Journal of Physical Education and Sport ® (JPES), Vol. 22 (issue 10), Art 304, pp. 2386 - 2392, October 2022
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Monitoring body composition and physical fitness of elite female basketball players after 16 weeks of in-season training

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Published online: October 31, 2022
(Accepted for publication October 15, 2022)
DOI:10.7752/jpes.2022.10304

Abstract
Understanding the physiological changes in players' profiles during the season is crucial to optimize training prescription according to players' needs towards a high-level game performance. The purpose of this study was to assess the variation in body composition and physical fitness of elite female basketball players after 16 weeks of in-season training. The sample was composed of 13 elite female basketball players aged 19.7 ± 4.3 years (height: 173.7 ± 9.8 cm, body mass: 70.4 ± 11.3 kg). Body composition, static strength, lower-body explosive strength, speed, agility, and aerobic endurance, were assessed initially (T1) and 16 weeks after the regular season (T2). Significant improvements were found between T1 and T2 for the squat jump (t = -2.433, $p \leq 0.05$, d = -0.39), the 20 m linear sprint (t = 2.493, $p \leq 0.05$, d = 0.87), and the Yo-Yo Intermittent Endurance Test-Level 2 (t = -3.746, $p \leq 0.01$, d = -0.34). Lower-body explosive strength showed a significant contribution to agility and speed. The visceral fat area presented a greater negative correlation with the aerobic and anaerobic capacity. Sports practitioners and coaches should be aware of the importance of monitoring players' body composition and physical fitness to assess the physiological responses to the training process and to optimize training prescription. Training contents may be adjusted according to the responses recorded to achieve the defined goals. The positive contribution of lower-body explosive strength to speed and agility, emphasizes the need to include in-season strength programs targeted to enhance players' overall physical fitness.
Keywords: **speed; agility; explosive strength; visceral fat; countermovement jump; squat jump**

Introduction

Basketball demands high levels of physical conditioning to allow players to exploit their technical and tactical skills during the game (Schelling & Torres-Ronda, 2016). Understanding the physiological changes in players' profiles during different training phases of the year is important to recognize to optimize training prescription, reduce injury risk, and allow players to compete at the highest level possible (Kim, Delisle-Houde, Reid, & Andersen, 2018). Therefore, worldwide, assessing players' physical attributes has gained popularity in sports training.

Several studies developed with elite athletic populations have reported that improved body composition may have a positive impact on performance parameters, such as maximal oxygen consumption (Högström, Pietilä, Nordström, & Nordström, 2012), maximal strength (Granados, Izquierdo, Ibanez, Ruesta, & Gorostiaga, 2008) and muscle power (Ferioli, Bosio, Zois, La Torre, & Rampinini, 2020). Indeed, body composition assessments have been recommended to be incorporated as part of the standard test battery by their strong relationship with the players' overall health and on-field performance (Kim et al., 2018). In a study developed with 38 professional and semi-professional male basketball players during an entire season, the authors reported a significant decrease of 1.2% in body fat percentage (BF%). However, body mass did not change significantly. Additionally, the players' aerobic and anaerobic performance improved between 20 to 30%, and significant improvements were also observed in vertical jumping (Ferioli et al., 2020). In another study on youth basketball, a single season was associated with substantial improvements at the molecular, cellular, tissue, and whole-body level of body composition in both male and female players (Allison, Sardinha, & Silva, 2014). Overall, body

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composition and physical fitness parameters have improved during the competitive basketball season, representing a response to the training prescription.

Despite several studies investigating the seasonal changes in physical fitness in youth basketball, only a few data are available on elite basketballers. A study conducted on seven male players competing in the National Basketball Association showed improvements in lower-body power, repetitive jump ability, and reaction time during an entire season (Gonzalez et al., 2013). Another study, in nine male Brazilian professional basketball players, described a considerable improvement in the aerobic and anaerobic endurance capacity, and a moderate-to-large increase in jumping performance, particularly in the squat jump test after 45 training sessions (Aoki et al., 2017). Overall, the literature recommends monitoring players' development throughout the season to provide a more suitable training prescription according to individual needs and competition demands. However, most of the investigations conducted on basketballers have privileged male players, and longitudinal research regarding fitness and body composition assessment in elite female basketball players is lacking (Reina et al., 2020).

