International Journal of Sports Physiology and Performance, (Ahead of Print)
https://doi.org/10.1123/ijspp.2023-0199

First Published Online: Mar. 20, 2024

Human Kinetics
ORIGINAL INVESTIGATION

Absence of Monotony and Strain Effects on Referees' Physical Performance During International Basketball Federation World Cup Basketball Competition

Rūtenis Paulauskas,[1] Alejandro Vaquera,[2,3] and Bruno Figueira[1,4,5]

[1]Educational Research Institute, Education Academy, Vytautas Magnus University, Kaunas, Lithuania; [2]Faculty of Physical Activity and Sports Sciences, VALFIS Research Group, Institute of Biomedicine (IBIOMED), Universidad de León, León, Spain; [3]School of Sport and Exercise Science, University of Worcester, Worcester, United Kingdom; [4]Departamento de Desporto e Saúde, Escola de Saúde e Desenvolvimento Humano, Universidade de Évora, Évora, Portugal; [5]Comprehensive Health Research Center (CHRC), Universidade de Évora, Évora, Portugal

Purpose: The study aimed to conduct a comparative analysis of physical performance indicators and assess the levels of performance monotony and strain experienced by basketball referees. ***Methods:*** The study involved the participation of 12 basketball referees (mean age: 40.0 [4.9] y) affiliated with the International Basketball Federation. The investigation was carried out throughout 2 density tournaments, wherein the maximum heart rate, average heart rate, performance monotony, and performance strain were documented for 3 variables. ***Results:*** The findings indicated significant variations in the mean heart rate, maximum heart rate, total distance monotony, total distance strain, the total number of sprints monotony, the total number of sprints strain, calories monotony, and calories strain ($P < .05$). Decreasing the density of elite-level basketball competitions has been observed to reduce the monotony and strain experienced by referees. However, this action does not increase motion distance or speed zones. ***Conclusions:*** The environmental stressors experienced by senior-level athletes (World Cup) differ from those encountered by younger athletes (World Cup Under 19). Further investigation is required to ascertain the potential effects of competition monotony and strain on decision-making processes and the overall quality of refereeing.

Keywords: exertion, total distance, density, workload, external load

The professionalization of sports refereeing has led to an increasing demand for a similar approach to that of professional athletes.[1] In order to maintain the standard of the competition, it is imperative that referees consistently maintain their physical fitness and enhance their psychological and technical–tactical proficiencies.[2] Moreover, in various sports,[3] including basketball, the judgment of the referee is impacted by the ideal position, which is ascertained through physical motion on the court.[4] The physical performance of basketball referees has garnered scientific interest as a means to enhance the overall quality of the basketball game.[5]

Multiple approaches can be employed to conduct performance analysis in refereeing. Nevertheless, wearable tracking technologies have emerged as a crucial instrument for objectively measuring the workload during the match.[6] The available research on the workload of basketball referees has mainly focused on investigating cardiovascular demands,[7,8] activity profiles,[9,10] and energy expenditure (EE) during the game.[11] Several research studies have indicated that basketball referees typically exhibit heart-rate (HR) levels ranging from 70% to 80% of their maximum HR (HR_{max}) during gameplay.[8,12,13] Previous studies have found no significant difference in HR variability throughout the entire duration of the game and during various time intervals within the match.[14,15] According to Nabli et al,[16] the HR-monitoring data indicated that a basketball referee exhibited considerable levels of aerobic energy generation during the game and intervals characterized by anaerobic energy conversion. According to Leicht's study in 2007, there was a notable discrepancy in aerobic power between elite basketball referees and the general population.

According to Borin et al,[17] time–motion analysis indicates that basketball referees cover approximately 1200 m per quarter, with around 60% to 70% of the distance being attributed to walking, about 2% to sprinting, and the remaining distance being attributed to jogging, or running. According to a study conducted by García-Santos et al. (2019), the referee's maximum speed was approximately 19 km per hour during transitional movements or sprint actions. Borin et al[17] discovered that the extent to which basketball referees cover the distance is contingent upon the stages of the competition. Additionally, Leicht[18] observed that subelite basketball referees encounter activity demands that are significantly less than those of players in the same game.

The majority of research has exhibited a disproportionate emphasis on the analysis of internal and external load data while concurrently disregarding other variables that may constrain the physical capabilities of referees. The frequency of officiating during a tournament appears to be a crucial variable in workload assessment, particularly when referees are assigned varying match durations. The density of games pertains to the correlation between the configuration of gameplay and recovery, which could potentially result in a reduction of the referees' skills. The evaluation of performance ought to encompass not only the quantification of workload but also the investigation of whether the tournament's density impacts the variability of ability.

A workload study could offer referees opportunities for recuperation and mitigate the risk of excessive strain.[19] This is because such strain may significantly affect both physical and mental exhaustion among referees.[20] The phenomenon of mental fatigue is characterized by alterations in the psychobiological state that

Paulauskas https://orcid.org/0000-0003-0001-697X
Vaquera https://orcid.org/0000-0003-1018-7676
Figueira (bruno.figueira@uevora.pt) is corresponding author, https://orcid.org/0000-0001-7600-4874

arise from prolonged periods of strenuous activity.[21] This condition has been found to have a detrimental effect on sport-specific psychomotor performance[22] and endurance performance in healthy athletes.[20] In their recent study, Pizzera et al[23] observed that referees experienced more significant physical fatigue under physical and psychological stress, which had a detrimental impact on their decision-making abilities compared to the resting condition. The fluctuation in workload, intrabrief and interbrief tournaments, can significantly aid referees in avoiding performance monotony while carrying out in-game duties. Furthermore, through the utilization of suitable monitoring techniques, it is possible to identify daily variations in conditions[24] and the immediate load (total load over a week) that referees experience during different high-density competitions.[25]

