ISSN: 2651-4451 • e-ISSN: 2651-446X

Turkish Journal of Physiotherapy and Rehabilitation

2025 36(1)92-103

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Received: 20.04.2024 (Geliş Tarihi)
Accepted: 21.04.2025 (Kabul Tarihi)

THE RELATIONSHIP BETWEEN HEART RATE VARIABILITY AND ATHLETIC PERFORMANCE IN BASKETBALL PLAYERS

ORIGINAL ARTICLE

ABSTRACT

Purpose: For basketball players, improving athletic performance is one of the main keys to success and the autonomic nervous system can also affect athletic performance. Heart rate variability (HRV) can be associated with sportive performance as a marker of the autonomic nervous system. Our study was planned to investigate the relationship between HRV method and basketball-specific sportive performance.

Methods: The study was conducted with 20 male basketball players. Vertical jump and seated chest pass test were used to evaluate strength, T agility test was used to evaluate agility, lower and upper extremity Y balance tests were used to evaluate balance and Johnson Basketball Test Battery was used to evaluate basketball specific performances. Autonomic nervous system was evaluated by heart rate variability. The relationships between HRV results and performance results were analyzed.

Results: Correlations were found at various levels between the vertical jump and seated chest pass tests and some parameters of the HRV between the T agility test and some parameters of the HRV, and between the Johnson Basketball Test Battery and some parameters of the HRV ($p<0.05$). No statistically significant correlation was found between upper and lower extremity Y balance tests and HRV parameters ($p>0.05$).

Conclusion: Since the results of our study show that HRV may be related to performance, it is suggested that measuring HRV assessments at different periods during the whole season may be useful for athlete evaluations. However, it is thought that more detailed studies are needed in this field for clearer information.

Keywords: Autonomic nervous system, Basketball, Heart rate variability, Performance.

BASKETBOLCULARDA KALP HIZI DEĞİŞKENLİĞİ VE SPORTİF PERFORMANS ARASINDAKİ İLİŞKİ

ARAŞTIRMA MAKALESİ

ÖZ

Amaç: Basketbol oyuncuları için atletik performansı artırmak başarının ana anahtarlarından biridir ve otonom sinir sistemi de atletik performansı etkileyebilir. Kalp hızı değişkenliği (KHD), otonom sinir sisteminin bir belirteci olarak sportif performans ile ilişkilendirilebilir. Çalışmamız kalp hızı değişkenliği yöntemi ile basketbola özgü sportif performans arasındaki ilişkiyi araştırmak üzere planlanmıştır.

Yöntem: Çalışma 20 erkek basketbolcu ile gerçekleştirildi. Kuvveti değerlendirmek için dikey sıçrama ve oturarak göğüs pas testi, çevikliği değerlendirmek için T çeviklik testi, dengeyi değerlendirmek için alt ve üst ekstremite Y denge testleri ve basketbola özgü performansları değerlendirmek için Johnson Basketbol Test Bataryası kullanıldı. Otonom sinir sistemi kalp atım hızı değişkenliği ile değerlendirilmiştir. KHD sonuçları ile performans sonuçları arasındaki ilişkiler analiz edildi.

Sonuçlar: Dikey sıçrama ve oturarak göğüs pas testleri ile KHD'nin bazı parametreleri arasında, T çeviklik testi ile KHD'nin bazı parametreleri arasında ve Johnson Basketbol Test Bataryası ile KHD'nin bazı parametreleri arasında çeşitli düzeylerde korelasyonlar bulundu ($p<0,05$). Üst ve alt ekstremite Y denge testleri ile KHD parametreleri arasında istatistiksel olarak anlamlı bir korelasyon bulunmadı ($p>0,05$).

Tartışma: Çalışmamızın sonuçları KHD'nin performansla ilişkili olabileceğini gösterdiğinden, KHD değerlendirmelerinin tüm sezon boyunca farklı dönemlerde ölçülmesinin sporcu değerlendirmeleri için yararlı olabileceği önerilmektedir. Ancak daha net bilgiler için bu alanda daha detaylı çalışmalara ihtiyaç olduğu düşünülmektedir.

Anahtar kelimeler: Basketbol, Kalp atım hızı değişkenliği, Otonom sinir sistemi, Performans.

INTRODUCTION

Defined as "a complex product of cognitive information about the current situation and past events and a player's ability to produce the required sport skill(s)" (1), sportive performance is considered as one of the main key factors to success for athletes (2). The way to improve sportive performance depends on physical fitness parameters. While the physical fitness parameters related to health are mostly related to daily activities, the parameters related to performance form the basis of the skills that need to be met in sports (3).

Heart rate variability (HRV) is a non-invasive measure of the balance between sympathetic and parasympathetic activity of the autonomic nervous system in physiological and pathological conditions and reflects the time variability between consecutive heart beats (4, 5). It can be observed as the variability of the interval of the beats of the heart called N-N (normal beat to normal beat) or RR (R wave to R wave) during the electrocardiogram. It is considered a quantitative marker to assess adequate cardiac regulation by the autonomic nervous system in response to both physical and psychological stimuli (6).

