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The Effect of High Interval Intensity Training (HIIT) on the Performance of Basketball Players 10-15 Years Old

El efecto del entrenamiento de alta intensidad en intervalos (HIIT) sobre el rendimiento de jugadores de baloncesto de 10 a 15 años

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Abstract. Basketball is a game of seconds. A characteristic of this sport is the high intensity, the pressure of one or more different opponents, and very short recovery times. From a physiological-biomechanical point of view, basketball is classified among the sports activities with alternating aerobic-anaerobic energy commitment, with district demands of medium to high strength and endurance. Based on the High Interval Intensity Training Program (HIIT), in 8 weeks in a group of children aged 10-15, taking into account the efficiency of time, we look up to help the athletic youth progress, offering the improvement of other important skills, such as coordination skills, speed, and performance. This study aims to identify the biomechanical variables that directly affect their progress. In this study participated 15 subjects (age: 12.53 ± 2.09; height: 1.59 ± 0.10; body mass: 49.82 ± 16.78; BMI: 19.21 ± 3.98), basketball players of the basketball team "Sonia Basket." To achieve this aim, the CMJ (countermovement jump) and SJ (squat jump) vertical jump tests were performed on the force platform. The evaluation of the data was made using statistical analysis processing methods. The independent t-test results revealed a statistical improvement of 3 cm in the maximum height in the CMJ test and 90N in the maximum force in the SJ test due to the method called "HIIT." The results of this study of the HIIT method show a positive physical and physiological development of the players in such a way as to offer them the opportunity to express the highest level of performance in the game of basketball. If this training method is used for an even longer time, the results will be many times higher and will affect even more the improvements of all biomechanical parameters.
Keywords: "HIIT" training**,** countermovement jump (CMJ), squat jump (SJ), biomechanical variables, coordination skills, speed performance.

Resumen. El baloncesto es un juego de segundos. Una característica de este deporte es la alta intensidad, la presión de uno o más oponentes diferentes y tiempos de recuperación muy cortos. Desde el punto de vista fisiológico-biomecánico, el baloncesto se clasifica entre las actividades deportivas con compromiso energético alternante aeróbico-anaeróbico, con exigencias distritales de fuerza y resistencia medias a altas. Basado en el Programa de Entrenamiento de Alta Intensidad Interválica (HIIT), en 8 semanas en un grupo de niños de 10 a 15 años, teniendo en cuenta la eficiencia del tiempo, buscamos ayudar a los jóvenes deportistas a progresar, ofreciendo la mejora de otras habilidades importantes, como habilidades de coordinación, velocidad y rendimiento. Este estudio pretende identificar las variables biomecánicas que inciden directamente en su evolución. En este estudio participaron 15 sujetos (edad: 12,53 ± 2,09; altura: 1,59 ± 0,10; masa corporal: 49,82 ± 16,78; IMC: 19,21 ± 3,98), jugadores de baloncesto del equipo de baloncesto "Sonia Basket". Para lograr este objetivo, se realizaron las pruebas de salto vertical CMJ (salto con contramovimiento) y SJ (salto en cuclillas) sobre la plataforma de fuerza. La evaluación de los datos se realizó mediante métodos de procesamiento de análisis estadístico. Los resultados de la prueba t independiente revelaron una mejora estadística de 3 cm en la altura máxima en la prueba CMJ y de 90 N en la fuerza máxima en la prueba SJ debido al método denominado "HIIT". Los resultados de este estudio del método HIIT muestran un desarrollo físico y fisiológico positivo de los jugadores de tal manera que les ofrece la oportunidad de expresar el más alto nivel de rendimiento en el juego de baloncesto. Si este método de entrenamiento se utiliza durante un tiempo aún más prolongado, los resultados serán muchas veces mayores y afectarán aún más a la mejora de todos los parámetros biomecánicos.
Palabras clave: entrenamiento "HIIT", salto con contramovimiento (CMJ), salto en cuclillas (SJ), variables biomecánicas, habilidades de coordinación, rendimiento de velocidad.