The monitoring of overtraining syndrome used information on training monotony and strain.[26] The daily mean load divided by the SD, which may be estimated over a week or macrocycle, is how monotony is calculated. The result of a person's weekly training load and training monotony is their level of strain.[26] Higher training strain suggests greater acute loads imposed with slight within-week variations, and higher training monotony scores present greater acute loads imposed with low mean SDs.[27] Practitioners can ascertain the degree to which recovery may be insufficient by tracking load, monotony, and strain over time. The athletes' performance declined, and they displayed symptoms of tiredness when the resting days were less relaxing, and the monotony of the training increased.[28] The number of participating teams, the format of the play, and the length of the International Basketball Federation (FIBA) World Cup (WC) events vary. However, it is unclear whether the physical performance of referees depends solely on the number of games scheduled or how frequently they occur. No studies have been done on performance monotony and performance strain in top-level referees at various tournament densities. Such studies should advance our knowledge of the dynamics of the burden faced by professional referees in different tournament densities. Furthermore, it will be possible to learn more about the requirements of various density tournaments from the fluctuation in load and the amount of performance monotony and strain that can rely on internal and external factors.[25] Therefore, the 2 goals of this study were to compare the external and internal physical performance indicators of the referees in these competitions, which were of different densities, and to evaluate performance monotony and strain among basketball referees during the FIBA WC and FIBA U-19 WC (WC-U19) competition. The WC-U19 features phases of higher competition density with some games scheduled consecutively, while the WC maintains a more evenly distributed game schedule with regular rest days, indicating a lower overall competition density (Figure 1). We hypothesized that a lower density tournament would allow for more significant intensity indicators during play since there would be less performance and overall load stress fluctuation.

Methods

Participants

Twelve basketball referees from the FIBA participated in this study (age: 40.0 [4.9] y, height: 185.3 [4.6] cm, weight: 91.0 [6.2] kg, body fat 22.4% [3.2%], body mass index 26.3 [1.4], referring experience: 19.2 [3.1] y). Male participants from the FIBA regions of Europe, Asia, Oceania, and America made up the whole court. The maximum (n – 7) games officiated in the two 2019 FIBA WC championships (WC and WC-U19) served as the inclusion criterion. Before providing their informed agreement to participate, the referees were thoroughly told about the experimental methods and any potential discomforts connected with the study. Furthermore, every method used in the study was authorized by FIBA, approved prior to start of studyby the University of Extremadura's Ethical Committee (no17/2017), and in compliance with the Declaration of Helsinki.

Design

The research employed a descriptive, observational methodology to examine the external and internal physical performances exhibited by basketball referees participating in the FIBA WC and FIBA U-19 WC (WC-U19) competitions. The data collection process was executed across WC and WC-U19 competitions. Furthermore, the investigation calculated the indices of performance monotony,[26] denoting the fluctuations in workload during a competition, and performance strain,[26] representing the outcome of both monotony and acute load, for 3 parameters: total distance (TD), EE, and total count of sprints (TS). Monotony is calculated as daily mean load divided by daily SD. Strain is calculated as total weekly load multiplied by monotony. Finally, following the research objectives, this study presents the external load calculations for each measure and referee across 2 density basketball tournaments.

Methodology

Seven WC games and 7 WC-U19games were among the 14 international games in which all 12 referees were evaluated. There was a 2-month hiatus between the 2 competitions in 2019. The WC was played over 13 days, with 1 day off between each game for the officials. The referees worked for 2 days, took a day off, worked for 2 more days, took a day off, and then worked for 3 straight days during the 9-day WC (19; Figure 1). Throughout the games, each referee utilized a The Polar Team Pro System (Polar Electro OY) device. The FIBA Referee Department recommended the normal on-court warm-up, off-court static and dynamic stretching, and postmatch recovery techniques that the officials followed before each game.

The study recorded the HR_{max} and average HR values achieved by each official during the game. In addition, the study computed the measures of performance monotony,[26] which refers to the variation in load within a tournament, and performance strain,[26] which is the product of monotony and acute load, for 3 variables: TD, EE, and TS. Following the research objectives, this study presents the external load calculations for each measure and referee across 2 density basketball tournaments.

External-Load Data Collection

The Polar Team Pro System (Polar Electro OY) unit was used by all referees consistently throughout both tournaments. The device comprised a combination of various sensors, including a 10-Hz GPS, accelerometer, gyroscope, and digital compass, all capable of sampling at a rate of 200 Hz. Additionally, the device was equipped with proprietary software that determined velocity and distance within indoor environments. The devices mentioned above utilized non-GPS sensors and proprietary algorithms developed by the manufacturer to determine speed and distance traveled. This feature renders the sensors appropriate for indoor environments, as it facilitates the effective processing and analysis of external workload data, as noted by Fox et al.[29] According to Huggins et al,[30] the