Among female basketballers, previous literature has been mainly focused on physical fitness assessment (Banda, Beitzel, Kammerer, Salazar, & Lockie, 2019; Gür, Soyal, & Doğan, 2022; Kutseryb, Hrynkiv, Vovkanych, & Muzyka, 2019) and shooting performance topics (França, Gouveia, Coelho-e-Silva, & Gomes, 2021; França, Gouveia, Coelho-e-Silva, & Gomes, 2022). To the best of our knowledge, only one study was found concerning monitoring the training stimulus imposed on elite female basketball players (Nunes et al., 2014). According to the authors, after 12 weeks of a basketball-periodized training plan, players improved significantly in strength, agility, and aerobic and anaerobic variables (Nunes et al., 2014). However, no data was found on body composition and speed parameters, nor the interrelationship between body composition and physical fitness performance. The recent growth of high-level female basketball players worldwide supports the need to research this population, as in the case of male basketball (Reina et al., 2020). Understanding changes in the physiological parameters that may occur during the season is crucial for sports practitioners and coaches, particularly for the organization of the training process, monitoring players' evolution, and optimizing performance at different training stages. Therefore, the purpose of this study was to assess the variation of body composition and physical fitness of elite female basketball players after 16 weeks of in-season training and to investigate the interrelationship between body composition and physical fitness performance.

Material & Methods

Participants

Thirteen elite female basketball players aged 19.7 ± 4.3 years (height: 173.7 ± 9.8 cm, body mass: 70.4 ± 11.3 kg) and competing in the first division of the Portuguese Women's league were evaluated. Players' training experience was 11.5 ± 4.8 years. According to the competitive schedule, training sessions average seven times per week. All procedures applied were approved by the Ethics Committee of the Faculty of Human Kinetics, CEIFMH N. º 34/202. Informed consent was provided and signed by all participants or respective legal guardians during the enrollment phase before any assessment. The investigation was conducted following the Declaration of Helsinki. Participation in this study was voluntary, and players could withdraw anytime. All data collection and management procedures considered the participants' privacy and confidentiality.

Procedures

This study used a single-group design with a longitudinal approach over 16 weeks during the season. Pre-season testing (T1) was performed in the first week of the season in September of 2021 and was repeated 16 weeks later, before the Christmas break in December of 2021 (T2). A wide range of tests has been administered to achieve a detailed analysis of the players' profiles. The body composition was assessed in a laboratory during the early morning (from 8.00 am to 08.45 am), approximately two hours before a regular training session. The fitness tests were conducted on an official basketball court with a wood floor after an initial general warm-up. Fitness assessment included static strength, linear sprints, agility, aerobic endurance, and lower-body explosive strength. All assessments were conducted by trained staff from the investigation team, familiarized with each protocol. Medical screening indicated that all participants were in good health and had not been injured the week before data collection.

Training sessions

The first six weeks corresponded to the pre-season, and no competition was scheduled. In the following ten weeks, players usually competed on Sunday, having the next day off. Game time was typically set at 4.00 pm. In away games, players must be traveled by plane (mean duration: 1h30m to 1h45m) and by bus (mean duration: 40 to 1h30m), on the day before or the same day of the competition. The morning training sessions involved resistance training (RT) and shooting tasks. This training session had a mean duration of 90 m (45 m for RT and 30 m for shooting tasks). Before the RT sessions, players performed a general warm-up of 15 m based on shooting, dribbling, dynamic stretching, and mobility exercises. In the first six weeks, RT was performed three times per week on non-consecutive days (Tuesday, Thursday, and Saturday) and consisted of 3 to 4 sets of 10 repetitions targeting the strength training of main muscular groups. The rest interval between sets ranged between 30 and 45 s. The following ten weeks consisted of two weekly RT sessions on non-consecutive days (Tuesday and Thursday) aiming at strength and power training, with 4 to 5 sets of 4 to 8 repetitions. The rest interval between sets varied between 60 to 120 s. The afternoon sessions had a mean duration of 90 m and were focused on technical and tactical content according to the coaches' goals. The final practices of the week (Friday and Saturday) contemplated the scouting of the opponent team for that weekend. In those sessions, tactical adaptations were performed based on scouting. A typical weekly schedule is presented in Table I.

