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EFFECTS OF BASKETBALL-SPECIFIC HIGH-INTENSITY INTERVAL TRAINING ON AEROBIC CAPACITY IN ADOLESCENT FEMALE BASKETBALL PLAYERS

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ABSTRACT. Introduction: Basketball-specific high-intensity interval training (HIIT) has been documented to be a time-efficient, skill focused training method for enhancing the aerobic performance. The aim of this study was to investigate the effects of basketball-specific HIIT on aerobic capacity in adolescent female basketball players. **Materials and methods:** Participants were 16 female basketball players, aged 13-15 years. They were equally and randomly divided into two groups: a control group and an experimental group. The subjects from the experimental group performed a basketball-specific HIIT protocol for 6 weeks (2 times per week, 25 minutes per session), before the basketball training. The control group followed a basketball training program for the same period, with the same frequency (2 times a week, 90 minutes per session). Pre- and post-intervention, the multi-stage fitness (beep) test was used to assess aerobic endurance. **Results:** After 12 training sessions, the experimental group showed a significant increase in test scores (p = .002, with a mean difference of 1.263). When compared to the control group, post-intervention, the experimental group showed significantly higher test scores

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(p < .001, with a mean difference of 1.69). The findings suggest that aerobic endurance increases in adolescent basketball athletes after 6 weeks of training. **Conclusion:** Basketball-specific HIIT appears to be a solid option for improving aerobic performance in adolescent female players while maintaining focus on basketball skills.

Keywords: *basketball drills, aerobic performance, multi-stage fitness test, adolescent females*

INTRODUCTION

Basketball is a court-based team sport requiring players to exert high-intensity effort interspersed with low- to moderate-intensity effort (Stojanović et al., 2018). Characterized by frequent changes in movements due to repeated transitions between offence and defence, the basketball game is physically demanding to the extent that both aerobic and anaerobic energy systems are used during matches (García et al., 2020; Stojanović et al., 2018). Throughout a match, basketball players must jump, sprint, accelerate, decelerate, and change directions, activities which emphasize the need to achieve a physical fitness level that allows them to perform maximal efforts (García et al., 2020; Heishman et al., 2020; Hernández et al., 2018; Stojanović et al., 2018).

Aerobic endurance, along with other key physical fitness components, is essential for athletes' ability to execute basketball skills and enhance their overall gameplay (Aschendorf et al., 2019). In young elite basketball players, physical match performance (i.e., distance travelled in high-intensity shuffle) and aerobic capacity (i.e., VO_{2max}) were proved to be correlated (Aschendorf et al., 2019; Ben Abdelkrim et al., 2007; Narazaki et al., 2009). Overall, a higher level of aerobic performance enhances the athlete's capacity to frequently carry out high-intensity actions during a basketball game and to recover from high-intensity effort (Aschendorf et al., 2019).

Proved to positively affect both the metabolic and cardiovascular functions of athletes, high-intensity interval training (HIIT) is defined as a training method that alternates bouts of strenuous exercise with recovery periods (Deak & Boros-Balint, 2017; Stankovic et al., 2023). When compared to alternative training programs, HIIT was found to improve to a greater degree the aerobic and anaerobic capacity of young athletes (Engel et al., 2018). A systematic review and meta-analysis reported that running-based HIIT had significantly better benefits on soccer players' sprinting time than small-sided games (Clemente et al., 2021). Regarding the improvement of endurance

performance and VO_{2max} in male and female youth and adult soccer players, the findings of Clemente et al. (2023) suggest similar effects generated by both running-based HIIT and small-sided games. Comparable results were reported by Delextrat et al. (2018) in elite junior basketball players. Similarly enhanced aerobic fitness, anaerobic capacity and muscle oxygenation during repeated sprint were observed after 6 weeks of different training interventions (i.e., HIIT and small-sided games, respectively) (Delextrat et al., 2018). A recent study evaluated the effectiveness of HIIT on the aerobic capacity and sport-specific skills in basketball players. After 5 weeks (10 sessions) of HIIT, significant increases were reported in VO_{2max}, control dribble, passing skills, lower body power and shooting skills in the experimental group (Kumari et al., 2023).

Although there is solid evidence regarding the benefits of HIIT on the physical performance of male team sport athletes, there are insufficient results to conclude about the effects of HIIT in female team sport athletes (Stankovic et al., 2023). The existing studies indicate that HIIT had a significant positive effect on VO_{2max}, repeated sprint ability, change of direction speed, speed, and explosive strength of the lower limbs in female athletes who are involved in team sports, regardless of the training level or competitive experience (Stankovic et al., 2023). 5 weeks (2 training sessions per week) of basketball-specific HIIT, with short and long intervals, were sufficient to increase the aerobic performance in youth female basketball players with no adverse effects on power-related performances (Aschendorf et al., 2019). After 6 weeks (2 training sessions per week) of HIIT, the aerobic performance of regional-level U19 female basketball players improved in both experimental groups (i.e., cardiopulmonary-based HIIT and neuromuscular-based HIIT, respectively) (Rodríguez-Fernández et al., 2023).