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Introduction

Sport is a physical activity that is easily carried out by various groups (Sudirman et al., 2024). The physical qualities required for performance are related to tasks inherent to the sport, such as acceleration, deceleration, speed of change direction, repeated sprints, agility, and dribbling (Gualter Santana et al., 2024). Good physical and technical ability will have a positive impact on the course of strategy and tactics used in a match (Liskustyawati et al., 2024). Basketball is a team sport that requires a high level of anaerobic and aerobic skills (Scalan et al., 2012; Aschendorf et al., 2019). When basketball is practiced with minors, the educational component cannot be ignored, regardless of the tactical and technical skills that characterize it (Suárez Manzano et al., 2022). Exercise with an intensity close to maximal oxygen consumption (VO_2 max) represents the best stimulus to develop aerobic capacity (Delextrat & Martinez, 2014).

Vigorous physical activity has been found to potentially lead to exercise-induced muscle damage (Anugrah et al., 2024). Playing basketball on different surfaces throughout the season may increase the number of injuries (Toro Román et al., 2020). The most accurate training method is to perform high-intensity interval training (HIIT) (Billat, 2001) to modify some physiological characteristics in players (Falcone et al., 2019). Therefore, the study of a specific training method, such as low volume, high-intensity training, and its effectiveness has practical significance for improving health and preventing diseases

(Nurmukhanbetova et al., 2023). HIIT has gained popularity globally, ranking as the third most prevalent exercise trend worldwide (Vigriawan et al., 2024). HIIT is characterized by high exercise intensity with shorter duration (Fuentes-Barría et al., 2024).

High-Intensity Interval Training (HIIT) is a sustainable and effective method that can provide rapid development for cardio-respiratory fitness (CRF) levels (Kul et al., 2022) and also improve it in adolescents, which is proven to produce equal or greater improvements in CRF, when compared to other training exercises in adolescents (Martin-Smith et al., 2020). High-intensity interval training (HIIT) may be a feasible and efficacious strategy for improving health-related fitness in young people (Costigan et al., 2015). It also consists of changing heart rate through a continuous transition from medium to high frequencies and vice versa during the same exercise (Altınkök, 2015). This type of recovery favors high-intensity anaerobic performance because it allows the disposal of some of the accumulated lactate. It is a form of mixed cardiovascular training compared to the more popular moderate-intensity aerobic training, with constant heart rate, and steady-state training (SST)12 (D'Elia et al., 2021). High-intensity interval training (HIIT) has emerged as a time-efficient strategy to improve children's and adolescents' health-related fitness in comparison to traditional training methods (Leahy et al., 2020).

One of the most interesting aspects is that high-intensity interval training can produce the same physiological benefits as steady-state training, even if the session duration is more than half as short. Recent systematic reviews and meta-analyses of adolescent HIIT reviewed the effects of HIIT on CRF in comparison to control groups in normal weight, overweight, and obese adolescents (Delgado-Floody et al., 2019; Cao et al., 2019; Martin-Smith et al., 2020; Denga & Wang., 2024). Some studies have shown the positive impact of high-intensity interval training on the aerobic performance of team sports athletes. (Delextrat et al. 2018) found a similar increase in maximal aerobic performance among adolescent basketball players after adding 12 HIIT sessions to in-season training. The study by (Eather et al. 2020) showed significant improvements in aerobic performance after implementing specific high-intensity training with different direction changes in basketball players. The impact of the "HIIT" program on the aerobic performance and physical capacities of basketball players. In team sports, basketball is composed of open skills aimed at modifying the execution of the technique according to the environmental conditions (Mejia et al., 2021).

The basketball player must possess special physical qualities for the effective development of the game. Characteristic of this sport is the continuous repetition of such efforts under the pressure of one or more opponents and with a very short recovery time (Stoll et al., 2008). Dribbling requires good agility and support from elements of good physical condition to provide the ability to move faster (Liskustyawati et al., 2024). Taking this information into consideration, the coach's primary goal in planning and periodizing workouts, including intensity, load, volume, density, and frequency (Sanabria Navarro et al., 2024), should be to get his players in peak athletic shape. "Peak point" represents the synthesis, at the highest level, of the motor, energetic, technical, and psychological potentials that an athlete can achieve based on his initial level (D'Elia et al., 2020). According to Bompa & Haff (2009), peak conditioning is essential for achieving optimal athletic performance.