Table I. Typical training sessions schedule during the week according to the season phase.

Week	Time of the day	Schedule Mon	Tue	Wed	Thur	Fri	Sat	Sun
1-6	Morning		RT & Shoot (75m)		RT & Shoot (75m)		Tec & Tac (90 m)	Rest
	Afternoon	Tec & Tac (90m)	Tec & Tac (90m)	Tec & Tac (90 m)	Tec & Tac (90m)	Tec & Tac (90m)		
6-16	Morning	Rest	RT & Shoot (90m)		RT & Shoot (75m)		Sco & Tac (90 m)	Game
	Afternoon		Tec & Tac (90m)	Tac (90 m)	Tec & Tac (90m)	Sco & Tac (90m)		

Tec (Technical); Tac (Tactical); RT (resistance training); Shoot (Shooting series); Sco (Scouting); Shooting series: 7x20 2-point shots plus 100 free-throws; or 7x15 3-point shots plus 100 free-throws; or 250 shots scored from several positions choose by players; Technical & tactical: balanced (2x2, 3x3, 4x4) and unbalanced small side games (2x1, 3x2, 4x3) to explore specific technical and tactical options; exercises with temporary numerical variability to enhance fast-break; defensive work through on 1x1 situations; Tactical: training situations focused on the team's tactical components, usually using 4x4 and 5x5 game situations; Scouting and tactical: tactical adjustments made according to the opposition characteristics.

Body composition

Participants were barefoot and used only their underwear for the body composition assessment. Height was measured to the nearest 0.01 cm using a stadiometer (SECA 213, Hamburg, Germany). The InBody 770 (InBodyUSA, Cerritos, CA) was used to measure the body mass to the nearest 0.1 kg, body fat percentage (BF%), and the visceral fat area (VFA). The device uses a hand-to-foot bioelectrical impedance analysis to predict a set of body composition variables. The reliability of InBody has been tested previously, including in the assessment of VFA (Ogawa et al., 2011). At measurement, participants were fasting and standing with both arms 45º apart from the trunk and with both feet bare on the spots of the platform.

Static strength and lower-body explosive strength

The handgrip was applied to measure static strength. The protocol consisted of two alternated data collection trials for each arm performed using a hand dynamometer (Jamar Plus+, Illinois, USA). Participants were instructed to hold the dynamometer in one hand, laterally to the trunk with the elbow on a 90º position and squeeze as hard as possible. The best score of the dominant side was retained for analysis. Lower-body explosive strength were assessed using the countermovement jump (CMJ) and the squat jump (SJ) protocols, which included four data collection trials. All jumps were assessed using the Optojump Next (Microgate, Bolzano, Italy) system of analysis and measurement. In both tests, players were encouraged to jump for maximum height, and the best score was used for analysis. Before data collection, three experimental trials were performed by each participant to ensure correct execution. The SJ protocol testing began with the participant in a squat position at a self-selected depth of approximately 90º of knee flexion. If a dipping movement of the hips was evident, then the trial was repeated. The participant resets to the starting position after each jump. In the CMJ protocol, participants began in the tall standing position, with feet placed hip-width to shoulder-width apart. Then, participants dropped into the countermovement position to a self-selected depth, followed by a maximal effort vertical jump. Hands remained on the hips for the entire movement to eliminate any influence of arm swing. If the hands were removed from their hips at any point, or excessive knee flexion was exhibited during the countermovement, the trial was repeated. The participant resets to the starting position after each jump.

Agility and Speed

Agility was evaluated through the t-test. The t-test is a four-directional agility and body control test that assesses the ability to change direction rapidly while maintaining balance and without losing speed. Participants sprinted 9.14 m straight, then shuffled 4.75 m to the left side. Next, participants shuffled to the right side 9.14 m and immediately shuffled 4.75 m back. Finally, participants run backward until they pass the starting point. On the other hand, linear speed was assessed through maximal sprints at 10- and 20 m, starting at a stationary position. Both t-test and sprint times were recorded in seconds using Witty-Gate photocells (Microgate, Bolzano, Italy) and the best score was used for analysis.