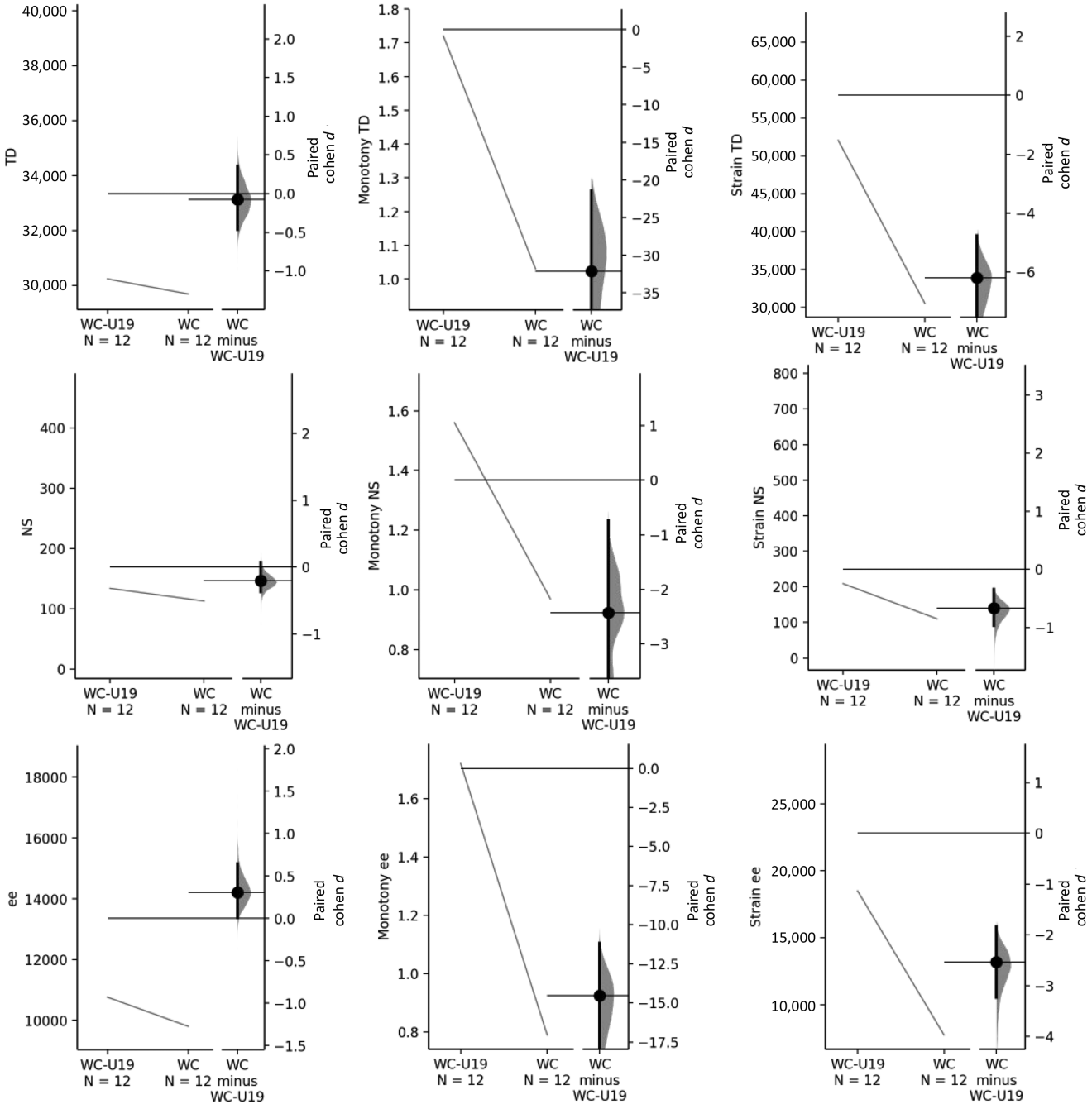

Figure 1 — Game density during WC and WC-U19. TD indicates total distance; WC, world championship; WC-U19, WC under 19 years of age; NS, number of sprints; ee, energy expenditure.

Polar Team Pro System demonstrated reliability in measuring locomotory activities such as velocity and distance in outdoor settings. As per the guidelines provided by the manufacturer, every referee donned a sensor affixed to an elastic strap situated on the lower sternum. Clemente et al[31] employed a uniform sensor across all referees to reduce interdevice variability. The sensor was initiated within the locker room 20 minutes before the commencement of the game and was utilized for 5 minutes following the game. The recordings encompassed both passive and active periods of the prematch and postmatch time, in addition to the actual playing time, including relevant match stoppages such as free throws, time-outs, and fouls, and violation calls.[32] The complete match recording was transferred to a local computer through the interface provided by the manufacturer and an online solution known as the Polar Team Pro System to conduct subsequent analyses. According to Suárez Iglesias et al,[33] a session is the

complete recording of activities that commence with the warm-up, encompass the entire match, and conclude with postmatch recovery procedures.

The metrics about external load, namely TD expressed in meters, EE expressed in kilocalories, and TS expressed in frequencies, were gathered. The determination of speed zones was based on the locomotive categories already in place, as outlined by Cunniffe et al.[34] The study determined the distances traveled in different speed zones, namely speed zone 1 (3.00–6.99 km/h − 1; DC 1), speed zone 2 (7.00–10.99 km/h − 1; DC 2), speed zone 3 (11.00–14.99 km/h − 1; DC 3), speed zone 4 (15.00–18.99 km/h − 1; DC 4), and speed zone 5 (>19.00 km/h − 1).

Calculations of Referee's Performance Workload

The following variables were computed using the methods of TD, TS, and EE: The performance monotony metric refers to the average of the performance load, which includes TD, TS, and EE, throughout the tournament, divided by the tournament's SD of the performance load. The calculation of the total performance loads (TD, TS, and EE) for all games officiated during the tournament is multiplied by PM, as outlined in the works of Clemente et al[31] and Nobari et al.[35] The 2 tournaments exhibited variations in terms of their respective durations and how the nominations for refereeing were organized. Therefore, the computation of performance monotony and performance strain involved assigning a 0 value to the Day Offload.

Statistical Analysis

Table 1 presents a descriptive analysis, where the data are displayed as means with corresponding SDs. The verification of normality and sphericity assumptions preceded the utilization of parametrical statistical procedures. The statistical analysis employed in this study involved the utilization of the paired student's *t* test in comparing tournaments. Additionally, Cohen *d* was computed as the effect size (ES) measure. The predetermined alpha level for all statistical tests was $\alpha = .05$, and the computations were conducted utilizing IBM SPSS Statistics for Windows (version 24.0). The established benchmarks for ES statistics were as follows: <0.2, considered trivial; <0.6, classified as small; <1.20, categorized as moderate; <2.0, deemed large; and >2.0, characterized as very large. The statistical calculations were performed using a dedicated postonly crossover spreadsheet for every group.[36]

Results

Table 1 displays the results of the game density for both tournaments. The following performance variables showed differences between the WC and WC U-19 events; average HR ($P = .0092$, ES = 0.594); HR_{max} ($P = .0034$, ES = 0.763), monotony TD ($P = .0006$, ES = −32.2), strain TD ($P = .0006$, ES = −6.2), monotony TS ($P = .0006$, ES = −2.43), strain TS ($P = .0014$, ES = −0.669), monotony calories ($P = .0$, ES = −14.5), and strain calories ($P = .0$, ES = −2.54; Figures 2 and 3). In opposition, the comparison between both tournaments presented no significant effect on TD, TS, calories, distance in sprint zone 1, distance in sprint zone 2, distance in sprint zone 3, distance in sprint zone 4, and distance in sprint zone 5 ($P > .05$, no effect).

Discussion

Our study sought to determine how basketball referee workload fluctuated and to compare it among tournaments of various densities. The results of this investigation only partially support our claim. However, the lower density competition did not enhance the volume of the overall distance or the distance in different speed zones. Instead, it considerably reduced performance monotony and strain. In contrast to what we predicted, WC had fewer sprints but a more significant HR response and higher energy consumption.

Table 1 Descriptive Analysis of External-Load Variables According Both Tournaments.