The aim of this study was to investigate the effects of basketball-specific HIIT on aerobic capacity in adolescent female basketball players. We hypothesized that 6 weeks (2 training sessions per week) of HIIT using basketball-specific drills would generate positive effects on aerobic performance in young female basketball athletes.

MATERIALS AND METHODS

Subjects

The study included 16 female basketball players aged 13-15 years. All participants were actively competing in the Romanian National Championship for their age category. The subjects were randomly divided into two groups: the experimental group (EG, $n = 8$) and the control group (CG, $n = 8$).

The mean height of the experimental group was 164.48 cm (*SD* = 3.02), while the control group had a slightly greater mean height of 169.09 cm (*SD* = 5.33).

In terms of weight, the experimental group had a mean of 51.15 kg (*SD* = 3.43), whereas the control group had a higher mean weight of 58.91 kg (*SD* = 9.70). The sample consisted of trained athletes, ensuring a competitive and homogenous population for the study.

Ethical approval for this study was obtained from the ethics committee of the Faculty of Physical Education and Sport, Babeş-Bolyai University, ensuring compliance with ethical research guidelines. Prior to participation, all subjects and their legal guardians provided written informed consent, acknowledging their voluntary participation in the study. Participants were fully informed about the purpose, procedures, and potential risks involved. They were also made aware of their rights, including the option to withdraw from the study at any time without any consequences. Confidentiality and anonymity of the data were maintained, with all personal information securely stored and used solely for research purposes. The study adhered to ethical principles regarding research with human subjects, ensuring respect for participants' autonomy and well-being.

Testing procedures

Aerobic capacity was assessed using the multi-stage fitness (beep) test (Léger & Lambert, 1982), a widely used field test for estimating cardiorespiratory endurance. Participants performed the test in groups, running back and forth between two lines placed 20 meters apart at increasing speeds dictated by audio signals. If a participant failed to reach the line before the beep, they received a warning; the test ended when they could no longer keep pace. Baseline testing was conducted before the training intervention, and post-testing was performed at the end of the training period.

Training intervention

The intervention lasted six weeks, with HIIT sessions conducted twice per week (Mondays and Wednesdays) in addition to regular basketball training. The HIIT protocol was integrated into the warm-up phase of the basketball practice and was designed to enhance aerobic capacity while incorporating basketball-specific skills.

Each HIIT session consisted of:

- Work-to-rest ratio: 45 seconds of high-intensity effort followed by 30 seconds of active recovery.

- Training structure: 4 sets with varying series (3, 2, 2, and 4 repetitions per set).
- Rest intervals: 3-minute passive recovery between sets.

Exercise protocol

The HIIT training sessions incorporated a variety of basketball-specific exercises designed to enhance both aerobic capacity and technical skills. The Monday sessions focused on dribbling and agility, beginning with high-intensity cross-over dribbles, behind-the-back dribbles, and dribbling between the legs. These were followed by more complex movements such as lunges combined with dribbling under the front leg and controlled dribbling from a lunge position, challenging both coordination and endurance. To further develop lower-body power, the sessions included vertical jumps, with and without trunk rotation, ensuring explosive movement patterns were reinforced. Footwork and agility were also emphasized through lateral movements, including side steps in an "X" pattern and quick lateral shuffles, helping players improve their defensive and transition movements.

The Wednesday sessions shifted the focus toward running endurance while integrating basketball dribbling. Participants performed repeated bouts of submaximal running with dribbling, pushing their aerobic capacity while maintaining ball control. These high-intensity efforts were alternated with light jogging to allow for active recovery while keeping players engaged in continuous movement. By integrating technical dribbling elements with sprint-based conditioning, the HIIT program provided a sport-specific approach to improving cardiovascular endurance while reinforcing essential basketball skills.

To ensure the safety of participants, participants' perceived exertion and ability to maintain intensity were observed, with improvements noted after approximately four weeks.

Control group protocol

Participants in the control group followed their standard basketball training program three times per week, without additional HIIT sessions. Their training focused on technical and tactical basketball drills without structured aerobic conditioning beyond regular practice.

This methodological approach allowed for the evaluation of the effects of HIIT on aerobic endurance while maintaining ecological validity by integrating training within a basketball-specific context.