Aerobic and anaerobic endurance

Endurance was assessed using the Yo-Yo Intermittent Endurance Test-Level 2 (YYIE2). The players ran back and forth, completing two 20 m shuttle runs in time with the "beep" sound from a CD player. Following each shuttle run, players walked or jogged the 2.5 m behind the marking cone until getting back to the starting point within 5 s. The running speed increases progressively, and the test is over when the player is as not able to keep the pace twice. The total distance covered was considered as the test score.

Statistical analysis Descriptive statistics included mean and standard deviation. All data were checked for normality using the Shapiro-Wilk test. Paired samples t-test was applied to assess differences in the body composition and fitness tests between T1 and T2. Effect size was interpreted using d-Cohen as follows (Cohen, 2013): d<0.2 (small), 0.2<d<0.6 (moderate), 0.6<d<1.2 (large), 1.2<d<2.0 (very large). The Pearson product-moment correlation coefficient was used to explore the relationship between body composition and fitness variables. All analyses were performed using the Statistical Package for Social Sciences (IBM SPSS software, version 26) and the significance level was set at 5%.

Results

Results of paired samples t-test are presented in Table II. Significant statistical differences were found between T1 and T2 for the SJ (t = -2.433, $p \leq 0.05$, d = -0.39), the 20 m linear sprint, (t = 2.493, $p \leq 0.05$, d = 0.87) and the YYIE2 (t = -3.746, $p \leq 0.01$, d = -0.34). Overall, slight improvements were observed through the mean comparisons for all variables, except for BF% and 10 m linear sprint time.

Table II. Descriptive statistics and paired t-test results to examine mean differences for body composition and fitness tests between T1 and T2.

Variables	T1	T2	Mean comparisons		
	Mean ± SD	Mean ± SD	t	*p*	d
Body mass (kg)	70.4 ± 11.3	71.6 ± 12.0	0.080	0.94	-0.11
BF %	20.4 ± 4.2	21.1 ± 4.0	0.072	0.94	-0.18
VFA (cm^2)	60.1 ± 21.2	57.6 ± 21.0	1.367	0.20	0.12
Handgrip (kg)	35.4 ± 6.2	35.8 ± 6.7	-0.327	0.75	-0.06
3 kg ball throw (m)	5.3 ± 0.8	5.6 ± 0.9	-1.834	0.16	-0.36
Sit-ups (n)	44.5 ± 8.8	46.3 ± 8.1	-1.502	0.09	-0.22
SJ height (cm)	25.9 ± 3.6	27.1 ± 2.9	-2.433	0.03*	-0.39
CMJ height (cm)	27.4 ± 3.8	28.1 ± 3.9	-1.446	0.17	-0.22
T-test (s)	10.74 ± 0.55	10.58 ± 0.49	1.766	0.10	0.32
10 m linear speed (s)	1.97 ± 0.07	1.98 ± 0.06	-0.591	0.56	-0.16
20 m linear speed (s)	3.54 ± 0.17	3.42 ± 0.12	2.493	0.03*	0.87
YYIE2 (m)	821.5 ± 306.3	921.5 ± 307.7	-3.746	0.01**	-0.34

T1 (time 1), T2 (time 2), SD (standard deviation), BF% (body fat percentage), VFA (visceral fat area), SJ (squat jump), CMJ (countermovement jump), YYIE2 (yo-yo intermittent endurance test-level 2), *$p \leq 0.05$, **$p \leq 0.01$

The significant Pearson product-moment correlation coefficients for body composition and fitness tests according to T1 and T2 are presented in Table III and Table IV, respectively. In T1, body mass, BF%, and VFA showed significant correlations with the handgrip (positive) and YYEI2 (negative). BF% was substantially related with VFA (r = 0.79, $p \leq 0.01$). Among the fitness tests, the YYEI2 presented the highest number of relationships, including the body composition variables, static strength (r = -0.56, $p \leq 0.05$), and lower-body explosive strength tests (SJ: r = 0.65, $p \leq 0.05$, and CMJ: r = 0.67, $p \leq 0.05$). Both SJ and CMJ were significantly and negatively related to the t-test. The t-test also presented a significant and positive relationship with the 10 m linear sprint (r = 0.68, $p \leq 0.05$), but not with the 20 m linear sprint. In T2, body mass and VFA were substantially and positively related to the handgrip. As in T1, BF% was significantly correlated with VFA (r = 0.74, $p \leq 0.01$). The YYEI2 only presented significant relationships with VFA (r = -0.58, $p \leq 0.05$), and the SJ (r = 0.56, $p \leq 0.05$). The 20 m linear sprint and the SJ showed the highest number of relationships among the fitness tests. The 20 m linear sprint presented negative relationships with lower-body explosive strength, and positive relationships with the t-test and 10 m linear sprint times. The 10 m sprint time was strongly correlated with lower-body explosive strength (SJ: r = 0.58, $p \leq 0.05$, and CMJ: r = 0.56, $p \leq 0.05$), and with the t-test (r = -0.54, $p \leq 0.05$).