The physical demands of different sports vary significantly. Actions of short duration and maximal effort, such as sprinting, characterized by being strength-power actions, are decisive in different team sports, including basketball (León Muñoz et al., 2024). The combination of strength and resistance training during the same session, on the same day, or even on alternate days is well-known as current training (Gómez & Merellano, 2024). When strength training was combined with aerobic activities, significant increases in muscle strength, CRF capacity, and flexibility were observed (Le-Cerf Paredes et al., 2022). Therefore, the athlete who wants to specialize or excel in a single sport must follow a sport-specific exercise program. This study aims to identify biomechanical variables influencing the performance of basketball players through the application of a high-interval intensity training program.

Materials and Methods

Participants

Subjects participating in the study are in the age group of 10-15 years, through the application of tests performed on the strength platform. The measurements of this study were carried out in the biomechanics laboratory at the Sports University of Tirana with the children's basketball team of the private sports club "Sonia Basket." Figure 1 shows the stages during different high-intensity training in small age groups. The study was approved and provided by the Ethics Committee of the Sports University of Tirana. Approval was obtained from the subjects' parents to consider them as study participants.

Instrument and testing protocol

The study was performed in the Biomechanics Laboratory of the Sports University of Tirana, and all data were recorded in its licensed equipment. The main apparatus utilized for this study was force plate Leonardo Mechanography (GRF), version 2011. Standard jump testing protocol was used for data collection in two different forms: the CMJ test (counter-movement jump), the maximum height test, performed with arm movement, and the SJ test (squat jump), a test for maximum strength, jumping without the help of arms. When CMJ is compared to SJ, results have shown that the average jump height is greater than 10% when arms are used, based on several reported studies (Acero et al., 2012; Harmman et al., 1990).

Figure 1. Different high-intensity exercises in small age groups.

Procedure measurements on the force platform

Initially, the anthropometric parameters of the subjects were measured (before the test), and the body height parameter was measured using a graduated ruler. The mass was recorded automatically by the Leonardo software, and the body mass index (BMI) was calculated. Measurements were performed in three phases: The first phase is the preliminary measurements on the strength platform in the CMJ and SJ tests. The second phase is the training phase. The third phase, the final measurements, after the completion of the 8-week training phase.

Testing subjects

Subjects were tested in 2 forms: Two vertical jump tests: The first test was CMJ (countermovement jump)—a test for maximum height with the help of arms. The second test, SJ (squat jump), is the test for maximum strength without the help of arms placed at the waist. Figure 2 shows the illustration of the subject performing the first CMJ vertical jump test, while Figure 3 shows the subject performing the second SJ vertical jump test.

Figure 2. Illustration of the subject performing the first CMJ vertical jump test.

Figure 3. Illustration of the subject performing the second SJ vertical jump test.

Study period

The study period includes two phases: The first phase (initial): taking measurements before starting training. The second phase (final): taking measurements 8 weeks after the start of training. The children's basketball team "Sonia Basket" performed 2 measurements, from which the average value of the parameters recorded for each of the two training phases was obtained. The study period for this team includes both of the above 8-week phases.

Training methodology

The children's basketball team "Sonia Basket" has been training, applying loads and different training tools for the development of (strength, speed, stability, coordination, etc.), but including them with the new "HIIT" method. Training with the "HIIT" method was performed in an active children's basketball team for 60 minutes, 3 days/week for 8 weeks. The training phases included two different types of HIIT sessions, with a total training time of 25 minutes (15–16 minutes load, 9–10 minutes rest). Session (A) consisted of 4 × 4 min high-intensity intervals with 3 min recovery.