Variables	WC-U19	WC	*P*	ES
HRavg, beats·min^{-1}	114.25 (9.87)	120.83 (12.18)	.0092[a]	0.594
HR_{max}, beats·min^{-1}	162.50 (10.04)	170.83 (11.75)	.0034[a]	0.763
TD, m	33,348.17 (2832.94)	33,132.17 (2794.42)	.712	−0.0768
Monotony TD, a.u.	1.74 (0.02)	1.02 (0.02)	.0006[a]	−32.2
Strain TD, a.u.	58,005.58 (4630.16)	33,906.00 (2968.54)	.0006[a]	−6.2
NS	169.25 (125.50)	147.08 (93.61)	.0944	−0.2
Monotony NS, a.u.	1.37 (0.25)	0.92 (0.07)	.0006[a]	−2.43
Strain NS, a.u.	249.57 (209.18)	140.37 (98.03)	.0014[a]	−0.669
EE, kcal	13,553.58 (2499.67)	14,195.92 (3046.70)	.068	0.302
Monotony EE, a.u.	1.70 (0.04)	0.93 (0.06)	.0001[a]	−14.5
Strain EE, a.u.	22,801.75 (4406.31)	13,176.00 (3053.57)	.0001[a]	−2.54
Distance in SZ1, m	2257.58 (306.20)	2360.09 (178.92)	.121	0.409
Distance in SZ2, m	834.42 (200.50)	778.22 (92.85)	.295	−0.36
Distance in SZ3, m	687.92 (70.95)	688.42 (88.81)	.972	0.00625
Distance in SZ4, m	456.58 (88.81)	460.49 (93.58)	.928	0.0302
Distance in SZ5, m	225.58 (179.19)	198.21 (118.43)	.448	−0.18

Note: The values expressed as mean and SD both in WC-U19 and in WC. Abbreviations: avg, average; a.u., arbitrary units; EE, energy expenditure; ES, effect size; HR, heart rate; max, maximum; NS, number of sprints; *P*, between group-subject effect; SZ = speed zone; TD, total distance; U19, under-19; WC, world championship.
[a]Significant differences between conditions.

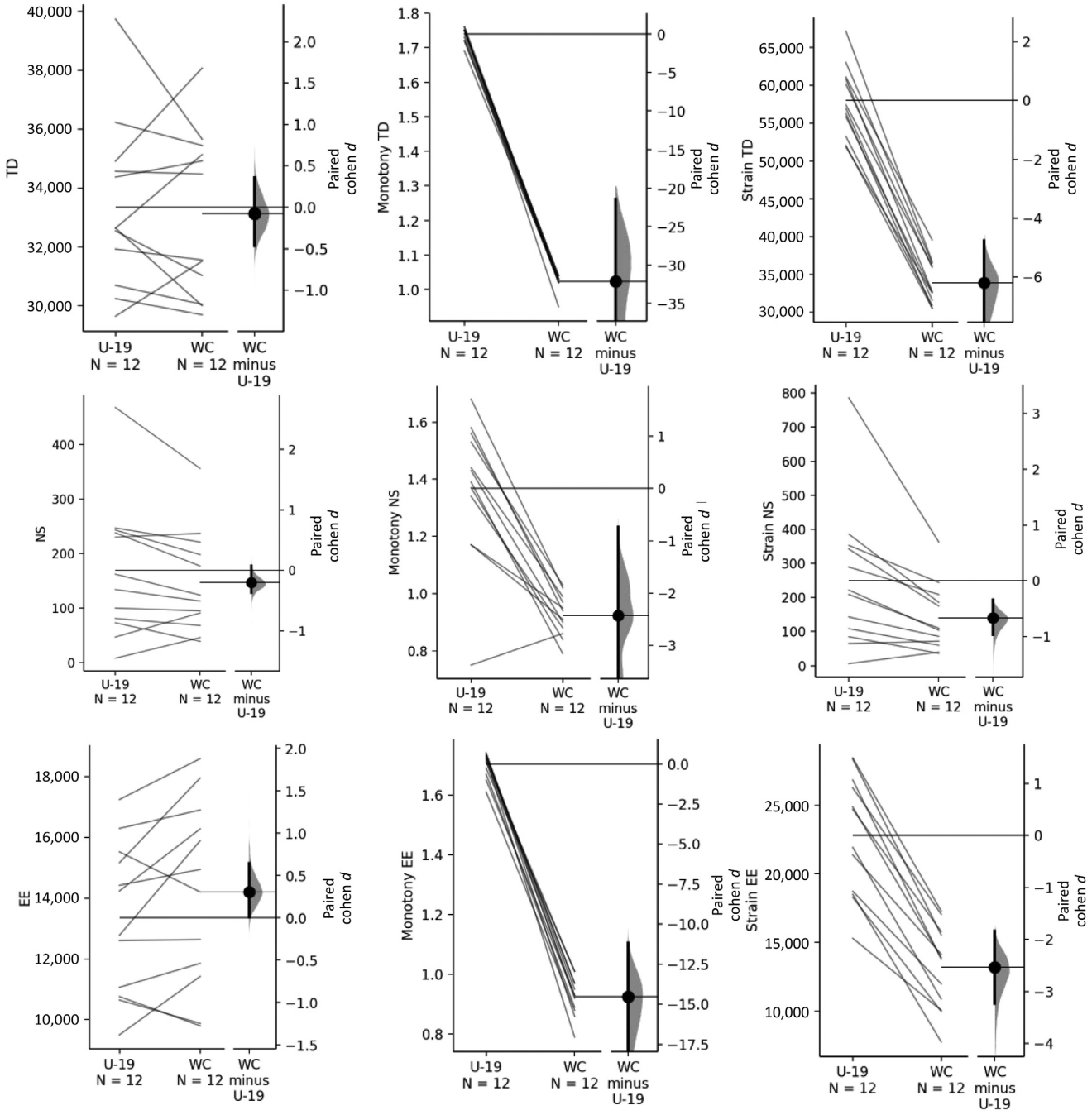

Figure 2 — The paired Cohen *d* between WC-U19 and WC. EE indicates energy expenditure; NS, number of sprints; TD, total distance; U19, under-19; WC, world championship.

