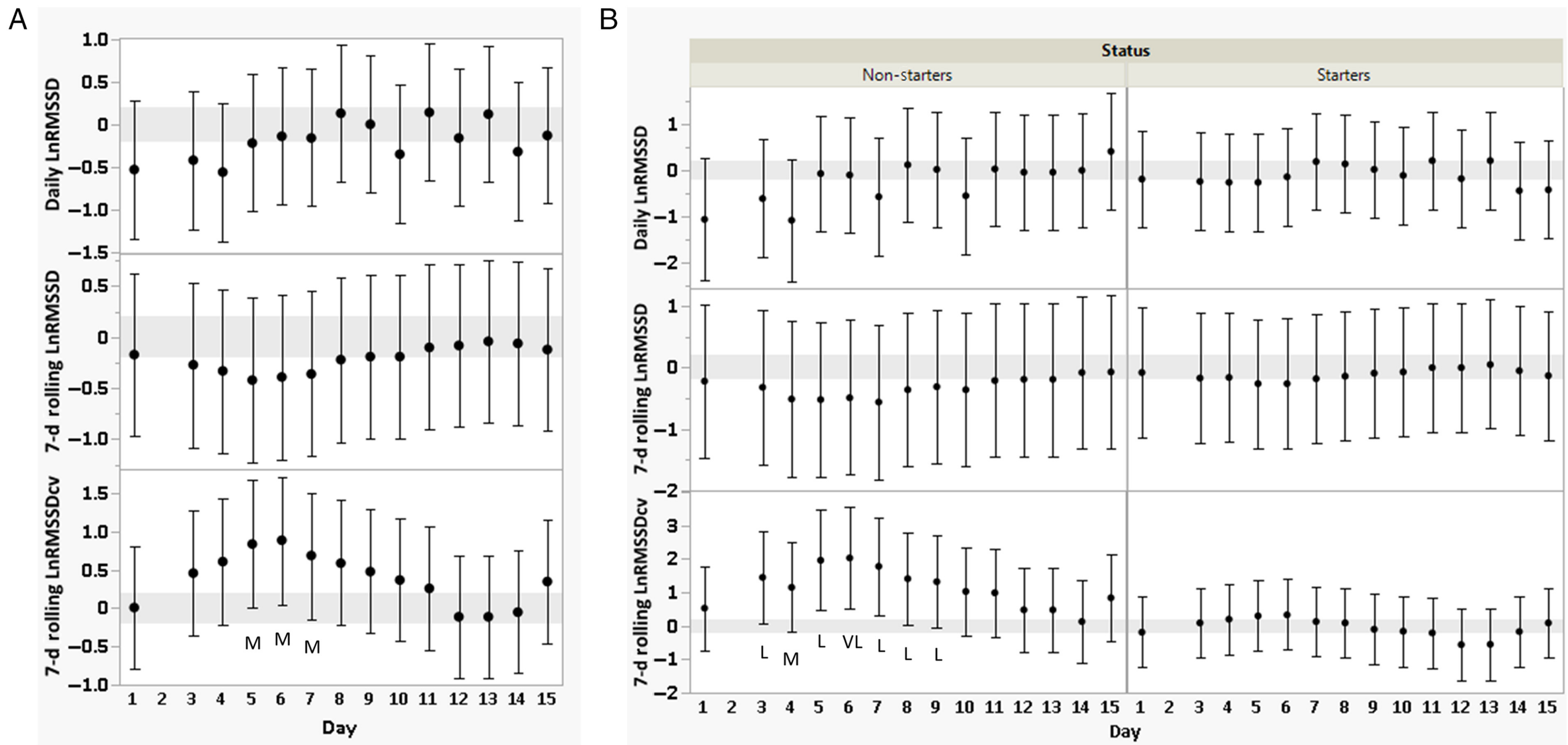

Figure 3 — Effect size and 95% confidence interval for daily, rolling average, and rolling CV of the LnRMSSD for (A) the entire roster (N = 12) and (B) starters (n = 7) versus nonstarters (n = 5). Shaded area represents the trivial zone (–0.2 to 0.2). CV indicates coefficient of variation; L, *large*; LnRMSSD, logarithm of the root mean square of successive difference; M, *moderate*; VL, *very large*. All values without a letter are interpreted as *unclear*.