HRV levels may differ between exercise and resting states, which is closely related to the modulatory effects of exercise on the autonomic nervous system. Studies have demonstrated that HRV parameters show a negative relationship with increasing exercise intensity and that sympathetic system dominance in sympathovagal balance increases with the effect of high physical stress during exercise (7, 8). In addition, the fact that HRV is regulated by the autonomic nervous system indicates that HRV is a reflector of neuro-cardiac functions, and HRV studies conducted after high-intensity training may be an indicator to determine training and recovery strategies for athletes (10). In this context, HRV is also important for clinical use because it shows physiological changes in autonomic functions (11).

Basketball is a team sport that includes important physical fitness parameters such as endurance, flexibility, speed, power, strength, coordination, agility, and game-specific skills (12). The game is a high-intensity sport in which the tempo of the game decreases and increases frequently and includes runs, sprints, jumps (rebounds, blocks, throws, etc.), and movements with the ball (13, 14), which highlight the characteristics of athletes depending on their physiology and motor skills (15). In a game like basketball, in which players move all around the court, HR is affected by both the physical demands on the court and the emotional intensity. In some cases, athletes' HRs can be abnormally elevated even before competitions. From this point of view, HRV monitoring is emerging as a supportive method to improve sport-specific performance in basketball players potentially through improved breathing and vagal modulation of parasympathetic activity (16). It has been reported that HRV biofeedback training reflects autonomic nervous system homeostasis and a positive psychophysiologic change and is a self-regulatory intervention aimed at reducing psychophysiologic stressors resulting in improvement in sport-specific skills and optimal performance (16, 17).

In a game such as basketball, in which the physiological and psychological stress level can change rapidly and frequently during the game, HRV in the players may affect their physical fitness and thus their sporting performance. In addition, players' physical fitness and therefore their game performance may be affected by the balance in the autonomic nervous system. Based on these contexts, the aim of this study was to examine the relationship between HRV parameters and sportive performances of basketball players.

METHODS

Participants

Thirty-two male licensed basketball players who met the inclusion criteria for the study were interviewed and the study was completed with 20 eligible participants (Figure 1). Before starting the study, the volunteers were verbally informed about the content, purpose, duration, and evaluations to be performed, and the participants also read and signed the Informed Consent Form.

The inclusion criteria were as follows: male gender, being between 18 and 25 years of age, having an active basketball license and having been in active

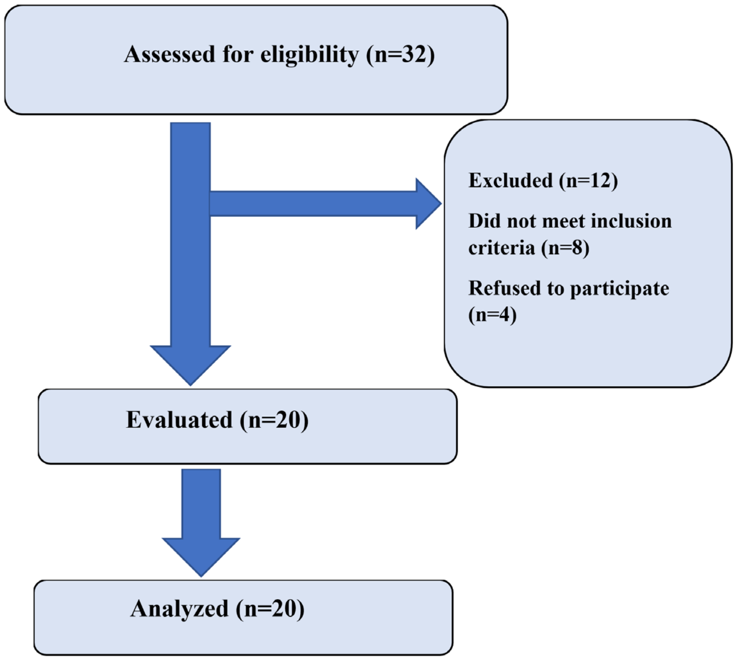

Figure 1. Flowchart of the study.

competition for at least 4 years, not having any pain or discomfort at the time of the assessment, not having participated in intense activity that would affect the assessments at least 24 hours before the test, being full, not having consumed alcohol, cigarettes, and caffeine at least 24 hours before the test, and having slept at least 8 hours on the night of the day of the assessment. Exclusion criteria were: having an injury within the last 6 months that required a break from sports and having any systemic disease.

Procedure

The ethics committee approval of this cross-sectional study was obtained from X University Ethics Committee (#46, Date:14/01/2021). The evaluations in our study were conducted in Y Basketball Club Sports Hall between January 2021 and September 2022. In addition to demographic information, the participants' explosive power (Vertical Jump Test), upper extremity power (Seated Medicine Ball Throw Test), agility performance (T Agility Test), lower extremity balance (Lower Extremity Y Balance Test), upper extremity balance (Upper Extremity Y Balance Test), basketball performance (Johnson Basketball Performance Tests), and HRV (Polar H10 Chest Strap) were evaluated.