This study represents a novel contribution to the literature, as it is the first known investigation into the workload fluctuations experienced by basketball referees. The study employs established scientific concepts of monotony and strain to analyze threshold levels. The observed values of TD, NS, and EE during both the WC and the WC-U19 tournaments diverged significantly from our anticipated outcomes for events of varying density. Therefore, the precise threshold for monotony referees should tolerate remains to be determined. It is not feasible to compare the monotony and strain experienced by referees and other individuals in sports, as each sport has unique characteristics encompassing factors such as the energy system, muscle group, and skill training.[37] According to Leicht et al,[18] it has been established that subelite basketball referees undergo an absolute external load during the match that

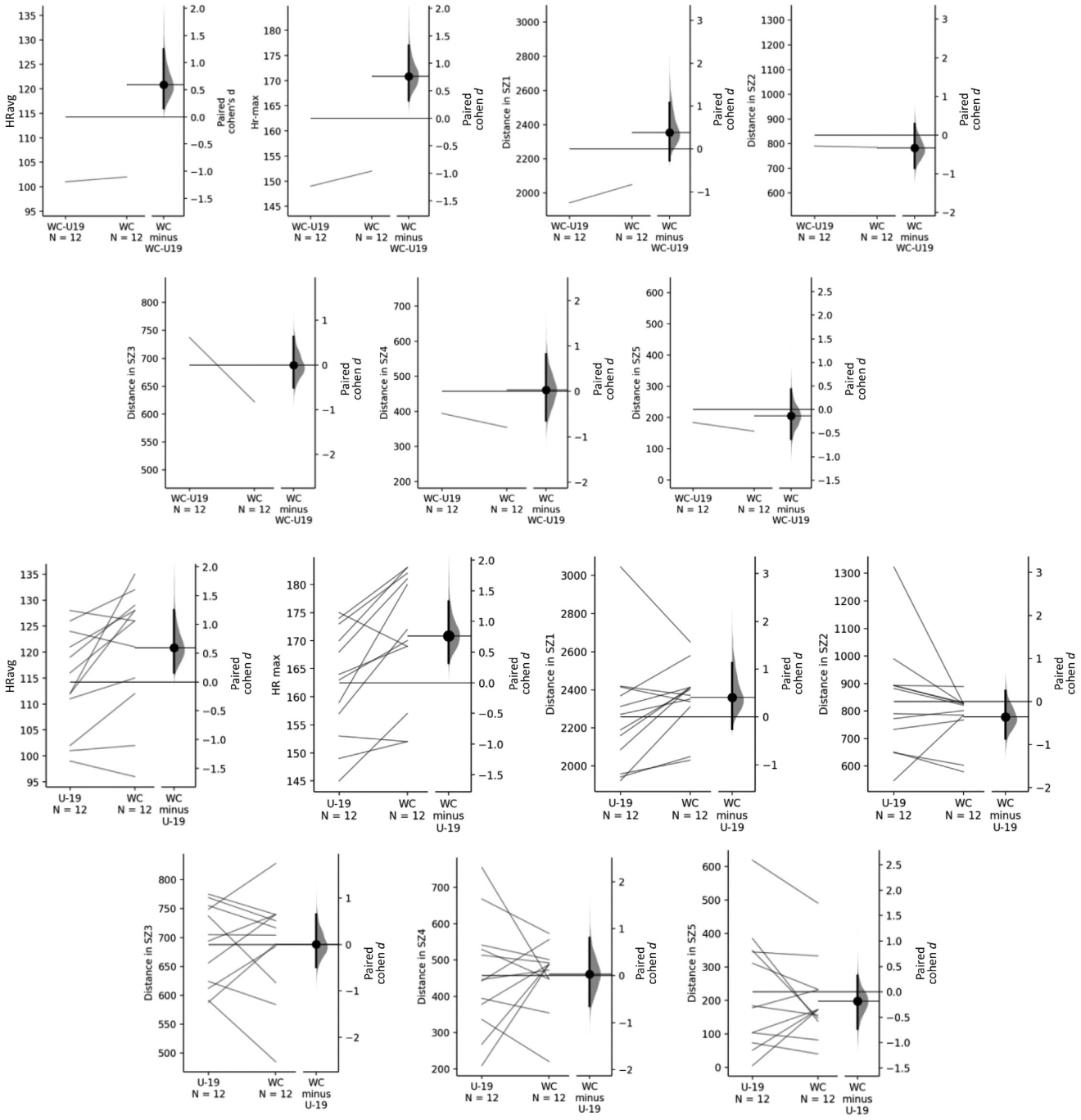

Figure 3 — The paired Cohen *d* between WC-U19 and WC. avg indicates average; HR, heart rate; max, maximum; SZ, speed zone; TD, total distance; U19, under-19; WC, world championship.

is approximately 40% lower than that of basketball players. The study revealed that the referees' mean threshold distance during the 2019 WC was 1.74 (0.02), whereas, during the previous WC, it was 1.02 (0.02) AU. The monotony TS of the referees during the 2019 WC was 1.37 (0.25), while during the WC, it was 1.02 (0.02). The main distinction between competitions may be seen in monotony energy expenditure. The monotony of the EE in WC-U19 was recorded at 1.7 (0.04), whereas in WC, it exhibited a decrease to 0.9 (0.06) AU.

Compared with WC-U19, the TD, NS, and EE strain dramatically decreased during the WC. The study conducted by Foster et al[28] demonstrated that a reduction in the restfulness of recovery

days and an increase in the monotony of training resulted in a decline in athletes' running performance and the manifestation of overtraining symptoms. According to Thornton et al,[38] surpassing the threshold for training strain in a cohort of athletes was associated with a heightened incidence of illness. Given the disparate mean threshold distance and strain total distance outcomes of the 2 tournaments, there is no statistically significant variation in TD (33,348.17 [2832.9] m and 33,132.17 [2794.4] m). The findings of the TD are consistent with prior research conducted by Nabli et al.[12] According to Borin et al,[17] the examination of the Brazilian and Slovenian leagues reveals that referees traverse a distance of 4020 m and 5291 m, respectively, throughout a game. Similarly, García-Santos et al[9] report that referees cover approximately 4330 m during the U-16 European Women's Championship. It has been established that the degree of competition can impact the physical activity of the referee. The distance traveled by the Brazilian basketball referees in the qualification phase was substantially shorter than that in the semifinal and final stages ($P = .05$).[17]