Session (B) consisted of 15 × 30 s high-intensity intervals with 15 s recovery between repetitions and 3 min recovery between sets. To perform HIIT at 90–95% of maximum heart rate (HR max), the workouts were designed to keep each player moving with no recovery time during the interval (Aschendorf et al., 2019). All training sessions where the "HIIT" method is used are designed to include various high-intensity basketball exercises that contain basic skills, such as dribbling, passing, shooting, exercises with a change of direction, etc. During sports training, it is aimed at creating a new concept of training related to the application of exercises with short intervals but with high intensity.

Biomechanical parameters

The Leonardo Mechanography program is based on the results of the analysis of the following parameters for both two jump tests (CMJ and SJ): Vmax: maximum speed of COG in z-axis direction (up & down, in m/s); H_{max}: maximum COG displacement height during vertical jump, variation of COG height relative to starting point (in m);

Fmax: full force; left, right along z-axis (kN); P_{max}: full power, left, right, M/D difference, (kW); $Ft_{ot.rel}$: total force per body weight (F_{max}/Fg ratio, unitless) exerted at the center of mass; P_{max}/kg: Maximum power (peak anaerobic power) per body mass (P_{max}/mbody ratio, unit W/kg); Energy: The kinetic and potential energy of the center of gravity (COG); Duration: Total test duration, time per iteration, t_1 to t_2, flight time, ground contact time, takeoff time (for repeated movements including standard deviation); EFI: shows the performance that is expressed by the maximum power produced during the jump phase in relation to the subject's body mass in relation to an optimal reference group of the same age and sex. A value of 100% equals the mean of the reference group, and movement efficiency is the relationship between peak force and peak power of the specific movement (normalized by mass, age, and sex).

Statistical Analysis

To calculate the subjects' data, descriptive statistics were used in terms of the number of subjects (n), average value, standard deviation SD, coefficient of variation CV, and range (min-max) for anthropometric sizes as well as biomechanical parameters of the two tests. Statistical analysis was performed using the statistical program SPSS, version 26. In this study, this type of statistical analysis was applied to the recorded biomechanical parameters: analysis by t-test, for the differences that exist between 1 or 2 measurements of the same parameter for each test as well as their statistical and practical significance. Statistical significance was set for all statistical procedures at $p \leq 0.05$.

Results

The analysis of the independent t-test applied to the "Sonia Basket" basketball team, through the comparison of the averages of the same parameter measured in two different training phases, highlights the differences that exist between them in the jump tests and the importance of their statistical and practical. Table 1 gives the descriptive statistics of the anthropometric parameters of this team. The children who are part of this team (n = 15) are in the age group of 10-15 years, with an average age of (12.53 ± 2.09) years. Their anthropometric characteristics are height (1.59 ± 0.10) m, body mass (49.82 ± 16.78) kg, and body mass index (BMI) (19.21 ± 3.98) kg/m².

Table 1.
Descriptive statistics of anthropometric parameters of CMJ – SJ.

Measurements		Variable	Mean ±SD	Range	Min. value	Max. value	Variance
Anthropometric Variables		Age	12.53 ± 2.09	7.00	9.00	16.00	4.41
		Height (m)	1.59 ± 0.10	0.34	1.45	1.79	0.01
		Weight (kg)	49.82 ± 16.78	54.4	32.5	86.9	281.65
		BMI (kg/m²)	19.21 ± 3.98	13.24	14.86	28.1	15.84
CMJ test	Phase I	H_{1max} (m)	0.36 ± 0.07	0.26	0.26	0.52	0.005
	Phase II	H_{2max} (m)	0.39 ± 0.06	0.24	0.31	0.55	0.004
SJ test	Phase I	F_{1max} (kN)	1.20 ± 0.37	1.12	0.77	1.89	0.138
	Phase II	F_{2max} (kN)	1.29 ± 0.37	1.07	0.88	1.95	0.141

Table 1 also generates descriptive statistics for the variables obtained during the two measurements of the CMJ and SJ tests. The results obtained from these measurements are used to describe their characteristics. The CMJ test is the maximum height (Hmax) test, and the second SJ is the maximum force (Fmax) test with variables obtained in two different phases of the HIIT training program. The results obtained from the measurements are used to describe the characteristics of Hmax and Fmax in both jump tests. Table 2 generates the descriptive statistics for the variables obtained during the two measurements of the first jump test. The results of these measurements were used to describe the characteristics of the jumps in the first CMJ test.

