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International Journal of Physical Medicine and Rehabilitation

Research Article

Effects of a 16-week Basketball-Focused Sports Intervention on the Executive Functions of Male Attendees at a Compulsory-Isolation Drug Rehabilitation Centre

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ABSTRACT

Research has shown that sports and exercise may be an effective treatment for drug rehabilitation. This study examines the effects of basketball on the executive functions of male attendees at a compulsory-isolation drug rehabilitation centre. Data were collected from 40 male participants via convenience sampling from a compulsory-isolation drug rehabilitation centre in Linfen, Shanxi Province and divided into an intervention and a control group. The intervention group participated in 16 weeks of a basketball sports intervention, while the control group received the usual interventions. At three time points-baseline, 8 weeks after the intervention, and 16 weeks after the intervention, three components of the participants' executive functions-inhibition, updating, and shifting—were assessed using Flanker tasks, 2-back tasks, and more-odd shifting tasks. At 16 weeks after the invention, the intervention group had a significantly shorter reaction time ($p<0.05$) on average compared with the control group in terms of their inhibition, updating, and shifting functions. Within the intervention group, the reaction times for inhibition, updating, and shifting decreased as the intervention length increased. Long-term basketball training can effectively improve executive functions and encourage positive changes in the nervous systems of patients at compulsory-isolation drug rehabilitation centres.

Keywords: Sports rehabilitation; Compulsory-isolation; Executive functions; Basketball

INTRODUCTION

Drug abuse is a common social problem worldwide. According to the United Nations Office on Drugs and Crime's World Drug Report 2021, around 275 million people worldwide used drugs in 2020, amounting to 5.5% of the global population [1]. Drug abuse not only impacts physical and mental health but also causes severe social issues such as crime, financial loss, and social instability [2]. Data from World Drug Report 2022 show that in 2019, drug use killed about 500,000 people and caused mental disorders in 36.3 million individuals. Drug use disorder has also resulted in the loss of 18 million years of healthy lives [3]. In particular, drugs impair physical functions as well as the nervous system. Research has shown that the brain structure of long-term drug abusers differs from that of non-abusers, and that long-term drug abuse damages parts of the brain's overlay network. Changes to the brain's structure and functions can lead to frustration, anxiety, depression, unresponsiveness, memory decline, etc., especially impairments or disorders related to executive functions [4-7]. Consequently, those with drug use disorder struggle to control their desire for drugs and overcome their mental addiction [4]. As such, improving the executive functions of persons with drug use disorder is currently a key research topic in the field of drug rehabilitative treatment and relapse prevention.

At present, a common treatment for drug addiction is drug substitution therapy; however, long-term use of this therapy can also cause drug dependency [8]. Evidence shows that sports and exercises are effective in improving physical functions, reducing chronic disease risks, and enhancing cognition and executive functions [9-12]. In recent years, sports and exercise have also been considered as a potential drug rehabilitative treatment that is both economical and does not cause further harm [5]. On World Drug Day 2018, China's Ministry of Justice proposed the use of sports and exercise to shape China's drug rehabilitation system, which further facilitated the development and application of sports interventions in the drug rehabilitation field. Research has shown that sports can strengthen and improve the executive functions of persons with drug use disorders as well as enhance their self-discipline, which help overcome drug addiction [6,13]. However,

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Received: 27-Dec-2022, Manuscript No. JPMR-23-21185; **Editor assigned:** 30-Dec-2022, Pre QC No. JPMR-23-21185 (PQ); **Reviewed:** 16-Jan-2023, QC No. JPMR-23-21185; **Revised:** 23-Jan-2023, Manuscript No. JPMR-23-21185 (R); **Published:** 30-Jan-2023, DOI: 10.35248/2329-9096.23.11.663

Citation: Chen L, Wu Y, He Y, Li Q (2023) Effects of a 16-week Basketball-Focused Sports Intervention on the Executive Functions of Male Attendees at a Compulsory-Isolation Drug Rehabilitation Centre. Int J Phys Med Rehabil. 11:663

the effects of sports on executive functions vary depending on the activity. Participating in technical exercises and complex sports activities can help promote an individual's physiological activity with regard to the nervous system and the neural networks related to cognition. This process increases the activity level in the brain's superior frontal region and improves executive function [9]. For example, Zhai et al. [14] observed that basketball and Tae Bo induce stronger cognitive benefits compared with running.