Vertical Jump Test:

It is a method applied to measure the explosive power of individuals in the vertical direction (3). For this test, the athletes stood next to the wall with their feet shoulder-width apart. In this position, the highest point they could reach with their hand was marked with the help of a tape. Then the athlete was asked to jump in a vertical direction and again the highest distance reached was marked. After a total of three attempts, the distance between the marked points was measured. The best distance recorded was recorded in centimeters (cm) and then these measurement results were converted into watts using the following power formula (18)

Power (watts) = 21.67 x Body weight (kg) x Vertical displacement (m) x 0.5 (3).

Seated Ball Throw Test

During this test, the athletes were asked to sit on the floor with their waist, back, shoulders, and head supported against the wall to evaluate upper extremity strength and power. Care was taken to ensure that their knees were in full extension. Then, they were asked to throw a medicine ball weighing two kilograms (kg) to the farthest distance using both hands without disturbing the back, shoulder,

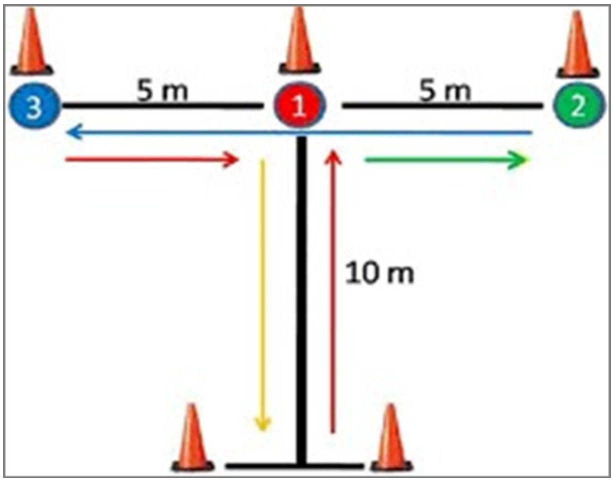

Figure 2. T Agility Test

and head support. The distance the ball fell was marked and recorded in cm. Arm lengths measured before the test were subtracted from the distances obtained to normalize the results. A total of four trial throws were made and the mean value of these throws was taken as the basis. The distance between the wall and the most proximal end of the chalk mark was subtracted from the total shot distance. The mean distance was calculated for further analysis (3, 18, 19).

T Agility Test

The aim of this test is to assess all-round speed, agility, and body control. The athlete was asked to first run forward starting from the center cone and touch the cone in front. Then they were asked to run sideways to the right and left cones and touch each in the same way. After touching the leftmost cone, they were asked to touch the cone in the middle and finally to run backwards towards the starting point. The stopwatch was stopped when they reached the starting point. A total of three trials were performed and the best time was recorded in seconds (3, 18, 20) (Figure 2).

Lower Extremity Y Balance Test

With the Lower Extremity Y Balance Test, dynamic balance and postural control on one leg were evaluated. Before starting the test, the floor was marked in three directions (anterior-posteromedial-posterolateral) according to the protocol. The angles between these marks were 135° -135°-90°. After warming up, the athlete placed one foot in the center of these marks for the starting position. The athlete was asked to reach the maximum distance in the preset direction and return to their original position. Three attempts were made for each direction and the same procedure was repeated for

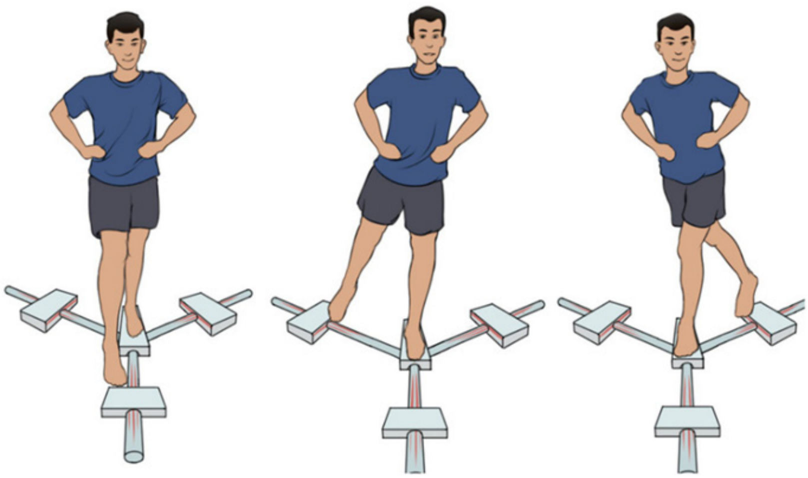

Figure 3. Lower Extremity Y Balance Test (22).

the contralateral side and the best results were recorded. While performing the test, the person should not lose balance and should not lift the heel off of the center. For normalization, the maximum reachable distance was divided by the leg length distance between the spina iliaca anterior superior and medial malleolus measured with a tape measure while lying supine and multiplied by 100 (21) (Figure 3).