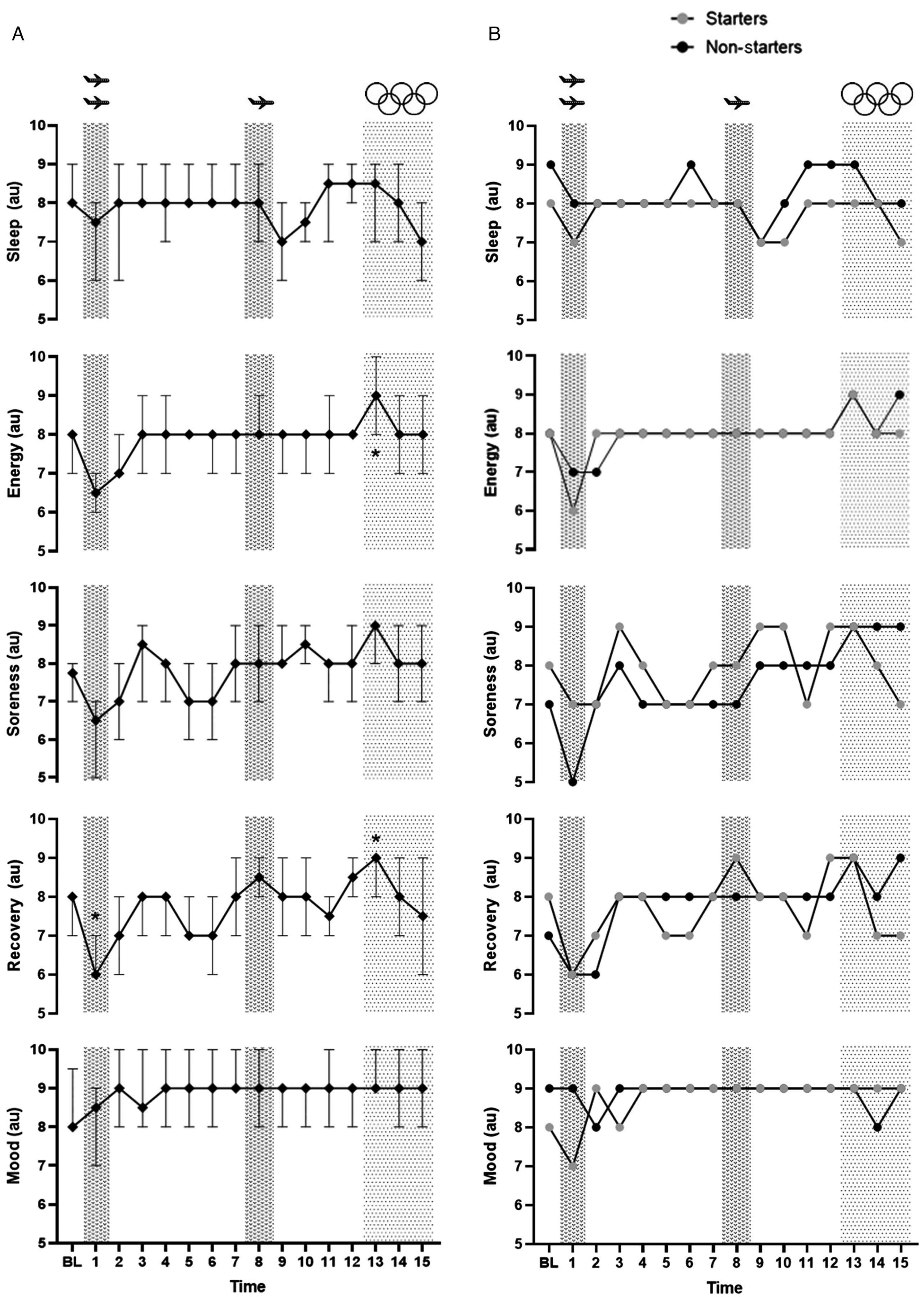

Figure 4 — Median and 95% confidence interval for subjective well-being markers for (A) the entire roster (N = 12) and (B) starters (n = 7) versus nonstarters (n = 5). Confidence intervals are not displayed in (B) for clarity. BL indicates baseline. *Different from BL ($P < .05$).

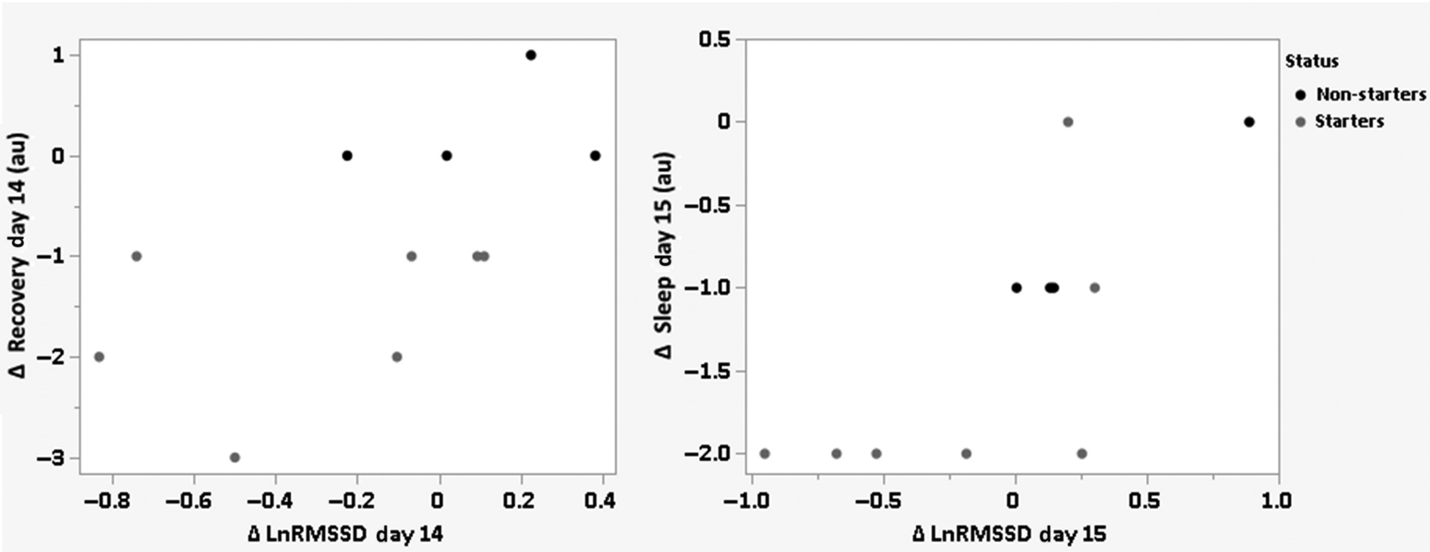

Figure 5 — Scatterplots representing associations between changes in the Δ LnRMSSD and changes in perceived recovery and sleep quality on days 14 and 15 amid the Olympic tournament, respectively. Au indicates arbitrary units; Δ LnRMSSD, natural logarithm of the root mean square of successive difference.

factors primarily in nonstarters, but were maintained at baseline or improved thereafter. Changes in LnRMSSD were associated with changes in perceived recovery (day 14) and sleep quality (day 15) on match days. Exceptionally high team performance was observed at the tournament, reflected in undefeated advancement to the gold medal final. We propose that various strategies and interventions implemented by team staff aided players' ability to cope with preparatory training as well as travel- and competition-related stressors, inferred from minor and unsustained changes in status markers throughout the observation period.