Statistical analyses

All statistical analyses were performed using SPSS statistics for Windows, version 17.0b. Continuous variables were defined by the mean ± standard deviation (SD). Shapiro-Wilk test was used for determination of normal distribution. To assess the intervention's effects, a paired-sample *t*-test was used to compare pre- and post-training results within each group, while an independent-sample t-test was applied to examine differences between the experimental and control groups. A p value of < 0.05 was considered statistically significant.

RESULTS

The assumption of normality was assessed using the Shapiro-Wilk test. Results indicated that all four datasets were normally distributed: BeepTest_EG_M1, $W(8) = 0.902$, $p = .169$; BeepTest_EG_M2, $W(8) = 0.939$, $p = .287$; BeepTest_CG_M1, $W(8) = 0.967$, $p = .728$; and BeepTest_CG_M2, $W(8) = 0.952$, $p = .532$. As all p values exceeded the .05 significance threshold, the null hypothesis of normality was not rejected, supporting the assumption that the data follows a normal distribution.

Since the Shapiro-Wilk test indicated that all datasets were normally distributed ($p > .05$), parametric tests could be appropriately applied to compare the data. A paired samples *t*-test was used to assess within-group differences over time, as it is suitable for comparing two related measurements from the same participants. Additionally, an independent samples *t*-test was conducted to compare the mean differences between the experimental and control groups at each measurement point. Normality assumption ensures the validity of these statistical tests, allowing for reliable inference about group differences and intervention effects.

Table 1. Paired sample *t*-test results between the initial (M1) and final measurements (M2) for both the experimental (BeepTest_EG) and control groups (BeepTest_CG) of the beep test

		N	Mean	Std. Deviation	Mean Difference	t	df	p (95%)
Pair 1	BeepTest_EG_M2	8	6.61	0.56	1.263	4.690	7	.002
	BeepTest_EG_M1	8	5.35	0.94				
Pair 2	BeepTest_CG_M2	8	4.93	0.56	.337	4.621	7	.002
	BeepTest_CG_M1	8	4.59	0.54				

A paired samples *t*-test was conducted to compare the Beep Test performance before and after the intervention for both the experimental and control groups. Results indicated a significant increase in performance for the experimental group from pre-test (BeepTest_EG_M1) (M = 5.35, SD = 0.94) to post-test (BeepTest_EG_M2) (M = 6.61, SD = 0.56), t (7) = 4.690, p = .002, with a mean difference of 1.263 (Table 1).

Similarly, the control group also demonstrated significant improvement from pre-test (BeepTest_CG_M1) (M = 4.59, SD = 0.54) to post-test (BeepTest_CG_M2) (M = 4.93, SD = 0.56), t(7) = 4.621, p = .002, with a mean difference of 0.337 (Table 1).

These findings suggest that both groups improved their performance over time, with a larger improvement observed in the experimental group.

Table 2. Independent sample *t*-test results between the experimental (BeepTest_EG) and control groups (BeepTest_CG) for both the initial (M1) and final measurements (M2) of the beep test

		N	Mean	Std. Deviation	Mean Difference	t	df	p (95%)
M1	BeepTest_EG	8	5.35	0.94	0.76	1.989	14	.067
	BeepTest_CG	8	4.59	0.54				
M2	BeepTest_EG	8	6.61	0.56	1.69	6.004	14	.000
	BeepTest_CG	8	4.93	0.56				

An independent samples *t*-test was conducted to compare the Beep Test scores between the experimental (EG) and control groups (CG) at both measurement points. At baseline (M1), the difference between EG (M = 5.35, SD = 0.94) and CG (M = 4.59, SD = 0.54) was not statistically significant, $t(14) = 1.989$, $p = .067$, though EG had a higher mean score (mean difference = 0.76) (Table 2). However, at post-test (M2), EG (M = 6.61, SD = 0.56) demonstrated significantly higher scores compared to CG (M = 4.93, SD = 0.56), $t(14) = 6.004$, $p < .001$, with a mean difference of 1.69 (Table 2). These results suggest that while the two groups started with relatively similar performance levels, the experimental group showed a significantly greater improvement following the intervention.

DISCUSSION

Recognized as one of the most effective methods of improving cardiorespiratory and metabolic function in both trained and untrained individuals, HIIT implies repeated short (< 45 s) to long (2-4 min) bouts of strenuous exercise intercalated with recovery periods (Buchheit & Laursen, 2013; Buchheit & Laursen, 2013a; Deak & Boros-Balint, 2017). In team sports, HIIT is used as an alternative, time-efficient training technique, to continuous low-intensity running protocols for enhancing aerobic fitness (Buchheit & Laursen, 2013; Buchheit & Laursen, 2013a; Rodríguez-Fernández et al., 2023). HIIT was also proved to be successful as a means of increasing skill-related performance in team sports (Stankovic et al., 2023).