Table III. Significant correlation coefficients for body composition and fitness tests at T1.

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. Body mass		0.88**		0.91**						-0.63*
2. BF%			0.79**	0.56*						-0.56*
3. VFA				0.83**						-0.76**
4. Handgrip										-0.56*
5. SJ						0.94**	-0.65*			0.65*
6. CMJ							-0.64*			0.67*
7. T-test								0.68*		
8. 10 m LS									0.54*	
9. 20 m LS										
10. YYIE2										

T1 (time 1), BF% (body fat percentage), VFA (visceral fat area), SJ (squat jump), CMJ (countermovement jump), LS (linear speed), YYIE2 (yo-yo intermittent endurance test-level 2), * $p \leq 0.05$, ** $p \leq 0.01$

Table IV. Significant correlation coefficients for body composition and fitness tests at T2.

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. Body mass			0.85**	0.83**						
2. BF%			0.74**							
3. VFA				0.59*						-0.58*
4. Handgrip										
5. SJ						0.95**		-0.58*	-0.60*	0.56*
6. CMJ								-0.56*	-0.59*	
7. T-test								0.54*	0.64*	
8. 10 m LS									0.95**	
9. 20 m LS			0.85**	0.83**						
10. YYIE2										

T2 (time 2), BF% (body fat percentage), VFA (visceral fat area), SJ (squat jump), CMJ (countermovement jump), LS (linear speed), YYIE2 (yo-yo intermittent endurance test-level 2), * $p \leq 0.05$, ** $p \leq 0.01$

Discussion

This study aimed to examine the variation in body composition and physical fitness of elite basketball players after 16 weeks of the season. Significant improvements were observed in the 20 m linear sprint, YYIE2 distance, and SJ height. In contrast, no significant differences were found in body composition variables.

Although there was a significant improvement in the 20 m linear sprint after 16 weeks in-season, the sprint time at the 10 m distance increased by nearly 0.1 s. These results indicate that players improved their capability to achieve maximal speed but not accelerate. However, maximal sprint has been pointed out as an important discriminator between players at different competition levels. Another study focused on comparing the physical attributes of adolescent female basketball players competing in different European Divisions, the results showed that the distinctively slowest players in the 20 m linear sprint were the ones from the last Division (Erculj, Blas, & Bracic, 2010). Also, there were significant positive correlations between ¾ court sprint (nearly 22.8 m) and some game-related performance variables, such as assists and steals, in 23 Spanish elite female youth basketball players (Fort-Vanmeerhaeghe, Montalvo, Latinjak, & Unnithan, 2016). Even though, the capacity to accelerate in a short period is an essential attribute for basketball players. Therefore, our data may underline the need to promote or adjust specific training contents, such as plyometric training to improve power and speed.

Meanwhile, in this study, players significantly improved their aerobic and anaerobic capacity from T1 to T2. These results are consistent with previous literature on elite basketball, particularly concerning male players (Aoki et al., 2017; Ferioli et al., 2020). Regarding female basketball, only one study reported in-season longitudinal data. In Brazilian players aged 26.0 ± 5.0 years, significant improvements in the YYIE2 distance were described, followed by 12 weeks of periodized basketball training (Nunes et al., 2014). However, in this study, the enlargement of aerobic and anaerobic capacity might result from the greater workload of the initial phase of the season, which followed the break period between seasons. Indeed, Ferioli et al. (2020) assessed players' physical attributes in three moments of the season (T1: mid-Agust; T2: mid-October; T3: end-January), concluding that the increase the aerobic and anaerobic capacity was only significant from T1 to T2.