Upper Extremity Y Balance Test

The Upper Extremity Y Balance Test is a widely used clinical and field test to investigate the mobility and stability of the upper quadrant (23). For the test, the floor was marked in three directions (inferolateral-superolateral-medial) at 135°-135°-90° angles with the help of tape. The athlete took a push-up position with their feet shoulder-width apart. The hand to be tested was placed at the junction of the three lines. The other free hand was then moved as far as it could reach in the specified direction and returned to its original position. This process was repeated three times in all directions for both extremities and the best result for each direction was recorded. To ensure normalization between athletes, the distance from the C7 spinous process to the most distal third finger was measured with a tape measure with their shoulders in 90° abduction and elbows in full extension position, and the best distance recorded at the end of the test was divided by arm length and multiplied by 100 (24).

Johnson Basketball Performance Test Battery

The Johnson Basketball Test Battery was developed by L. William Johnson to assess potential basketball talent and basic basketball skills. The evaluation of basic basketball skills is categorized under three headings, namely, fast throw test, accurate throw test, and dribbling tests (25).

Johnson Field Goal Speed Test

The aim of this test is to evaluate the successful throwing performance of a person under stress. During the test, the athlete was asked to take a position under the basket and shoot for 30 seconds without stopping. The athlete was given 1 point for each successful shot. At the end of the time, the total number of successful shots was recorded. Three attempts were made and the average of these attempts was taken and analyzed (26).

Johnson Throw for Accuracy

Three rectangles were drawn on the wall, which were nested according to the protocol. Then, a point with a distance of 12.2 meters (40 feet) from the wall was marked and the athlete stood on this point to start. They were asked to throw ball 10 times from this point and hit the innermost rectangle. The innermost rectangular area was worth 3 points, the outer rectangular area was worth 2 points, and the outermost rectangular area was worth 1 point. Zero point was given for the shot that did not hit the rectangular area. A total of three trials were performed and the average of these trials was taken and recorded (25, 26).

Johnson Dribble Test

The aim of this test is to assess a person's dribbling ability and agility. According to the protocol, a total of five cones were required. The distance between the start and the next cone was set to 3.65 m (12 feet), while the distance between the other cones was set to 1.82 m (6 feet). The athlete started dribbling from the starting point and when they reached the last cone, they turned around the cone and continued dribbling towards the starting point. They were asked to perform this cycle continuously for 30 seconds. The athlete received 1 point for each cone they passed and their score for the duration was calculated. A total of three trials were performed and the average of these trials was taken for analysis (25, 26).

HRV Assessment

In our study, a Polar H10 (Polar Electro, Kempele, Finland) chest strap, which was validated, was used as a HR monitor (27). Elite HRV, which is a mobile phone application with established validity and reliability, was used to analyze the data obtained (28). The protocol for the evaluation of HRV was determined in accordance with the guidelines of the European Society of Cardiology and the North American Electrophysiology Society for standardizing physiological and clinical studies (29). The evaluations were performed for each athlete in a quiet, semi-dark room with a temperature of 22-25°C (30). It was ensured that the athlete had not participated in a strenuous activity 24 hours before the assessment and had slept at least 8 hours on the day of the assessment (30). The portable HR monitor was placed on the xiphoid process of the athlete via a chest strap in a non-disturbing manner and the measurements were continued by connecting with the phone application. Then, the athlete rested for 15 minutes and the protocol was started. The test was performed in the supine position for 8 minutes and then in standing position for 7 minutes. The 3rd to 8th minute lying position and the 9th to 14th minute standing position results were recorded (29). The measurements were repeated in 5-min recordings in these positions, before and after the assessments and during the Johnson Basketball Performance Tests, taking into account the hypothesised changes in HRV during rest, assessment and recovery (25, 26). Root Mean Square of Successive Differences (RMSSD), Standard Deviation of NN Intervals (SDNN), Total Power (TP), Low-Frequency/High-Frequency (LF/HF) ratio, LF and HF parameters were recorded.

Statistical Methods and Analysis

IBM SPSS Statistics 21 (IBM, Chicago, IL) computer program was used for statistical analysis and calculations. In the sample size calculation made using the G-Power 3.1 program before starting the study, the correlation coefficient r=0.7942 (strong correlation) in the study examining the relationship between vertical jump and LF/HF, which is a parameter reflecting sympathetic and parasympathetic modulation in basketball players, was taken as r=0.7942 (strong correlation) and it was predicted that 12 people are needed in the study for 90% power and 95% confidence interval (31). However, due to the availability of more athletes, the study was conducted with 20 participants.

The demographic data of the athletes are expressed as mean±standard deviation. Shapiro-Wilks test was used to test the conformity of the data to normal distribution. The correlations between HRV and sportive performances were analyzed using Pearson's correlation analysis test. According to the correlation coefficient (r), the degree of association was interpreted as weak (0.00-0.29), low (0.30-0.49), moderate (0.50-0.69), strong (0.70-0.89) and very strong (0.90-1.00). The significance level was accepted as $p<0.05$ for all analyses.