In the ~10 weeks preceding the Olympics, aims were to further improve players' high physical capacities and technical abilities while emphasizing tactical cohesion among new and existing roster members. Early weeks prioritized aerobic fitness. Long (1- to 4-min efforts, 1:1 work–rest ratio) and short (15- to 30-s efforts, 2:1-1:1 work–rest ratio) high-intensity interval training methods were used to accumulate time spent at >90% of estimated aerobic power.[18] Rugby training was used in later weeks to generate physical intensities that exceeded "worst case" match scenarios. Combined with participation in multiple international tournaments during this period, players were well-adapted to competition and intracontinental travel demands.

Staff promoted a theme of resiliency with a collective goal of being the most adaptable team at the tournament. Mental exercises for dealing with adversity and overcoming unforeseen challenges were introduced. Postmatch debrief meetings were held to identify alternative responses to situations that were handled poorly. In separate discussions, hypothetical adverse events that may occur were identified along with plans for how they would adjust, by focusing on factors within their control. Plans were successfully put into practice when dealing with travel delays, hot weather, disorganized competitions, and in player loss to injury.

Overreaching was intentionally avoided. Interventions were used when acute fatigue was indicated by decrements in monitoring variables. For example, when daily LnRMSSD decreased by >0.5 × percentage of coefficient of variation of the preparatory 28-day average[10] for 3 consecutive days, one or more of the following were prescribed: low-intensity aerobic activity (10–20 min),[9] cold water immersion,[12] reduced training loads,[15] or supplemental vitamin C (1000 mg)[19] in case of elevated infection risk.[10,15] Subjective data were considered when selecting interventions. Current and previous[6,7] analyses confirm the absence of sustained reductions in status markers. Prior group-level reductions only occurred in response to competition and chaotic travel events.[7] Despite substantial variations in weekly training load, values were otherwise maintained or improved.[6] Weekly averaged (SD) LnRMSSD from the early, mid, and late (current baseline) preparatory period were 4.41 (0.36),[6] 4.53 (0.40),[7] and 4.56 (0.42), respectively (early vs late ES = 0.38). To our knowledge, group values observed predeparture are the highest 7-day averages reported in the literature. Factors contributing to such high vagal-mediated HRV are likely numerous. A high-training age and aerobic fitness level characteristic of elite sevens players[4] are associated with higher resting-state LnRMSSD and faster posttraining LnRMSSD recovery.[9,14] In addition, staff allocated 1 to 3 days per week for passive rest and often incorporated low-intensity training between high-intensity days. These programming strategies (ie, adequate rest and sensitivity to player recovery status) limit fatigue-related decrements and increase the likelihood that high-intensity training occurs when HRV is not reduced.[9] Superior training adaptations and increases in vagal-mediated HRV have been observed following a similar training approach.[20] Nutrition staff selected posttraining menus to facilitate glycogen replenishment and muscle repair, and provided individual guidance to promote maintenance of energy balance and adequate micronutrient intake. Finally, exposure to whole-body cryotherapy on 2 consecutive days (4 min, −120°C) amid tournament simulation during the current baseline period may have also contributed to elevated LnRMSSD.[21] Key outcomes of the training methodology implemented by staff and their attentiveness to individual recovery status were that players approached departure for the Olympics with an autonomic profile (ie, peak cardiac-parasympathetic function) considered primed for physical[22] and mental[23] adaptability.