The findings of our study indicate that the variation in tournament density did not significantly impact the TD of the game. Nonetheless, certain discrepancies exist between WC and WC-U19 in the DC 1 and DC 2 regarding low-intensity running and jogging activities. The primary physical efforts observed during games are of a low to moderate intensity, characterized by velocities below 10.11 km per hour, and constitute roughly 88% of the overall duration. However, high-intensity activities are primarily utilized to measure physical performance.[39] The high-intensity thresholds for basketball refereeing fall from 14.83 to 18.72 km per hour.[16] It has been observed that there are no discernible differences between the 2 tournaments, WC and WC-U19, in the intensity zones of DC 4 and DC 5. Referee activity profiles have been utilized to comprehend possible fatigue during play in tournaments with a more rigorous match schedule. Changes in the high-intensity activity profile may indicate accumulating referee fatigue.[40] Compared with the first half of the game, U-19 basketball referees spent significantly more time in the low-intensity zone, such as walking and standing, according to Nabli et al.[16] According to Reilly and Gregson,[41] this ruling may be related to the game's decreased speed and the players' corresponding decrease in work rate.

The present investigation revealed a notable difference in TS across tournaments, with a lower value recorded in the WC than in the WC-U19. The observed phenomenon cannot be attributed to the reduced stress and repetitiveness characterizing the tournament. The referees were allowed to recuperate and adequately condition themselves for the matches. The pace of the basketball game during WC-U19 may have contributed to the increased frequency of sprints by referees.

The findings of this investigation indicate that the caloric energy intake of referees was significantly greater ($P = .04$) in a tournament with a lower density compared with one with a higher density. The WC tournament, characterized by a relatively smaller number of matches, featured teams predominantly comprising senior players. This composition of teams implies a potentially heightened psychological influence on the referees, which, in turn, may manifest in discernibly elevated internal load indicators among the referees. Empirical research conducted previously has underscored the significance of various factors, including instances of verbal abuse directed at referees by coaches and players, the pressure exerted by spectators, and the referees' perceived stress levels, as influential contributors to the increased workload experienced by referees during matches.[5] In addition, prior research has examined diminished executive function during gameplay, particularly in the final quarter of the match.[15] Our study's findings indicate that no significant variations were observed in the TD decrement in TS during tournaments in WC, as well as the increase in EE. This controversial outcome could be ascribed to the notable elevation of HR_{max} and average HR observed during the workout. Furthermore, previous research has reported the utilization of HR in combination with regression equations to establish the correlation between HR and oxygen uptake, which is obtained from laboratory assessments, to approximate EE.[16] Although exercise intensity may vary during gameplay, the mean HR during a game can reasonably approximate the energy expended.[42] The correlation between HR variability and enduring emotional stress was first observed in the research conducted by Sloan et al.[43] However, this relationship was unrelated to age, gender, trait anxiety, and cardiorespiratory fitness.[44] Referees are constantly exposed to psychological stress during the games,[5] and about 5% of the situations that arise in a game cause high levels of stress, while the normal development of a game presents low or medium values.[45,46] However, no correlations were found between the years of officiating experience and the factor of influence of individual players, teams, and spectators.[47] Significant events during a competition, such as the analysis of moves on instant replay or instances of physical or verbal abuse resulting in disqualification or technical fouls for players or coaches, are associated with elevated stress levels.[5] The WC competition garners a larger audience in physical arenas, boasts a greater number of broadcasts, and holds a higher level of prestige among players and coaches compared with the WC 2019. In competitions of an elevated level, referees bear a significant responsibility and frequently experience pressure when making decisions that hold considerable weight in determining the outcome of the game.[48] In addition, referees' duties encompass overseeing players and coaches, upholding and implementing the sport's regulations, and collaborating with fellow officials.[49] Previous research has revealed that sports referees often experience elevated levels of perceived stress due to the high-pressure nature of their work environment.[50] The absence of discernible dissimilarities in external load indicators, such as TD and TS, about physical performance suggests that HR fluctuations observed in varying-density tournaments may be attributed to environmental stress. Further investigation is warranted in this regard. It is imperative to ascertain and delineate the diverse stress-inducing circumstances encountered by referees across various competition tiers and evaluate their impact on human resources and other organizational functions.

While this study furnishes both practical and scientific evidence concerning the external and internal physical performance indicators of referees in competitions characterized by varying densities, it is imperative to acknowledge certain limitations. The principal constraints of this study revolve around the relatively brief duration of high-level tournaments and the restricted pool of referees available for nomination in the context of a greater number of matches across diverse density tournaments, thereby impacting their inclusion in this research. Additionally, the computation of intraindividual variation remains unattainable for monotony and strain. These variables are delineated for each participant who presided over an identical quantity of matches, albeit in tournaments characterized by disparate durations. Consequently, a solitary individual parameter is ascribed to each participant for the entirety of the tournament. The main strength of this study lies in its pioneering role as the inaugural investigation delving into the fluctuation of workload encountered by basketball referees.

Practical Applications

The physical performances, both external and internal, demonstrated by basketball referees are subject to variation based on the characteristics of the players involved. Therefore, coaches should tailor their training sessions based on the proficiency level of their players. Additionally, coaches should prioritize implementing recovery strategies specifically targeted toward the distribution of games throughout the tournament. Consequently, coaches may make informed decisions when designing training sessions by considering the referees' performances during tournaments. New research is needed to understand whether competition monotony and strain impact decision making and quality of refereeing.

Conclusions

Our initial hypothesis suggested that lower-density tournaments would yield more pronounced intensity indicators owing to diminished fluctuations in performance and overall load stress. While our study partially supported this hypothesis, several unexpected findings emerged. Specifically, our investigation determined that the density of basketball tournaments did not exert a significant influence on the total distance covered by referees. Nevertheless, it did exert a discernible impact on their physical performance and stress levels. The higher-density tournament was associated with reduced monotony and strain; however, it exhibited an increased heart-rate response and greater energy consumption. This underscores the intricate interplay between tournament conditions, referee workload, and physiological responses.