RESULTS

The study was completed with 20 male basketball players with a mean age of 19.40±1.04 years. The mean number of years of being a licensed athlete was 7.95±2.43 and the mean number of exercise days per week was 6.00±.00. Data on other demo-

Table 1. Demographic characteristics of the athletes.

	n	Mean±SD
Age (year)	20	19.40±1.04
Height (cm)	20	194.65±8.26
Weight (kg)	20	90.00±10.86
BMI (kg/m^2)	20	23.68±1.51
License Year (year)	20	7.95±2.43
Exercise Frequency (days/week)	20	6.00±.00

cm: Centimeter, kg: Kilogram, n: Number of participants, SD: Standard Deviation.

Table 2. Descriptive data of sportive performance parameters.

	n	Mean±SD
Vertical jump test (watt)	20	585.59±54.89
Seated chest ball throw test (watt)	20	7422.01±1484.31
T agility test (s)	20	10.02±.59
Lower Extremity Y Balance Test (%)	20	99.04±9.08
Upper Extremity Y Balance Test (%)	20	92.67±11.96
Fast throwing performance (point)	20	19.77±1.92
Accurate throwing performance (point)	20	20.97±2.50
Dribbling performance (point)	20	34.56±3.78

n: Number of participants, SD: Standard Deviation, s: second, %: Percent

Table 3. Relationships between vertical jump test, Seated chest ball throw test, T Agility Test and HRV parameters

	Measuring Positions		Time Dependent Parameters		Frequency Dependent Parameters			
			RMSSD (ms)	SDNN (ms)	TP (ms²)	LF/HF	LF (ms²)	HF(ms²)
Vertical Jump (watt)	LDBE	r	-.066	.119	-.039	.323	.101	-.081
		p	.782	.618	.870	.164	.673	.734
	SBE	r	-.087	-.185	-.226	-.251	-.080	-.011
		p	.715	.435	.339	.286	.738	.965
	FT	r	-.188	-.380	-.165	-.111	-.195	-.126
		p	.427	.098	.486	.640	.409	.596
	AT	r	.311	-.350	.150	-.490	-.065	.322
		p	.182	.130	.527	.028*	.787	.166
	D	r	-.104	-.687	-.514	-.444	-.626	-.198
		p	.663	.001*	.020*	.050	.003*	.402
	LDAE	r	-.454	-.304	-.579	.277	-.576	-.481
		p	.044*	.193	.007*	.238	.008*	.032*
	SAE	r	-.432	-.502	-.457	.156	-.463	-.471
		p	.057	.024*	.043*	.510	.040*	.036*
Seated Chest Ball Throw Test (watt)	LDBE	r	-.859	-.704	-.717	.598	-.635	-.860
		p	.001*	.001*	.003*	.005*	.003*	.001*
	SBE	r	-.644	-.435	-.445	.426	-.385	-.680
		p	.002*	.056	.049*	.061	.094	.001*
	FT	r	-.395	-.244	-.380	.256	-.278	-.490
		p	.084	.301	.098	.277	.235	.028*
	AT	r	-.220	-.272	-.125	.051	-.140	-.171
		p	.352	.246	.600	.830	.556	.470
	D	r	-.244	.331	-.057	-.155	-.149	-.026
		p	.300	.154	.811	.514	.531	.915
	LDAE	r	-.278	-.218	.030	.471	.137	-.233
		p	.235	356	.900	.036*	.565	.323
	SAE	r	-.362	-.367	-.343	-.005	-.343	-.209
		p	.116	.112	.139	.985	.139	.376
T Agility Test (sec)	LDBE	r	.017	.060	-.057	-.009	-.012	.017
		p	.942	.801	.811	.970	.960	.942
	SBE	r	-.065	-.058	.223	.120	.254	-.052
		p	.784	.808	.345	.615	.279	.828
	FT	r	-.087	-.081	-.144	-.428	-.067	-.099
		p	.714	.736	.545	.060	.779	.677
	AT	r	-.129	-.035	-.073	-.023	-.070	-.173
		p	.589	.885	.760	.922	.769	.465
	D	r	-.091	.146	-.053	-.064	-.047	.084
		p	.701	.539	.825	.789	.843	.726
	LDAE	r	.227	.076	.409	-.156	.373	.314
		p	.335	.750	.074	.512	.105	.178
	SAE	r	.078	.009	-.024	-.644	-.072	.370
		p	.743	.970	.920	.002*	.762	.108

AT: Accurate throwing, D:Dribbling, FT: Fast throwing, HF: High frequency, LDAE: Lying down after evaluation, LDBE: Lying down before evaluation, LF/HF: Low frequency/high frequency, LF: Low frequency, ms: Milliseconds, SAE: Standing after evaluation, SBE: Standing before evaluation, TP: Total power (HRV measurements were taken after the athletes rested for 15 minutes after the test). According to the correlation coefficient (r), the degree of association was interpreted as weak (0.00-0.29), low (0.30-0.49), moderate (0.50-0.69), strong (0.70-0.89) and very strong (0.90-1.00). The significance level was accepted as p*<0.05 for all analyses.

graphic and descriptive characteristics of the players are shown in Table 1.