Air travel and time zone changes alter immune function and various markers of stress and performance for several days following relocation.[2,24] However, strategically timed interventions applied during preflight, during flight, and postflight travel components can mitigate symptoms of travel fatigue and jet lag.[13] Circadian phase-shifting efforts began 72 hours predeparture to minimize jet lag severity. Estimated rates of circadian adaptation range between 0.5 and 1 day per hour time difference.[13] Thus, sleep, wake, afternoon training, and mealtimes were incrementally delayed 1 hour each day to initiate acclimation to a 4-hour time differential.[13] Morning training sessions were moved to ~noon (08:00 Rio time) to simulate primer sessions, typically performed on competition mornings. Also starting 72 hours predeparture and continuing daily postarrival, prophylactic supplementation with probiotics and vitamin C (Healthspan, St Peter Port, Guernsey, United Kingdom) were used to support digestive and immune health.[3,25] The travel itinerary on day 1 required an earlier wake time (07:00) than which players were adjusting to in the preceding days, possibly contributing to impaired subjective recovery and *unclear* decrements in daily LnRMSSD (reduced in 8/12 players) following tournament simulation. Consistent with these findings, *moderate–large* decrements in subjective markers and *unclear* decrements in LnRMSSD were previously observed 1 day following a local tournament.[7] Decrements in LnRMSSD were of greater magnitude in nonstarters than starters (ES = −1.06 vs −0.19, *unclear*, Figure 3B), in support of previous work demonstrating minimal training-related changes in LnRMSSD among higher competitive status athletes.[14]

Team staff emphasized maintenance of adjusted sleep–wake times by discouraging sleep on the plane outside nighttime hours of the destination time zone.[13] Caffeine supplementation (100–200 mg) via coffee or chewing gum (Healthspan) was used to reduce daytime sleepiness on flights. Prepackaged meals (Sport Kitchen, Bristol, United Kingdom) were distributed to players on flights in accordance with their adjusted feeding schedule to reduce the risk of gastrointestinal disturbances associated with airline catering. Electrolyte tablets and sealed beverages were provided to promote hydration. Players wore compression stockings on flights and were encouraged to move often to support hemodynamic functioning, mitigate decrements in O_2 saturation levels, and limit lower-limb venous pooling.[26] No illnesses were reported during or after relocation to Brazil. Following a 01:00 local time hotel arrival, players were encouraged to sleep in on day 2. An active recovery session involving various static and dynamic stretches was performed outdoors in morning sunlight before breakfast. Morning activity following westward long-haul travel may contribute to circadian resynchronization in elite athletes as part of a comprehensive strategy.[27] Moreover, low intensity activity is more conducive to restoring next-day HRV than high-intensity exercise.[9]

Travel-related factors cumulatively impacted cardiac-autonomic activity in players, reflected in a lower rolling LnRMSSD average and increased LnRMSSDcv relative to baseline. Alterations in cardiovascular parameters, including increased resting and exercise heart rate have previously been observed in athletes following westward long-haul travel.[28] However, stable perceptual measures ($P > .05$), unchanged daily LnRMSSD ($P > .05$), and *unclear* ESs for the rolling average indicate that impacts were relatively minor and somewhat heterogeneous. Interindividual variability in travel fatigue and jet lag symptoms are expected.[2] Assessment based on starting status indicates that altered LnRMSSD parameters posttravel are primarily observed in nonstarters (Figure 3B). Athletes of elite competitive status exhibit higher and more stable HRV profiles than lower-level teammates.[14] Greater familiarity with long-haul travel may have contributed to smaller decrements among starters.[13] Contrastingly, residual effects of tournament simulation may have contributed to larger effects in nonstarters. For example, LnRMSSDcv remained altered from baseline for 7 days after relocation, driven primarily by *unclear* daily LnRMSSD reductions on days 1 to 4 (Figure 3B). Of note for starters, LnRMSSDcv progressively decreased after relocation to the Olympic village, with minimum values observed preceding the tournament (days 12–13, ES = −0.56, *unclear*), concurrent with group-level improvements in perceived energy and recovery. These responses indicate that players approached competition unencumbered by perceived or physiological stressors.