Table 2.
Descriptive statistics for the two measures of the first CMJ test.

Measurements	Parameters	Mean ±SD	Range	Min. value	Max. value	Variance
Phase I	H_{1max}	0.36 ± 0.07	0.26	0.26	0.52	0.005
	V_{1max}	2.28 ± 0.24	0.80	1.93	2.73	0.520
	F_{1max}	1.22 ± 0.40	1.38	0.76	2.14	0.152
	P_{1max}	2.16 ± 0.84	2.95	1.12	4.07	0.709
	$F_{1.tot.rel}$	2.52 ± 0.28	1.12	1.96	3.08	0.083
	P_{1max}/kg	43.25 ± 7.78	30.87	29.89	60.76	60.469
	$E.F.I._1$	1.01 ± 0.15	0.60	0.66	1.26	0.020
	$Efficency_1$	0.96 ± 0.88	0.34	0.80	1.14	0.008
Phase II	H_{2max}	0.40 ± 0.06	0.24	0.31	0.55	0.004
	V_{2max}	2.35 ± 0.20	0.73	2.02	2.75	0.040
	F_{2max}	1.33 ± 0.40	1.45	0.83	2.28	0.164
	P_{2max}	2.30 ± 0.84	2.98	1.21	4.19	0.709
	$F_{2.tot.rel}$	2.83 ± 0.41	1.72	2.15	3.87	0.166
	P_{2max}/kg	47.68 ± 8.27	32.50	67.81	67.81	68.289
	$E.F.I._2$	1.10 ± 0.16	0.65	0.70	1.35	0.030
	$Efficency_2$	1.10 ± 0.12	0.37	0.91	1.28	0.015

According to the t-test, t (degrees of freedom) is represented by the t-value and the p-value gives the level of statistical significance. For a difference to be considered statistically significant, the level of statistical significance must be less than 5% ($p<0.050$). The statistic comparing pairs of parameters in the t-test analysis gives their mean values for each test.

Results for the first CMJ test

The first CMJ test is the maximum height test (H_{max}), with variables obtained during two different training phases. Because of the main parameter H_{max}, all other jump parameters were studied. Table 3. Gives the results of the t-test (paired t-test). This information relates to the differences between the 2 jump measurements, based on the mean values of the biomechanical parameter measurements in the first CMJ test, and whether these differences are statistically and practically significant. To evaluate H_{max}, several measurements were performed, comparing the average values between pairs of jump variables, based on which values are reported as follows: The main variable of the first CMJ test: maximum vertical jump height (H_{max}). The results obtained from Table 2 for H_{1max} (0.36 ± 0.07) and H_{2max} (0.40 ± 0.06) indicate an improvement in average by (-0.03 ± 0.01), calculated by 10.0%. From Table 3, it is observed that the t-statistical

values are respectively: t (14) = -9.388; p = 0.000 < 0.005, which confirms the statistical significance of these differences.

Table 3.
Pairwise comparisons of the same parameters within the first CMJ test.

Variable	Variable pairs	Mean Differences ±SD	95% CI		t-test value	p-value
			Lower boundary	Upper boundary		
H_{max}	H1- H2	-0.03 ± 0.01	-0.04	-0.02	-9.388	0.000
V_{max}	V1 – V2	-0.15 ± 0.05	-0.18	-0.12	-11.109	0.000
F_{max}	F1 – F2	-0.11 ± 0.04	-0.13	-0.09	-11.303	0.000
P_{max}	P1 – P2	-0.13 ± 0.08	-0.18	-0.09	-6.391	0.000
$F_{.tot.rel}$	F1tot-F2tot	-0.31 ± 1.74	-0.47	-0.16	-4.352	0.001
P_{max}/kg	P1rel.-P2rel.	-4.42 ± 1.75	-5.39	-3.46	-9.834	0.000
E.F.I	EFI.1-EFI.2	-0.08 ± 0.03	-0.10	-0.06	-9.403	0.000
Effcency	Efic.1-Efic.2	-0.13 ± 0.07	-0.17	-0.10	-7.449	0.000