The descriptive data of Vertical Jumping, Seated Chest Ball Throw, T Agility, Lower Extremity Y Balance, Upper Extremity Y Balance, Fast Throw, Accurate Throw, and Dribble Tests results are shown in Table 2.

The relationships between the tests evaluating the

Table 4. Relationships between Lower Extremity Y Balance Test, Upper Extremity Y Balance Test, Fast Throw Performance and HRV parameters

	Measuring Positions		Time Dependent Parameters		Frequency Dependent Parameters			
			RMSSD (ms)	SDNN (ms)	TP (ms²)	LF/HF	LF (ms²)	HF (ms²)
Lower Extremity Y Balance (%)	LDBE	r	.063	.089	-.035	.202	.150	-.018
		p	.791	.710	.885	.394	.527	.940
	SBE	r	.239	.195	.113	-.259	.072	.104
		p	.310	.409	.636	.271	.762	.663
	FT	r	-162	-.080	-.027	-.086	-.008	-.131
		p	.494	.738	.910	.719	.975	.582
	AT	r	.167	.111	.277	-.066	.328	.305
		p	.482	.640	.238	.782	.158	.191
	D	r	-.285	-.272	-.370	.183	-.347	-.331
		p	.223	.246	.108	.439	.133	.154
	LDAE	r	-.340	-.083	-.224	.248	-.200	-.292
		p	.143	.729	.342	.292	.398	.212
	SAE	r	.056	.033	.126	-.014	.120	-.005
		p	.816	.890	.596	.955	.613	.985
Upper Extremity Y Balance (%)	LDBE	r	.209	.095	.238	-.077	.188	.143
		p	.376	.691	.313	.748	.427	.548
	SBE	r	.385	.311	.111	-.209	-.051	.314
		p	.094	.182	.640	.376	.830	.177
	FT	r	.244	.159	.278	.212	.186	.206
		p	.301	.502	.235	.369	.431	.384
	AT	r	.174	.002	-.006	.074	.041	.132
		p	.462	.995	.980	.758	.865	.578
	D	r	.063	-.147	.003	.197	.000	-.158
		p	.791	.535	.990	.405	1.000	.506
	LDAE	r	-.189	-.050	-.320	.095	-.310	-.208
		p	.424	.835	.169	.691	.184	.380
	SAE	r	.192	.230	.236	.328	.272	-075
		p	.416	.329	.316	.158	.246	.753
Fast Throw Performance (point)	LDBE	r	-.397	-.372	-.313	.004	-.339	-.336
		p	.083	.106	.179	.987	.144	.148
	SBE	r	-.183	.002	.024	.427	.060	-.206
		p	.440	.995	.920	.061	.801	.383
	FT	r	-.242	.070	-.205	.346	-.121	-.313
		p	.303	.769	.387	.136	.611	.179
	AT	r	-.601	.177	-.041	.668	.161	-.357
		p	.005*	.456	.865	.001*	.497	.123
	D	r	-.059	.493	.289	.327	.294	.004
		p	.806	.027*	.216	.160	.208	.987
	LDAE	r	.007	-.096	.209	.105	.224	.008
		p	.977	.688	.378	.661	.343	.975
	SAE	r	.042	.005	.125	.005	.105	.257
		p	.860	.982	.600	.985	.661	.275

AT: Accurate throwing, D:Dribbling, FT: Fast throwing, HF: High frequency, LDAE:Lying down after evaluation, LDBE: Lying down before evaluation, LF/HF: Low frequency/high frequency, LF: Low frequency, ms: Milliseconds, SAE: Standing after evaluation, SBE: Standing before evaluation, TP: Total power (HRV measurements were taken after the athletes rested for 15 minutes after the test). According to the correlation coefficient (r), the degree of association was interpreted as weak (0.00-0.29), low (0.30-0.49), moderate (0.50-0.69), strong (0.70-0.89) and very strong (0.90-1.00). The significance level was accepted as p*<0.05 for all analyses.

sportive performance of the basketball players participating in the study and the parameters of HRV are presented in separate tables for each test.

Relationships between vertical jump test, Seated chest ball throw test, T Agility Test and HRV parameters

- Statistically significant relationships were found between vertical jump test and RMSSD, SDNN, TP, LF/HF ratio, LF and HF parameters in various directions and at different levels before and after the evaluation ($p<0.05$) (Table 3).
- Statistically significant relationships were found between the Seated Chest Ball Throw Test and RMSSD, SDNN, TP, LF/HF ratio, LF and HF param-

Table 5. Relationship between accurate throwing performance, dribbling performance and HRV parameters.