Precompetitive arousal or anxiety is associated with elevations in cortisol and reduced vagal-related HRV.[11] Anxiety levels are enhanced by factors such as low athlete caliber, poor previous performance, high opposition ranking, and high trait anxiety.[29] Factors associated with lower anxiety include high team cohesion and self-efficacy.[29] No evidence of anxiety-related changes in status markers were observed on the first day of matches. Starters demonstrated *unclear* decrements (ES ≤ 0.44) in daily LnRMSSD on days 14 to 15, exceeding reductions observed posttournament simulation on day 1 (ES = −0.19, Figure 3B). Daily LnRMSSD responses for starters were nearly identical in magnitude to those observed throughout a domestic tournament performed several weeks previously.[7] However, international tournament participation *largely* reduced LnRMSSD on the second day of matches (ES = −1.21, $P < .05$), attributed to added stress from chaotic travel events in the 48-hour pretournament.[7] Matches spread over 3 days instead of 2 likely contributed to smaller decrements in daily LnRMSSD in the current study. In addition, cold water immersion was implemented following matches, which accelerates cardiac-parasympathetic reactivation postexertion[12] and was unavailable at the prior international tournament.[7] Decrements in LnRMSSD were *largely* associated with decrements in perceived recovery on day 14, and sleep quality on day 15. Impaired recovery[5] and sleep quality[30] are expected and were somewhat evident in starters (−1 au for sleep, recovery, and soreness vs baseline; Figure 4B). Match loads peaked on day 14 due to a period of extra time to resolve the evening quarter-final, potentially contributing to reduced sleep quality reported in starters on day 15. Whether anticipatory anxiety or arousal for final matches affected sleep or its association with LnRMSSD among starters on day 15 is unclear. Collectively, decrements in status markers were not exacerbated by the magnitude of competition or international location relative to previous observations.[7]

This study involved a retrospective analysis of preexisting data, which has inherent limitations relative to prospective investigations. In addition, without a control group of elite players we cannot be certain that strategies and interventions implemented by staff mitigated decrements in status markers or impacted performance. Another limitation is the small sample, which increases risk of type II errors. Finally, neuromuscular performance is a key component of player status, which was not included in this analysis.

Practical Applications

Team staff used a combination of proactive and reactive strategies to support training adaptations, mitigate the negative effects of long-haul travel, and maintain recovery status leading up to and throughout competition. This approach was seemingly effective for achieving and preserving cardiac-autonomic activity at peak levels during the Olympic expedition. Minor and temporary alterations in LnRMSSD and well-being, observed primarily in nonstarters, indicate that less experienced players may be more susceptible to short-term decrements in status markers following tournament simulation and long-haul travel. Attentiveness to player health and well-being using evidence-based strategies with guidance and feedback from noninvasive status markers may have indirectly contributed to medal-winning performance at the Olympics.

Conclusions

Limited posttournament simulation recovery time prior to departure combined with travel-related factors seem to have acutely disturbed subjective recovery and caused lower and less stable LnRMSSD trends in players, evident primarily in nonstarters for several days following relocation. Values were subsequently maintained at baseline or improved prior to opening day of the tournament. Decrements in LnRMSSD and perceptual markers among starters following matches were minor and comparable to responses observed during a domestic tournament. The various player-support strategies and interventions employed by team staff possibly mitigated decrements in status markers, which may have reduced the potential for fatigue- or stress-related performance impairment at the Olympics.

Acknowledgments

The authors thank the players and staff members for their support and involvement in this study.