Results for the second SJ test

The second SJ test is the maximum strength test (Fmax), with variables obtained during three different training phases. Because of the main parameter Fmax, all other jump parameters were studied. Table 4 generates the descriptive statistics for the variables obtained during the two measurements of the second jump test. The results obtained from these three measurements were used to describe the characteristics of the first and second jumps of the second SJ test.

Table 4.
Descriptive statistics for the two measures of the second SJ test.

Measurements	Variable	Mean ±SD	Range	Min. value	Max. value	Variance
Phase I	F_{1max}	1.20 ± 0.37	1.12	0.77	1.89	0.138
	V_{1max}	2.11 ± 0.18	0.67	1.80	2.47	0.032
	H_{1max}	0.29 ± 0.04	0.16	0.23	0.39	0.002
	P_{1max}	1.91 ± 0.68	2.28	1.1	3.38	0.471
	$F_{1.tot.rel}$	2.50 ± 0.36	1.15	1.89	3.04	0.129
	P_{1max}/kg	38.42 ± 5.90	21.62	28.56	50.18	34.726
	$E.F.I._1$	0.90 ± 0.14	0.57	0.63	1.20	0.020
	$Efficency_1$	0.87 ± 0.11	0.39	0.69	1.08	0.012
Phase II	F_{2max}	1.29 ± 0.37	1.07	0.88	1.95	0.141
	V_{2max}	2.16 ± 0.15	0.52	1.98	2.50	0.024
	H_{2max}	0.33	0.16	0.26	0.42	0.003
	P_{2max}	2.01 ± 0.69	2.32	1.17	3.49	0.475
	$F_{2.tot.rel}$	2.87 ± 0.37	1.19	2.13	3.32	0.143
	P_{2max}/kg	40.00 ± 5.36	20.75	30.12	50.87	28.742
	$E.F.I._2$	0.95 ± 0.13	0.57	0.66	1.23	0.019
	$Efficency_2$	1.03 ± 0.12	0.39	0.81	1.20	0.015

Table 5 gives the results of the t-test. This information relates to the differences between the two jump measurements based on the mean values of the biomechanical parameter measurements in the second SJ test and whether these differences are statistically and practically significant. The main variable of the second SJ test is the maximum vertical jump force (F_{max}). Evaluation of the results obtained from Table 4 for F_{1max} (1.20 ± 0.37) and F_{2max} (1.29 ± 0.37) has yielded an improvement in the average by (-0.09 ± 0.07), calculated by 6.98%. The statistical values of the t-test according to Table 5 are respectively: t (14) = - 4.886; p = 0.000 < 0.005, which confirm that these results are statistically significant.

Table 5.
Pairwise t-test comparisons for variables in SJ tests.

Variable	Variable pairs	Mean differences ±SD	95% CI		t-test value	p-value
			Lower boundary	Upper boundary		
F_{max}	F_1- F_2	-0.09 ± 0.07	-0.13	-0.05	-4.886	0.000
V_{max}	$V_1 – V_2$	-0.51 ± 0.04	-0.08	-0.03	-4.297	0.000
H_{max}	$H_1 – H_2$	-0.03 ± 0.005	-0.04	-0.03	-21.313	0.000
P_{max}	$P_1 – P_2$	-0.10 ± 0.07	-0.14	-0.06	-5.682	0.000
$F_{.tot.rel}$	F_{1tot}-F_{2tot}	-0.39 ± 0.13	-0.45	-0.31	-11.199	0.001
P_{max}/kg	$P_{1rel.}$-$P_{2rel.}$	-1.56 ± 1.43	-2.36	-0.77	-4.236	0.000
E.F.I	$EFI._1$-$EFI._2$	-0.04 ± 0.02	-0.06	-0.03	-7.014	0.000
Effcency	$Efic._1$-$Efic._2$	-0.16 ± 0.04	-0.18	-0.14	-15.236	0.000

The graph in Figure 4 shows the dependence of the variable H_{max} as a time (s) function for the two measures of the CMJ test, while the graph in Figure 5 gives the dependence of the other variable F_{max} in function of times (s) for the SJ test for all the basketball players of the "Sonia Basket" team.