Basketball as a sporting activity involves multiple techniques and complex scenarios. This study focused on these characteristics and designed a 16-week basketball intervention program to examine the effects on attendees at a compulsory-isolation drug rehabilitation centre. It aims to provide theoretical support and a practical foundation for drug rehabilitation management policymaking as well as the physical and mental treatment of persons with drug use disorder. This study expects that engaging in basketball sports long-term would boost the executive functions of male attendees at the compulsory-isolation center, and that as time exposure to the sporting activity increases, the improvements would also become more significant.

MATERIALS AND METHODS

The research participants were randomised into intervention and control groups. The intervention group participated in a 16-week basketball intervention, while the control group did not receive additional intervention. The research participants' executive functions were assessed at the baseline, 8 weeks after intervention, and 16 weeks after intervention. This study was approved by the Sports Science Experimental Ethics Committee of China Institute of Sport Science (Ethical code: CISSIRB-2016006) (Figure 1).

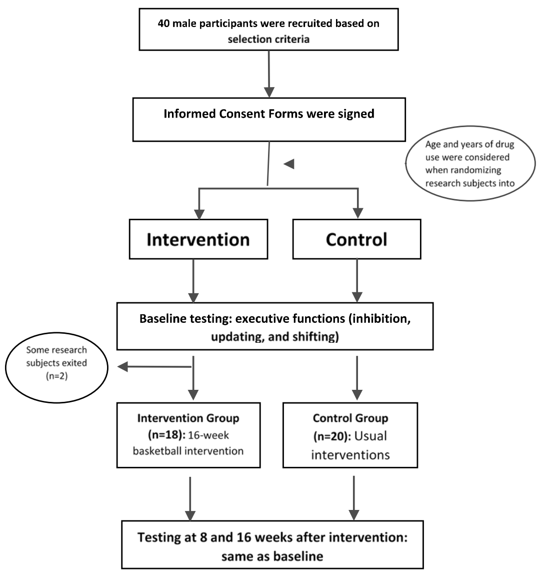

Figure 1: The research process.

Research participants

A total of 40 voluntary research participants were recruited from Team 3 of a compulsory-isolation drug rehabilitation center at Linfen, Shanxi Province. The participants were men with drug use disorders, who were receiving interventions at the center. The selection criteria were as follows: Participants were between 20–59 years, had completed physical rehabilitation and were in the recovery stage, were clinically assessed to be fit for sporting activities, and had no colour vision deficiencies or weaknesses. All research participants agreed to participate in the study by signing informed consent forms.

Randomised grouping

Block randomisation was used to group the 40 research participants, with consideration given to their age and years of drug use. The research participants were equally randomised into the intervention and control groups. Since two people were unable to participate in the experiment owing to physical reasons, 38 participants were finally included in the experiment, including 18 and 20 in the intervention and control groups, respectively.

Intervention implementation

The intervention group participated in 16 weeks of basketball intervention. The program mainly focused on learning techniques and practice, with supplementary gaming and competitive elements. The intervention took place three times a week for 60 mins each time. Each intervention class was structured into 10 mins of warm up, 45 mins of basic drills, and 5 mins of cool down. Each week, the first session focused on learning new techniques, and the second and third sessions focused on practicing those techniques. Each intervention session took place in the afternoon (17:30–18:30) outside of the research participants' working hours. This study's sports intervention was of moderate intensity, with a target heart rate range of 115-145 beats per minute. The intervention group participants wore heart rate monitor watches to ensure that the intensity was within range. The entire process was overseen by a police officer stationed at the center and a professional basketball coach. During the same period, the control group received the usual interventions (education, awareness, and labour services) (Table 1).