	Measuring Positions		Time Dependent Parameters		Frequency Dependent Parameters			
			RMSSD (ms)	SDNN (ms)	TP (ms²)	LF/HF	LF (ms²)	HF (ms²)
Accurate throwing (point)	LDBE	r	-.343	-.389	-.365	.476	-.092	-.384
		p	.139	.090	.114	.034*	.700	.094
	SBE	r	-.295	-.178	-.334	.235	-.266	-.398
		p	.206	.453	.150	.318	.257	.082
	FT	r	-.331	-.145	-.096	.341	-.186	-.155
		p	.154	.541	.686	.141	.432	.513
	AT	r	-.081	.012	.203	.065	.225	.094
		p	.733	.960	.391	.786	.341	.693
	D	r	-.164	.049	-.177	-.023	-.219	-.145
		p	.489	.838	.455	.925	.353	.543
	LDAE	r	-.180	.100	-.173	.475	-.047	-.282
		p	.447	.674	.465	.034*	.845	.229
	SAE	r	-.057	-.148	.081	.286	.087	-.127
		p	.810	.532	.735	.221	.716	.595
Dribbling performance (point)	LDBE	r	.075	.029	-.080	.083	.033	-.025
		p	.752	.902	.738	.728	.890	.917
	SBE	r	.234	.167	.019	-.325	.124	.258
		p	.320	.481	.937	.162	.601	.271
	FT	r	.028	.107	.208	.255	.187	.121
		p	.907	.653	.379	.277	.430	.613
	AT	r	-.019	-.048	.004	.023	-.003	.091
		p	.937	.840	.987	.922	.990	.702
	D	r	-.125	-.313	-.287	-.106	-.374	-.264
		p	.599	.179	.220	.658	.104	.261
	LDAE	r	-.462	-.127	-.525	.570	-.408	-.584
		p	.040*	.593	.017*	.009*	.074	.007*
	SAE	r	-.011	-.017	.067	.399	.084	-.152
		p	.965	.945	.779	.082	724	.522

AT: Accurate throwing, D:Dribbling, FT: Fast throwing, HF: High frequency, LDAE:Lying down after evaluation, LDBE: Lying down before evaluation, LF/HF: Low frequency/high frequency, LF: Low frequency, ms: Milliseconds, SAE: Standing after evaluation, SBE: Standing before evaluation, TP: Total power (HRV measurements were taken after the athletes rested for 15 minutes after the test). According to the correlation coefficient (r), the degree of association was interpreted as weak (0.00-0.29), low (0.30-0.49), moderate (0.50-0.69), strong (0.70-0.89) and very strong (0.90-1.00). The significance level was accepted as p*<0.05 for all analyses.

eters in differrent directions and levels before and after the evaluation ($p<0.05$) (Table 3).

• The relationships between T agility test and HRV parameters are shown in Table 3. According to these results, a moderate negative correlation was found for the frequency-dependent LF/HF parameter in the standing position after the evaluation and this relationship was statistically significant ($p<0.05$) (Table 3).

Relationships between Lower Extremity Y Balance Test, Upper Extremity Y Balance Test, Fast Throw Performance and HRV parameters

• The correlations between the Lower Extremity Y Balance Test and HRV parameters of the athletes are shown in Table 4. According to these results, no statistically significant correlation was found between these variables ($p>0.05$) (Table 4).

• The relationships between the Upper Extremity Y Balance Test and HRV parameters are shown in Table 4. According to these results, no statistically significant correlation was found between these variables ($p>0.05$) (Table 4).

• Statistically significant relationships were found between fast throw performance test and RMSSD, SDNN and LF/HF ratio parameters in different directions and levels ($p<0.05$). (Table 4).

Relationship between accurate throwing performance, dribbling performance and HRV parameters

• For the LF/HF parameter, statistically significant correlations were found in the pre-assessment lying position and in the lying down after evaluation ($p<0.05$) (Table 5).

• Statistically significant relationships were found between dribbling performance test and RMSSD, TP, LF/HF ratio and HF parameters in different directions and levels. ($p<0.05$) (Table 5).

DISCUSSION

This study aimed to examine the relationship between HRV parameters and sportive performances of basketball players, and we found various levels of relationships between some performance parameters and HRV parameters.

When studies in the literature in this field are examined, it is seen that the contexts for the relationship between physical performance, training status, muscle strength and cardiorespiratory fitness in athletes have been expanded (32, 33). Carrasco-Poyatos et al. followed the athletes' performance during the training period guided by HRV. The conclusion emphasized in this study was that training guidance designed to balance the autonomic nervous system may have a positive effect on athletes' athletic performance (32). In a study of 24 professional basketball players of the Spanish Basketball League, a significant correlation was found between HRV and respiratory threshold or anaerobic threshold. According to this study, when determining the respiratory threshold in basketball players, training loads can be evaluated in a practical and low-cost way with HRV. Therefore, it is emphasized that HRV will be an alternative method to assess respiratory threshold without laboratory technologies, which are difficult to use and quite expensive (33).