Regarding lower-body explosive strength, improvements were observed both in the SJ and CMJ. However, only the SJ performance showed a significant increase. In elite Brazilian female basketball players, authors observed a significant increase of nearly 3.5 cm in the SJ performance, followed by 12 weeks of basketball training periodization (Nunes et al., 2014). No data was displayed regarding the CMJ. According to the literature, there is a trend of greater gains in stretch-shortening cycle movements of the CMJ than in concentric-only movements of the SJ, particularly after implementing specific strength and conditioning programs (Stojanović, Ristić, McMaster, & Milanović, 2017). However, contrary results have been presented. For example, a study conducted to evaluate the effects of 8 weeks of plyometric training on the jump ability in female basketball players aged 20.9 ± 2.4 years, reported greater improvements in the SJ (+10.4%) than in the CMJ (+3.6%) (Cherni et al., 2020). Although different trends have been observed concerning the SJ and CMJ performance, the literature advocates that optimizing the players' jumping ability might be decisive for competition (Banda et al., 2019; Cherni et al., 2020).

Past sports research has underlined lower-body explosive strength as an important predictor of speed and agility (França, Gouveia, Caldeira, et al., 2022; Peñailillo, Espíldora, Jannas-Vela, Mujika, & Zbinden-Foncea, 2016). This study supports this conclusion through the significant and negative relationships between lower-body strength tasks, the t-test, and linear sprints. Higher levels of lower-body explosive strength are related to lower time spent in changes of direction and sprint times (França, Gouveia, Caldeira, et al., 2022; Padulo et al., 2017). Basketball is an intermittent activity characterized by changes of direction over short distances, short sprints, and several types of jumps using explosive contractions (Abdelkrim, El Fazaa, & El Ati, 2007). Therefore, the game performance should be associated with the players' capacity to accelerate the body mass as fast as possible through the lower limbs' ballistic movements (Padulo et al., 2017). Meantime, body composition variables did not display significant differences between T1 and T2. However, BF% and VFA presented the most substantial negative correlation with aerobic and anaerobic capacity. The detrimental effects of BF% on sports performance are well-known in the literature (Malina, Bouchard, & Bar-Or, 2004). This was the first study assessing VFA in elite female basketball to the best of our knowledge. Indeed, both BF% and VFA monitoring should be considered throughout the season, since they are strong indicators of the individual overall health status (Roelofs et al., 2020).

Some limitations are presented in this study, particularly the sample size and the lack of control over other important variables, such as the players' nutritional patterns. Expanding the sample size and including data related to dietary habits would allow a more precise evaluation of this population. Still, these study results are unique in monitoring elite female basketball players in-season. The training procedures were not modified in any way by this investigation. Future work on female basketball, mainly focused on the longitudinal assessment in-season, is still needed to address the literature gaps regarding this topic. Sports practitioners and coaches should be aware of the importance of monitoring players' body composition and physical fitness to assess their physiological responses to the training process. Training contents may be adjusted according to the responses recorded to achieve the defined goals. Moreover, the relationship between lower-body explosive strength, speed, and agility, emphasizes the previous recommendations in the literature of promoting specific strength programs to enhance players' overall physical fitness.

Conclusion

Our results showed significant improvements in speed, aerobic and anaerobic capacity, and lower-body explosive strength of elite female basketball players after 16 weeks in-season. Although no substantial changes were observed in body composition variables, BF% and VFA appear to be the greater detrimental factors for aerobic and anaerobic capacity. In contrast, lower-body explosive strength significantly contributed to speed and agility. This study confirms that the periodization plan implemented was beneficial to improve players' physical fitness, which may be used by coaches and sports agents involved in the basketball training process to guiding their management practices. Monitoring players' body composition and physical fitness during the season are crucial to assessing the training process's physiological responses, which may be done using easy-field tests. This data is of great interest to the basketball training process, allowing coaches to evaluate training prescriptions and adjust strategies according to players' needs. Due to the few investigations conducted in elite female basketball, future studies are still needed, particularly concerning the longitudinal effects of training prescription on players' profiles.

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