References

1. Schwellnus M, Soligard T, Alonso JM, et al. How much is too much? (Part 2) International Olympic Committee consensus statement on load in sport and risk of illness. *Br J Sports Med*. 2016;50(17):1043–1052. PubMed ID: 27535991 doi:10.1136/bjsports-2016-096572
2. Fowler PM, Knez W, Crowcroft S, et al. Greater effect of east versus west travel on jet lag, sleep, and team sport performance. *Med Sci Sports Exerc*. 2017;49(12):2548–2561. PubMed ID: 28719491 doi:10.1249/MSS.0000000000001374
3. Soligard T, Steffen K, Palmer D, et al. Sports injury and illness incidence in the Rio de Janeiro 2016 Olympic Summer Games: a prospective study of 11274 athletes from 207 countries. *Br J Sports Med*. 2017;51(17):1265–1271. PubMed ID: 28756389 doi:10.1136/bjsports-2017-097956
4. Higham DG, Pyne DB, Anson JM, et al. Physiological, anthropometric, and performance characteristics of rugby sevens players. *Int J Sports Physiol Perform*. 2013;8(1):19–27. PubMed ID: 22868376 doi:10.1123/ijspp.8.1.19
5. West D, Cook C, Stokes K, et al. Profiling the time-course changes in neuromuscular function and muscle damage over two consecutive tournament stages in elite rugby sevens players. *J Sci Med Sport*. 2014;17(6):688–692. PubMed ID: 24332752 doi:10.1016/j.jsams.2013.11.003
6. Flatt AA, Howells D. Effects of varying training load on heart rate variability and running performance among an Olympic rugby sevens team. *J Sci Med Sport*. 2019;22(2):222–226. PubMed ID: 30055959 doi:10.1016/j.jsams.2018.07.014
7. Flatt AA, Howells D, Williams S. Effects of consecutive domestic and international tournaments on heart rate variability in an elite rugby sevens team. *J Sci Med Sport*. 2019;22(5):616–621. PubMed ID: 30527686 doi:10.1016/j.jsams.2018.11.022
8. Robineau J, Marrier B, Le Meur Y, et al. "Road to Rio": a case study of workload periodization strategy in rugby-7s during an Olympic season. *Front Sports Act Living*. 2019;1:72. PubMed ID: 33344995 doi:10.3389/fspor.2019.00072
9. Stanley J, Peake JM, Buchheit M. Cardiac parasympathetic reactivation following exercise: implications for training prescription. *Sports Med*. 2013;43(12):1259–1277. PubMed ID: 23912805 doi:10.1007/s40279-013-0083-4
10. Plews DJ, Laursen PB, Kilding AE, et al. Heart rate variability in elite triathletes, is variation in variability the key to effective training? A case comparison. *Eur J Appl Physiol*. 2012;112(11):3729–3741. PubMed ID: 22367011 doi:10.1007/s00421-012-2354-4
11. Souza RA, Beltran OAB, Zapata DM, et al. Heart rate variability, salivary cortisol and competitive state anxiety responses during pre-competition and pre-training moments. *Biol Sport*. 2019;36(1):39–46. PubMed ID: 30899138 doi:10.5114/biolsport.2018.78905
12. Haddad HA, Parouty J, Buchheit M. Effect of daily cold water immersion on heart rate variability and subjective ratings of well-being in highly trained swimmers. *Int J Sports Physiol Perf*. 2012;7(1):33–38. doi:10.1123/ijspp.7.1.33
13. Reilly T, Atkinson G, Edwards B, et al. Coping with jet-lag: a position statement for the European College of Sport Science. *Eur J Sport Sci*. 2007;7(1):1–7. doi:10.1080/17461390701216823
14. Flatt AA, Hornikel B, Nakamura FY, et al. Effect of competitive status and experience on heart rate variability profiles in collegiate sprint-swimmers. *J Strength Cond Res*. Published online February 26, 2021. doi:10.1519/JSC.0000000000003992
15. Flatt AA, Allen JR, Keith CM, et al. Season-long heart-rate variability tracking reveals autonomic imbalance in American college football players. *Int J Sports Physiol Perf*. 2022;16(12):1834–1843. doi:10.1123/ijspp.2020-0801
16. Hedges LV. Distribution theory for Glass's estimator of effect size and related estimators. *J Educat Stat*. 1981;6(2):107–128. doi:10.3102/10769986006002107
17. Hopkins W, Marshall S, Batterham A, et al. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc*. 2009;41(1):3–12. PubMed ID: 19092709 doi:10.1249/MSS.0b013e31818cb278
18. Buchheit M, Laursen PB. High-intensity interval training, solutions to the programming puzzle: part I: cardiopulmonary emphasis. *Sports Med*. 2013;43(5):313–338. PubMed ID: 23539308 doi:10.1007/s40279-013-0029-x
19. Walsh NP. Nutrition and athlete immune health: new perspectives on an old paradigm. *Sports Med*. 2019;49:153–168. PubMed ID: 31691927 doi:10.1007/s40279-019-01160-3
20. Kiviniemi AM, Hautala AJ, Kinnunen H, et al. Endurance training guided individually by daily heart rate variability measurements. *Eur J Appl Physiol*. 2007;101(6):743–751. PubMed ID: 17849143 doi:10.1007/s00421-007-0552-2
21. Louis J, Theurot D, Filliard JR, et al. The use of whole-body cryotherapy: time- and dose-response investigation on circulating blood catecholamines and heart rate variability. *Eur J Appl Physiol*. 2020;120(8):1733–1743. PubMed ID: 32474683 doi:10.1007/s00421-020-04406-5
22. Hautala AJ, Kiviniemi AM, Tulppo MP. Individual responses to aerobic exercise: the role of the autonomic nervous system. *Neurosci Biobehav Rev*. 2009;33(2):107–115. PubMed ID: 18514313 doi:10.1016/j.neubiorev.2008.04.009
23. Perna G, Riva A, Defillo A, et al. Heart rate variability: can it serve as a marker of mental health resilience?: special Section on "Translational