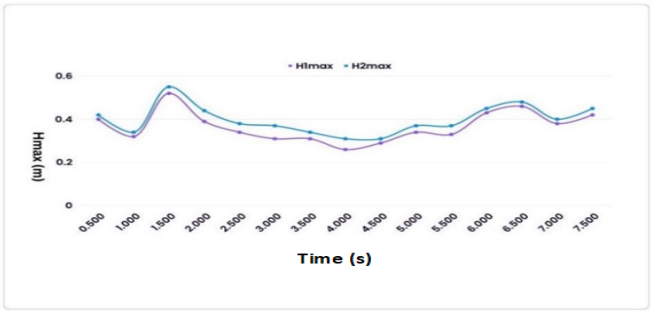

Figure 4. The graph of the dependence of H_{max} values on the time of the test for all subjects of the basketball team "Sonia Basket" for the two measurements of the CMJ test.

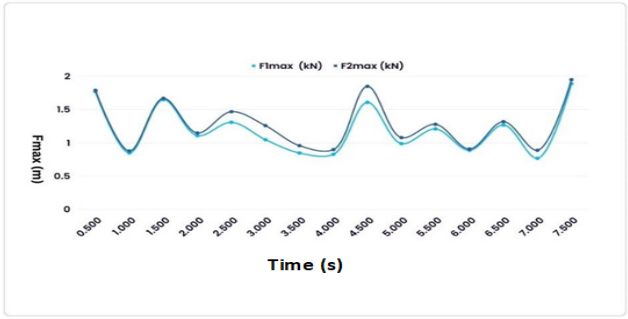

Figure 5. The graph of the dependence of F_{max} values on the test time for all subjects of the basketball team "Sonia Basket" for the two measurements of the SJ test.

Discussion

Based on the average values of the two CMJ jump measurements in the first test as well as the values reported by the t-test, we conclude that there is a significant improvement in vertical jump height (H_{max}) following the "HIIT" training method. In this case, the "HIIT" exercise had a positive effect on the improvement of the result, on average by 0.03 m, or 3 cm. Of course, if we take the results of each subject, we can get a difference of means of pairs with different results by 0.03 m. This is why it is important to look at the 95% CI of the confidence interval (or significance level). If we run this experiment 100 times, then 95% of the true value for the difference will lie within the 95% CI. In this case, as seen in Table 3, the 95% CI is

from -0.04 m to - 0.02 m. This shows that although the difference is statistically significant, it will be considered if this result is also practically significant. In the case of this team, there is a satisfactory improvement in the value of 0.03 m not only statistically but also practically. Evaluation of the mean values of the two measurements of the SJ jump in the second test (table 4) as well as the results of the t-test (table 5) prove that there is a significant improvement in the maximum explosive force during the second test of the SJ jump as a result of the training program with the "HIIT" method. In this case, the HIIT exercise improves the result, on average, by 0.09 kN, or 90 N. The confidence interval for the F_{max} parameter extends to the limits from -0.13 to 0.05 m. The results show that an improvement of 0.09 kN is not only statistically but also practically significant. The results of this study are in line with the previous study, which reported that proprioceptive training influences the improvement of parameter results, H_{max} with an improvement of 7 cm and F_{max} with an improvement of 320 N in both CMJ and SJ tests. Therefore, combined general and specific proprioception training is effective as power training for improving maximal jump height and maximal output vertical jumping tests, resulting in the jumping technique strongly affecting the mechanical output muscles and, as a consequence, the performance improvement (Bendo & Mara, 2020b).