Table 1: Intervention schedule

Week	Activities	Exercise intensity	Duration/ Frequency
1	Sprints: Change of direction, sideline, backwards	Target heart rate at 115-145 beats per minute	60 minutes/ session (10 minutes warm up+45 minutes basic drills+5 minutes cool down) 3 times/week (Monday, Wednesday and Friday from 17:30-18:30)
2	Lunges, jump stops, forward and reverse pivots		
3	Slides, step backs		
4	Chest passes+practice		
5	One-handed shoulder passes+practice		
6	Catching techniques (mid, high, low passes)+practice		
7	Stationary high and low dribbling		
8	Dribbling (change of direction)		
9	Pivoting while dribbling		
10	Stationary shooting		
11	Dynamic shooting		
12	Practice		
13	Give-and-go		
14	Break-and-pass		
15	Screen/back up		
16	Consolidated drills		

Executive functions testing

Executive functions-specifically, inhibition, updating, and shifting—were tested using the E-Prime 2.0 software. The testing method is described below.

Inhibition: Flanker tasks were used to assess inhibition. First, '+' was shown on the interstimulus interval screen for 500 ms. A string of alphabetical letters then appeared in the center of the computer screen, including both identical (e.g. 'FFFFF' or 'LLLLL') and non-identical letters (e.g. 'LLFLL' or 'FFLFF'). The interstimulus interval was 3 s. The participants were requested to respond as accurately as possible to the middle letter of each string. If the middle (i.e. third) letter was 'F', the research participant needed to press the 'F' key on the keyboard. If the middle letter was 'L', the research participant needed to press the 'L' key. It was equally likely that an identical or a non-identical string would appear. There were two parts to the testing, each comprising 60 attempts. Before the actual testing, the participants completed 10 practice attempts. The test results were derived by subtracting the reaction time for identical strings from the average reaction time for non-identical strings; the smaller the time difference, the stronger the inhibition.

Updating: Two-back tasks were used to assess the updating function. First, '+' was shown on the interstimulus interval screen for 500 ms. Individual letters appeared one by one in the center of the computer screen (each letter would disappear afterward, requiring the participant to remember what was shown). This process continued for 2,000 ms. From the third letter onward (the first two letters did not require the research participants to press any keys), the participants were required to immediately evaluate whether the current letter was the same as the one presented before. If the letters were the same, the participants needed to press the 'F' key; otherwise, they were required to press the 'L' key. There were two parts to the testing, each comprising 20 attempts. Before the actual testing, the participants completed six practice attempts; the shorter the reaction time, the stronger the updating function.

Shifting: More-odd tasks were used to assess the shifting function. Following Salthouse et al.'s approach, the participants were asked to evaluate digits from 1–9. Other than 5, the participants were required to assess all digits in relation to whether they were large or small, or odd or even. First, '+' was shown on the interstimulus interval screen page for 500 ms. Thereafter, individual digits appeared successively in the center of the screen. This process continued for 2,000 ms, with the interstimulus interval set at 3 s. Evaluation Task 1 (large/small): Black digits were shown. If the digit was smaller than 5, participants were required to press the 'F' key. If the digit was larger than 5, participants were required to press the 'L' key. Evaluation Task 2 (odd/even): Green digits were shown. If the digit was odd, participants were required to press the 'F' key. If the digit was even, participants should press the 'L' key. Evaluation Task 3 (large/small and odd/even): This task required the participants to use their shifting function during evaluation. If a black digit appeared on the screen, participants needed to evaluate it based on whether it was larger or smaller than 5. If a green digit appeared, it should be evaluated based on whether it was odd or even. There were six parts to the testing, following the sequence ABCCBA. Parts A and B did not require participants to switch tasks, and each part comprised 16 attempts. Part C required participants to switch tasks 32 times, with each part comprising 16 shifting attempts. Before the actual testing, the participants completed eight practice attempts before proceeding with their first attempts for parts A, B, and C. The test results were derived by calculating the difference in the average reaction times for the shifting and non-shifting tasks; the smaller the time difference, the stronger the shifting function.

Statistical methodology

IBM SPSS 24.0 was used to analyse the testing data. The data were represented as the mean ± standard deviation (M ± SD). Independent sample t-testing was used to compare the basic situation of the intervention and control groups. The K-S normality test was also used to examine whether the executive functions data were normally distributed. A 2 (intervention and control groups) × 3 (before intervention, 8 weeks after intervention, and 16 weeks intervention) two-way repeated-measures Analysis Of Variance (ANOVA) was used to examine the changes in executive functions for both groups at the baseline and at 8 and 16 weeks after the intervention. Owing to the variables in focus, Mauchly's sphericity test was used to test assumptions. If the assumption of sphericity was violated, then the Greenhouse-Geisser correction was used to adjust for the lack of sphericity. Thereafter, analyses were conducted using the Bonferroni test and simple-effects analysis. If $p<0.05$, the test result was statistically significant.