Numerous studies published in the last decade investigated the effects of different variations of HIIT on cardiovascular fitness in basketball players. The reported findings indicated that aerobic capacity significantly improved in both male and female athletes (Arslan et al., 2022; Aschendorf et al., 2019; Delextrat et al., 2018; Delextrat & Martinez, 2014; Fang & Jiang, 2024; Gantois et al., 2019; Kumari et al., 2023; Mourgan et al., 2024; Rodríguez-Fernández et al., 2023; Sanchez-Sanchez et al., 2018; Smith et al., 2022; Song et al., 2023; Zeng et al., 2022).

When compared to small-sided games training (SSG), HIIT elicited similar positive physical adaptations in adolescent male basketball players (Arslan et al., 2022; Delextrat et al., 2018; Delextrat & Martinez, 2014). After 6 weeks, greater improvements were observed in 30 meters sprint time in the HIIT group, while the SSG group induced significantly higher technical skills such as control dribbling and shooting skills (Arslan et al., 2022). The results reported by Delextrat and Martinez (2014) imply that both interventions (i.e., HIIT and SSG, respectively) enhanced aerobic capacity in male junior basketball players, with the difference that the SSG group showed greater improvements in defensive agility, shooting skills, and upper body power. In elite male junior basketball players, after 6 weeks of training, aerobic endurance, anaerobic power, and muscle oxygenation capacity significantly increased in both HIIT and SSG groups (Delextrat et al., 2018).

Aerobic performance improved in young female basketball athletes after 5 weeks of basketball-specific HIIT (Aschendorf et al., 2019; Mourgan et al., 2024), after 6 weeks of HIIT with one and three changes of direction (Sanchez-Sanchez et al., 2018), after 6 weeks of cardiopulmonary- and neuromuscular-based HIIT (Rodríguez-Fernández et al., 2023), and after 4 weeks of SSG and HIIT with changes of direction (Zeng et al., 2022). A study compared the effects of short sprint interval training on male and female

basketball players' aerobic endurance and anaerobic power (Fang & Jiang, 2024). The conclusion was that males and females equally gained from the integration of short sprint interval training into their basketball-specific training regime (Fang & Jiang, 2024).

Since evidence regarding the benefits of incorporating HIIT into the training program of young female basketball players is scarce, the current study was aimed at investigating the effects of basketball-specific HIIT on aerobic capacity in adolescent female basketball players. The results showed a significantly greater improvement in post-intervention scores of the multi-stage fitness (beep) test in the experimental group compared to the control group. These results align with the findings of studies which used basketball-specific HIIT as a method to positively impact aerobic endurance (Aschendorf et al., 2019; Mourgan et al., 2024). Although VO_{2max} was not measured directly in a laboratory setting due to practical reasons, the use of field tests as a valid alternative to estimate aerobic capacity is widely accepted (Batista et al., 2017). The multi-stage fitness test, also known as the 20-meter shuttle run test, or as the beep test, was found to be the most appropriate to evaluate the cardiorespiratory fitness of young people (Batista et al., 2017). In intermittent team sports (e.g., soccer, basketball etc.), the beep test and the Yo-Yo intermittent recovery test are used with similar results in assessing aerobic endurance (Berdejo-del-Fresno & González-Ravé, 2013; Gabryś et al., 2019).

Game performance is influenced not only by the physical fitness of athletes, but also by other important factors such as tactical and technical skills. SSG is known to be highly sport specific due to its integration of movements and tasks distinctly associated with a certain sport. The effectiveness of SSG with regards to improvements in aerobic endurance is generally acknowledged (Arslan et al., 2022; Clemente et al., 2023; Delextrat et al., 2018; Delextrat & Martinez, 2014; Zeng et al., 2022). Likewise, the training protocol designed for this study contained dribbling drills, sideway shuffling movements, change of directions, and jumps, which seem to occur often during basketball games (Ben Abdelkrim et al., 2007), executed in short intervals (45 seconds) with high intensity. Thus, basketball-specific HIIT appears to be a solid option for increasing aerobic performance while maintaining focus on basketball skills.

CONCLUSION

A court-based intermittent team sport, basketball is characterized by frequent changes in movements due to repeated transitions between offence and defence. Due to the physical, technical and tactical requirements of the

basketball game, athletes must achieve a physical fitness level that allows them to perform maximal efforts. Time-efficient and focused on basketball skills, basketball-specific HIIT can be carried out to improve aerobic performance in adolescent female players.

Conflict of interests

The authors declare that there is no conflict of interest in this research.

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