Another study has revealed that the application of the equations of regression in CMJ and SJ tests on a football team emerged these biomechanical parameters as the best predictor of the main variables for each test: for H_{max} in the CMJ test: Vmax and body mass; and for F_{max} in the SJ test: body mass and P_{max}/kg (Bendo & Mara, 2020a). Many studies have focused on the effect that the change in intensity can be made during interval training, suggesting that HIIT is an effective method to improve CRF fitness, regardless of the body composition (Martin-Smith et al., 2020; Costigan et al., 2015). A meta-analysis review conducted by Cao et al. (2019) has indicated that HIIT is a better training methodology for improving cardiorespiratory fitness among healthy children and adolescents compared to moderate-intensity continuous training (MICT) and considering its characteristics of effectiveness and efficiency. HIIT may be an effective approach to achieve improvements in CRF among healthy children and adolescents and also as an alternative to MICT with promising results in the rehabilitation of patients with chronic heart failure with reduced ejection fraction (Collados & Gutiérrez, 2023).

Another meta-regression analysis identified that prolonged high-volume HIIT programs are similarly effective to short-term low-volume HIIT programs, becoming of particular interest for those involved in school curricula, where short HIIT exercise may provide a pragmatic adjunct to the health benefits of Physical Education (PE) lessons (Martin-Smith et al., 2020). The HIIT programs showed improvements in the variables studied, with interventions 2-3 times weekly, so they can be used in schools as a strategy to combat the childhood obesity pandemic, and HIIT can be used alongside existing PE activities within the same lesson or in specific periods during day school (Delgado-Floody et al., 2019).

Another recent study has suggested that engaging adolescents in resistance or combined training is essential to the maintenance and/or improving muscular fitness (power, strength, and endurance) because these positive results have been inversely associated with clustered cardiometabolic risk, adiposity, and positive association with bone health and self-esteem in adolescents (Mendonça et al., 2022). A previous review has suggested that participation in HIIT can improve cognitive function and mental health in children and adolescents (Leahy et al., 2020).

The results of this study are also consistent with those of other investigations. The studies have shown that endurance training and HIT both elicit large improvements in the VO2 max of healthy, young to middle-aged adults, with the gains in VO_2 max being greater (Dávila Grisalez et al., 2021), following HIT when compared with endurance training (Milanović et al., 2015). The results of the analysis show that players with high concentration ability are better than players who have low concentration ability in the accuracy of free throws in basketball players (Ramadhan et al., 2024).

The results clearly show a significant improvement in H_{max} after HIIT training. This training has improved results by an average of 0.03 m (or 3 cm). As a result, there is a statistically significant difference between the means of the two measurements, which is statistically and practically significant and valuable for this team. Also, our results show a significant improvement in F_{max}, where after training with the "HIIT" method, it has increased in average values by 0.09 kN (or 90N). These results show a statistically significant difference between the means of the two measurements, which is also statistically and practically significant and valid for this team.

Conclusions

The results obtained from this study have shown that an 8-week training micro-cycle based on the principles of the high-intensity interval training method can positively increase the performance indicators of our players. The HIIT program that responds to the physical needs of basketball has an impact on the improvement of the biomechanical variables and physical skills of the players. In this way, the players are offered an opportunity to express the highest level of performance in the game of basketball. However, it should be taken into account that this study is associated with some limitations. The first is related to a small number of participants in the study, and the second is to the available period. Despite the limitations, the results showed a significant improvement, which suggests that over a longer period with this training method, the expectations will be even higher.

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Conflict of Interest

The author declares no conflicts of interest.

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Author Contributions

The authors were responsible for the conception and design of the study. A.B., S.B. and D.S. were responsible for literature reviewing. E.P. was responsible for analysis and interpretation of the data. A.B. and E.P. were responsible for drafting the manuscript. F.B. and M.B. were responsible for critical revision of the article for important intellectual content; A.B. was responsible for final approval of the manuscript. F.B. was also the translator of the study. All the authors have contributed equally.

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