RESULTS

Attendees at the compulsory-isolation drug rehabilitation center

As shown in Table 2, there were no statistically significant differences ($p>0.05$) between the intervention and control groups in terms of their BMI, age, and years of drug use. Consequently, in terms of general demographic indicators, both groups can be considered homogeneous (Table 2).

Analysis of executive functions test results

Inhibition: The K-S testing showed that the inhibition data at the baseline and at 8 and 16 weeks after the intervention were normally distributed ($p>0.05$). Mauchly's spherical testing confirmed that the assumption was met, with Mauchly's $W=0.860$ and $p=0.07$. The two-way repeated-measures ANOVA revealed that the main effect of time and group*-by-time interaction effect was significant ($p<0.05$), and that the main effect of group was not significant ($p>0.05$). Post hoc multiple comparison tests showed that at the baseline and at 8 weeks after intervention, there were no statistically significant differences ($p>0.05$) between the intervention and control groups. At 16 weeks after intervention, the intervention group's inhibition reaction time was significantly shorter than that of the control group ($p>0.05$). There were significant differences ($p<0.05$) in the inhibition reactions of the intervention group compared with data at the baseline and 8 weeks after intervention. Further, the inhibition reaction time at 16 weeks after intervention was significantly shorter ($p<0.05$) compared with the baseline data (Table 3).

Table 2: Overview of the research subjects.

Indicator	Intervention group (n=18)	Control group (n=20)	P-value
Age (years)	31.83 ± 4.85	34.45 ± 3.98	0.08
Height (cm)	173.94 ± 6.70	170.00 ± 4.86	0.05
Weight (kg)	68.00 ± 6.50	65.10 ± 5.78	0.15
BMI (kg/m^2)	22.49 ± 2.06	22.55 ± 2.08	0.93
Drug use (years)	9.72 ± 4.24	10.05 ± 6.13	0.85

Table 3: Inhibition reaction time (ms).

	Baseline (M±SD)	8 weeks after intervention (M ± SD)	16 weeks after intervention (M ± SD)	Repeated measures F tests		
				F-value	P-value	Partialη2
Intervention group	523.35 ± 49.76$^{\#\&}$	500.50 ± 37.10	483.34 ± 29.32*	-	-	-
Control group	505.08 ± 43.21	508.20 ± 30.19	512.20 ± 33.36	-	-	-
Main effect of group	-	-	-	0.352	0.56	0.01
Main effect of time	-	-	-	4.071	0.02	0.102
Group*-by-time	-	-	-	8.276	0.001	0.187

Note: "*" means that when comparing the intervention and control groups at the same time, p<0.05; "#" means that when comparing within the groups at the baseline and eight weeks after intervention, p<0.05; "&" means that when comparing within the groups at the baseline and 16 weeks after intervention, p<0.05.

Updating: The K-S testing showed that the updating function data at the baseline and at 8 and 16 weeks after intervention were normally distributed (p>0.05). Mauchly's spherical testing demonstrated that the assumption was met, with Mauchly's W=0.937 and p=0.32. The two-way repeated-measures ANOVA showed that the main effect of time and group*-by-time interaction effect was significant (p<0.05), and that the main effect of group was not significant (p>0.05). Post hoc multiple comparison tests demonstrated no statistically significant differences (p>0.05) between the intervention and control groups at the baseline or at eight weeks after intervention. At 16 weeks after intervention, the intervention group's updating reaction time was significantly shorter than that of the control group (p<0.05). Within the intervention group, there were significant differences (p<0.05) between the executive function reaction time at the baseline and at 8 weeks after intervention. Moreover, significant differences were observed between the updating reaction time at 8 and 16 weeks after intervention (p<0.05). Compared with the baseline data, the updating reaction time at 16 weeks after the intervention was significantly shortened (p<0.05). Within the control group, the updating reaction time at eight weeks after the intervention was significantly shorter (p<0.05) than at the baseline (Table 4).