References

1. García-Santos D, Ibáñez SJ. Diseño y validación de un instrumento de observación para la valoración de un árbitro de baloncesto (IOVAB). *SPORT TK-Rev Euroam Cienc Deporte*. 2016;5(2):15–26. doi:10.6018/264601
2. García-Santos D, Gamonales JM, León K, Muñoz J. A case study: characterization of physiological, kinematic and neuromuscular demands of handball referee during competition. *E-Balonmano Rev Cienc Deporte*. 2017;13(3):207–216. http://www.e-balonmano.com/ojs/index.php/revista/index
3. Martinho DV, Field A, Rebelo A, Gouveia ÉR, Sarmento H. A systematic review of the physical, physiological, nutritional and anthropometric profiles of soccer referees. *Sports Med–Open*. 2023;9(1):72. PubMed ID: 37561241 doi:10.1186/s40798-023-00610-7
4. Guillén F, Feltz D. A conceptual model of referee efficacy. *Front Psychol*. 2011;2:25. Accessed May 5, 2023. https://www.frontiersin.org/articles/10.3389/fpsyg.2011.00025
5. García-Santos D, Gómez-Ruano MA, Vaquera A, Ibáñez SJ. Systematic review of basketball referees' performances. *Int J Perform Anal Sport*. 2020;20(3):495–533. doi:10.1080/24748668.2020.1758437
6. Birk Preissler AA, Reichert T, Schons P, et al. External loads of elite soccer referees: a systematic review with meta-analysis. *Res Sports Med Print*. 2021;31(4):342–356. doi:10.1080/15438627.2021.1988948
7. Vaquera A, Renfree AJ, Thomas G, Gibson ASC, Calleja-Gonzalez J. Heart rate responses of referees during the 2011 Eurobasket Championship. *J Hum Sport Exerc*. 2014;9(1):43–48. doi:10.4100/jhse.2014.91.05
8. Vaquera A, Mielgo-Ayuso J, Calleja-González J, Leicht AS. Cardiovascular and perceptual stress of female basketball referees during women's International matches. *J Sports Med Phys Fitness*. 2017;57(4):476–482. PubMed ID: 26954571 doi:10.23736/S0022-4707.16.06230-7
9. García-Santos D, Pino-Ortega J, García-Rubio J, Vaquera A, Ibáñez SJ. Internal and external demands in basketball referees during the U-16 European Women's Championship. *Int J Environ Res Public Health*. 2019;16(18):3421. PubMed ID: 31540097 doi:10.3390/ijerph16183421
10. Leicht AS, Connor J, Conduit N, Vaquera A, Gómez MA. Impact of match type on exercise volume and intensity of semi-professional basketball referees during a competitive season. *Res Q Exerc Sport*. 2021;92(4):843–850. PubMed ID: 32840455 doi:10.1080/02701367.2020.1788207
11. Nabli MA, Abdelkrim N, Castagna C, Jabri I, Battikh T, Chamari K. Energy demands and metabolic equivalents (METS) in U-19 basketball refereeing during official games. *J Sports Med Doping Stud*. 2017;7(2):1–6. doi:10.4172/2161-0673.1000190
12. Nabli MA, Ben Abdelkrim N, Fessi MS, DeLang MD, Moalla W, Chamari K. Sport science applied to basketball refereeing: a narrative review. *Phys Sportsmed*. 2019;47(4):365–374. PubMed ID: 30942645 doi:10.1080/00913847.2019.1599588
13. Vaquera A, Mielgo-Ayuso J, Calleja-González J, Leicht AS. Match intensity and heart rate predictors in top level basketball referees during men's Eurobasket. *J Sports Med Phys Fitness*. 2016;56(9):1034–1040. PubMed ID: 26112817
14. Leicht AS. Physiological demands of basketball refereeing during international competition. *J Sci Med Sport*. 2008;11(3):357–360. PubMed ID: 17714989 doi:10.1016/j.jsams.2007.05.006
15. Rupčić T, Matkovic B, Knjaz D, Devrnja A, Popek S. Differences in physiological load of referees with concideration to the period of the backetball game. *SportLogia*. 2012;8(1):51–56. doi:10.5550/sgia.120801.en.051r
16. Nabli MA, Ben Abdelkrim N, Castagna C, Jabri I, Batikh T, Chamari K. Physical and physiological demands of U-19 basketball refereeing: aerobic and anaerobic demands. *Phys Sportsmed*. 2016;44(2):158–163. PubMed ID: 26831780 doi:10.1080/00913847.2016.1149424
17. Borin JP, Daniel JF, Bonganha V, et al. The distances covered by basketball referees in a match increase throughout the competition phases, with no change in physiological demand. *Open Access J Sports Med*. 2013;4:193–198. PubMed ID: 24379725 doi:10.2147/oajsm.s42489
18. Leicht AS, Fox J, Connor J, et al. External activity demands differ between referees and players during a sub-elite, men's basketball match. *Res Q Exerc Sport*. 2019;90(4):720–725. PubMed ID: 31479399 doi:10.1080/02701367.2019.1645268
19. Buchheit M, Simpson BM. Player-tracking technology: half-full or half-empty glass? *Int J Sports Physiol Perform*. 2017;12(suppl):S235–S241. doi:10.1123/ijspp.2016-0499
20. Van Cutsem J, Marcora S, De Pauw K, Bailey S, Meeusen R, Roelands B. The effects of mental fatigue on physical performance: a systematic review. *Sports Med Auckl NZ*. 2017;47(8):1569–1588. doi:10.1007/s40279-016-0672-0
21. Martin K, Meeusen R, Thompson KG, Keegan R, Rattray B. Mental fatigue impairs endurance performance: a physiological explanation. *Sports Med Auckl NZ*. 2018;48(9):2041–2051. doi:10.1007/s40279-018-0946-9
22. Smith MR, Coutts AJ, Merlini M, Deprez D, Lenoir M, Marcora S=M. Mental fatigue impairs soccer-specific physical and technical performance. *Med Sci Sports Exerc*. 2016;48(2):267. PubMed ID: 26312616 doi:10.1249/MSS.0000000000000762
23. Pizzera A, Laborde S, Lahey J, Wahl P. Influence of physical and psychological stress on decision-making performance of soccer