It has been suggested that during competition in the game of basketball, there is a decline in vertical jump performance as the athlete becomes fatigued, but this is not only a muscular response but also a response of the autonomic nervous system. At rest and during the inactive phases of the vertical jump, the main activity of the heart is controlled by the parasympathetic division of the autonomic nervous system. In addition, the activation of sympathetic activities increases during performance (31). In our study, there was a relationship between vertical jump and RMSSD, one of the time-dependent parameters, in all measurement positions, but the significance was only negative and low in the lying position after the evaluation. RMSSD is the main parameter used to monitor vagal-based changes observed in HRV, i.e., it appears as a reflection of the parasympathetic system (10). This may be explained by the fact that the RMSSD parameter mainly reflects vagal activity. Therefore, it can be accepted as a possible result that these parameters are related in the post-test recovery process. The result of this parameter in our study indicates, albeit weakly, that an increase in vertical jump performance is associated with a decrease in RMSSD. In other words, if the parasympathetic system effect decreases (which means that sympathetic system activity increases), vertical jump performance will be better. Negative moderate correlations were found between vertical jump performance and SDNN parameter during dribbling performance and negative moderate correlations were found in standing position after evaluation. SDNN is a general marker of autonomic nervous system activity, and its increase reflects general well-being (10). The fact that its increase reflects well-being may be interpreted as an increase in parasympathetic activation and the negative correlation may be an indication that sympathetic system activation is needed for vertical jump performance. We also found various correlations between the vertical jump performance of athletes and some of the frequency-dependent parameters, among which LF is known to reflect baroreflex activity, not cardiac sympathetic innervation in resting conditions (10). When respiration slows down, vagal activity can cause marked oscillations in heart rhythms that cross the LF band (34). Therefore, since the respiratory values of our athletes did not decrease dramatically in our study, we think that it would not be correct to comment only on LF. HF is considered to be an indicator of the parasympathetic nervous system because it is associated with HR affected by the respiratory cycle (34). It has been reported that the HF parameter correlates with parasympathetic activity and represents respiratory vagal activity (35, 36). The results of our study are consistent with the literature and show that vertical jump performance will increase in the decrease of HF parameter, that is, in the increase of sympathetic nervous system activity.

We found different levels of correlations with various parameters of HRV with the Seated Chest Ball Throw Test, which is used to evaluate the throwing skill, which is related to the concept of strength in the basketball game. Since lower RMSSD and SDNN values are generally indicators of good health (10), lower values of these parameters would improve the performance of the seated chest ball throw. The results of our study also indicate this. The LF/HF ratio is an indicator of sympatho-vagal balance and when a decrease in this ratio is accepted as a shift towards parasympathetic balance (8), as our results show, the positive relationship with the power parameter tested with the seated chest ball throw indicates that there should be sympathetic activity dominance for power increase.

It is advantageous to have good agility in movements such as fast offense, blocking, and throwing in basketball competition (20). In our results, a moderate negative correlation was found for the frequency-dependent LF/HF parameter in the standing position after the evaluation. According to this result, we can say that there is a relationship between the decrease in the time required for the agility test and the dominance of sympathetic activation. In a study investigating endurance training and HRV parameters in basketball players, it was shown that intermittent endurance training stimulated the vagus and decreased heart rate. This is related to increased parasympathetic activity (37).

We found statistically significant relationships between dribbling performance, one of the sub-domains of the Johnson Basketball Test Battery, and the parameters RMSSD, TP, LF/HF ratio and HF. Among these, the moderate negative relationship we found between the RMSSD parameter and LBDA during accurate shooting performance suggests that sympathetic system activation is necessary for fast shooting performance, since RMSSD is considered a reflection of the parasympathetic system, but our results do not support this idea (5). The low positive correlation we found for the SDNN parameter during dribbling performance suggests that SDNN should also increase for fast-throw performance, as SDNN is a general marker of autonomic nervous system activity and its increase reflects general well-being. However, the results obtained are not sufficiently powered to make such a generalization (5). The moderately significant positive correlations we found for the LF/HF parameter during accurate passing performance reflect that sympatho-vagal balance should also increase to increase fast throwing performance.

In summary, since these results may indicate that HRV may be related to various parameters of sportive performance and the addition of HRV to athlete assessments may be beneficial in terms of objective results, we suggest that HRV assessments should be measured at different periods throughout the season. In addition, the addition of HRV to the assessment phases of athletes may provide important information about autonomic control of training and recovery processes. However, it is thought that more detailed studies are needed in this field for clear information.

Compliance with Ethical Standards

Conflict of Interest: The authors declare that they have no conflict of interest.

Declaration of Generative AI and AIassisted technologies in the writing process: Generative AI and AIassisted technologies were not used in the writing of this article.

Submission declaration: This article has not been submitted to another journal for review.

Funding source: No funding sources were used in the production of this study.

Consent to participate: Informed consent was obtained from all individual participants included in the study.

Acknowledgments: Special thanks to volunteer basketball players who participated and consented to join this study. We would also like to thank Dr. Osman Topaç for the academic language translation of this article.

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