and Neuroscience Studies in Affective Disorders" Section Editor, Maria Nobile MD, PhD. *J Affect Disord*. 2020;263:754–761. PubMed ID: 31630828 doi:10.1016/j.jad.2019.10.017
24. Fowler PM, Duffield R, Lu D, et al. Effects of long-haul transmeridian travel on subjective jet-lag and self-reported sleep and upper respiratory symptoms in professional rugby league players. *Int J Sports Physiol Perform*. 2016;11(7):876–884. PubMed ID: 26788986 doi:10.1123/ijspp.2015-0542
25. Bermon S, Castell LM, Calder PC, et al. Consensus statement immunonutrition and exercise. *Exercise Immunol Rev*. 2017;23: 8–50.
26. Broatch JR, Bishop DJ, Zadow EK, et al. Effects of sports compression socks on performance, physiological, and hematological alterations after long-haul air travel in elite female volleyballers. *J Strength Cond Res*. 2019;33(2):492–501. PubMed ID: 30531419 doi:10.1519/JSC.0000000000003002
27. Cardinali DP, Bortman GP, Liotta G, et al. A multifactorial approach employing melatonin to accelerate resynchronization of sleep-wake cycle after a 12 time-zone westerly transmeridian flight in elite soccer athletes. *J Pineal Res*. 2002;32(1):41–46. PubMed ID: 11841599 doi:10.1034/j.1600-079x.2002.10820.x
28. Voltaire B, Galy O, Coste O, et al. Effect of fourteen days of acclimatization on athletic performance in tropical climate. *Can J Appl Physiol*. 2002;27(6):551–562. PubMed ID: 12500994 doi:10.1139/h02-031
29. Wolf SA, Eys MA, Kleinert J. Predictors of the precompetitive anxiety response: relative impact and prospects for anxiety regulation. *Int J Sport Exerc Psychol*. 2015;13(4):344–358. doi:10.1080/1612197X.2014.982676
30. Leduc C, Robineau J, Tee JC, et al. The travel demands of an elite rugby sevens team: effects on objective and subjective sleep parameters. *Int J Sports Physiol Perform*. 2021;16(5):688–694. PubMed ID: 33540379 doi:10.1123/ijspp.2020-0243