referees. *J Sports Sci*. 2022;40(18):2037–2046. PubMed ID: 36175198 doi:10.1080/02640414.2022.2127516
24. Fitzpatrick JF, Hicks KM, Russell M, Hayes PR. The reliability of potential fatigue-monitoring measures in elite youth soccer players. *J Strength Cond Res*. 2021;35(12):3448–3452. PubMed ID: 31498220 doi:10.1519/JSC.0000000000003317
25. Halson SL. Monitoring training load to understand fatigue in athletes. *Sports Med Auckl NZ*. 2014;44(suppl):139–147. doi:10.1007/s40279-014-0253-z
26. Foster C. Monitoring training in athletes with reference to overtraining syndrome. *Med Sci Sports Exerc*. 1998;30(7):1164–1168. PubMed ID: 9662690 doi:10.1097/00005768-199807000-00023
27. Clemente FM, Silva R, Castillo D, Los Arcos A, Mendes B, Afonso J. Weekly load variations of distance-based variables in professional soccer players: a full-season study. *Int J Environ Res Public Health*. 2020;17(9):3300. PubMed ID: 32397398 doi:10.3390/ijerph17093300
28. Foster C, Daines E, Hector L, Snyder AC, Welsh R. Athletic performance in relation to training load. *Wis Med J*. 1996;95(6):370–374. PubMed ID: 8693756
29. Fox JL, O'Grady CJ, Scanlan AT, Sargent C, Stanton R. Validity of the Polar Team Pro Sensor for measuring speed and distance indoors. *J Sci Med Sport*. 2019;22(11):1260–1265. PubMed ID: 31272915 doi:10.1016/j.jsams.2019.06.012
30. Huggins R, Giersch G, Belval L, et al. The validity and reliability of global positioning system units for measuring distance and velocity during linear and team sport simulated Movements. *J Strength Cond Res*. 2020;34(11):3070–3077. doi:10.1519/JSC.0000000000003787
31. Clemente FM, Silva AF, Sarmento H, et al. Psychobiological changes during national futsal team training camps and their relationship with training load. *Int J Environ Res Public Health*. 2020;17(6):1843. PubMed ID: 32178370 doi:10.3390/ijerph17061843
32. Leicht AS. Cardiovascular stress on an elite basketball referee during national competition. *Br J Sports Med*. 2004;38(4):E10. PubMed ID: 15273203 doi:10.1136/bjsm.2003.006908
33. Suárez Iglesias D, Leicht AS, Pojskić H, Vaquera A. Impact of contextual factors on match demands experienced by elite male referees during international basketball tournaments. *J Sports Sci*. 2021;39(8):936–943. PubMed ID: 33234010 doi:10.1080/02640414.2020.1851902
34. Cunniffe B, Proctor W, Baker JS, Davies B. An evaluation of the physiological demands of elite rugby union using Global Positioning System tracking software. *J Strength Cond Res*. 2009;23(4):1195–1203. PubMed ID: 19528840 doi:10.1519/JSC.0b013e3181a3928b
35. Nobari H, Aquino R, Clemente FM, Khalafi M, Adsuar JC, Pérez-Gómez J. Description of acute and chronic load, training monotony and strain over a season and its relationships with well-being status: a study in elite under-16 soccer players. *Physiol Behav*. 2020;225:113117. PubMed ID: 32750432 doi:10.1016/j.physbeh.2020.113117
36. Hopkins WG, Marshall SW, Batterham AM, Hanin J. 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
37. Reilly T, Morris T, Whyte G. The specificity of training prescription and physiological assessment: a review. *J Sports Sci*. 2009;27(6):575–589. PubMed ID: 19340630 doi:10.1080/02640410902729741
38. Thornton HR, Delaney JA, Duthie GM, Dascombe BJ. Developing athlete monitoring systems in team sports: data analysis and visualization. *Int J Sports Physiol Perform*. 2019;14(6):698–705. PubMed ID: 30676144 doi:10.1123/ijspp.2018-0169
39. Krustrup P, Bangsbo J. Physiological demands of top-class soccer refereeing in relation to physical capacity: effect of intense intermittent exercise training. *J Sports Sci*. 2001;19(11):881–891. PubMed ID: 11695510 doi:10.1080/026404101753113831
40. Weston M, Castagna C, Impellizzeri FM, Bizzini M, Williams AM, Gregson W. Science and medicine applied to soccer refereeing: an update. *Sports Med Auckl NZ*. 2012;42(7):615–631. doi:10.2165/11632360-000000000-00000
41. Reilly T, Gregson W. Special populations: the referee and assistant referee. *J Sports Sci*. 2006;24(7):795–801. PubMed ID: 16766507 doi:10.1080/02640410500483089
42. Reilly T. Energetics of high-intensity exercise (soccer) with particular reference to fatigue. *J Sports Sci*. 1997;15(3):257–263. PubMed ID: 9232551 doi:10.1080/026404197367263
43. Sloan RP, Shapiro PA, Bagiella E, et al. Effect of mental stress throughout the day on cardiac autonomic control. *Biol Psychol*. 1994;37(2):89–99. PubMed ID: 8003592 doi:10.1016/0301-0511(94)90024-8
44. Dishman RK, Nakamura Y, Garcia ME, Thompson RW, Dunn AL, Blair SN. Heart rate variability, trait anxiety, and perceived stress among physically fit men and women. *Int J Psychophysiol*. 2000;37(2):121–133. doi:10.1016/s0167-8760(00)00085-4
45. Rainey D, Winterich D. Magnitude of stress reported by basketball referees. *Percept Mot Skills*. 1995;81(3 pt 2):1241–1242. PubMed ID: 8684919 doi:10.2466/pms.1995.81.3f.1241
46. Stewart MJ, Ellery PJ, Ellery J, Maher L. Perceived psychological stress among high school basketball officials. *Percept Mot Skills*. 2004;99(2):463–469. PubMed ID: 15560333 doi:10.2466/pms.99.2.463-469
47. Gencay OA, Aydin EE. The effects of teams, individual players and spectators on basketball officials' decision-making processes. *The Anthropologist*. 2015;20(3):503–509. doi:10.1080/09720073.2015.11891754
48. Ritchie J, Basevitch I, Rodenberg R, Tenenbaum G. Situation criticality and basketball officials' stress levels. *J Sports Sci*. 2017;35(21):2080–2087. PubMed ID: 27879168 doi:10.1080/02640414.2016.1255770
49. Mascarenhas D, O'Hare D, Plessner H. The psychological and performance demands of association football refereeing. *Int J Sport Psychol*. 2006;37:99–120.
50. Balch MJ, Scott D. Contrary to popular belief, refs are people too! Personality and perceptions of officials. *J Sport Behav*. 2007;30:3–20.