Shifting: The K-S testing showed that the shifting function data at the baseline and at 8 and 16 weeks after the intervention were normally distributed (p>0.05). Mauchly's spherical testing confirmed that the assumption was met, with Mauchly's W=0.888 and p=0.126. The two-way repeated-measures ANOVA revealed that the main effect of time and group*-by-time interaction effect was significant (p<0.05), and that the main effect of group was not significant (p>0.05). Post hoc multiple comparison tests showed that at baseline and at eight weeks after intervention, there were no statistically significant differences (p>0.05) between the intervention and control groups. At 16 weeks after intervention, the intervention group's shifting reaction time was significantly shorter than that of the control group (p<0.05). Within the intervention group, there were significant differences (p<0.05) between the shifting function reaction time at baseline and at eight weeks after the intervention. There were also significant differences between the shifting reaction time at 8 and 16 weeks after intervention (p<0.05). Compared with the baseline data, the shifting reaction time at 16 weeks after intervention had significantly shortened (p<0.05). Within the control group, the shifting reaction time at eight weeks after intervention was significantly shorter (p<0.05) than at the baseline (Table 5).

Table 4: Updating reaction time (ms).

	Baseline (M ± SD)	8 weeks after intervention (M ± SD)	16 weeks after intervention (M ± SD)	Repeated measures F tests		
				F-value	P-value	Partialη2
Intervention group	822.11 ± 47.85$^{\#\&}$	797.47 ± 36.15$^{¥}$	763.20 ± 29.64*	-	-	-
Control group	805.08 ± 43.21$^{\#}$	781.72 ± 40.75	789.39 ± 34.89	-	-	-
Main effect of group	-	-	-	0.041	0.84	0.01
Main effect of time	-	-	-	20.721	<0.001	0.365
Group*-by-time	-	-	-	8.764	<0.001	0.196

Note: "*" means that when comparing the intervention and control groups at the same time, p<0.05; "#" means that when comparing within the groups at the baseline and eight weeks after the intervention, p<0.05; "&" means that when comparing within the groups at the baseline and 16 weeks after the intervention, p<0.05; "¥" means that when comparing within the groups at 8 and 16 weeks after the intervention, p<0.05.

Table 5: Shifting reaction time (ms).

	Baseline (M ± SD)	8 weeks after intervention (M ± SD)	16 weeks after intervention (M ± SD)	Repeated measures F tests		
				F-value	P-value	Partialη2
Intervention group	725.44 ± 47.53$^{\#\&}$	700.55 ± 36.40$^{¥}$	664.92 ± 22.16*	-	-	-
Control group	705.08 ± 43.21$^{\#}$	681.68 ± 40.75	689.39 ± 34.89	-	-	-
Main effect of group	-	-	-	0.197	0.66	0.05
Main effect of time	-	-	-	29.816	<0.001	0.453
Group*-by-time	-	-	-	13.002	<0.001	0.265

Note: "*" means that when comparing the intervention and control groups at the same time, $p<0.05$; "$^{\#}$" means that when comparing within the groups at the baseline and eight weeks after the intervention, $p<0.05$; "$^{\&}$" means that when comparing within the groups at the baseline and 16 weeks after the intervention, $p<0.05$; "$^{¥}$" means that when comparing within the groups at 8 and 16 weeks after the intervention, $p<0.05$.

DISCUSSION

This study examined the effects of a basketball-based sports intervention program on the executive functions of male attendees at a compulsory-isolation drug rehabilitation center. The results demonstrated that playing basketball can improve inhibition, updating, and shifting functions and that the longer the intervention time, the more significant the effects. Executive functions enable individuals to coordinate cognitive processes when completing complex cognitive tasks. These functions form a general control mechanism that ensures that the cognitive system can achieve specific goals flexibly and aptly. The three core sub-functions are inhibition, updating, and shifting [15, 16]. Long-term substance abuse can lead to impaired and dysfunctional inhibition, updating, and shifting functions, causing a decrease in an individual's ability to control their behaviour, maintain and shift focus, and overcome irrelevant stimuli [17]. In turn, these decreases cause persons with drug use disorder to succumb helplessly to their impulsive psychological desire for drugs [6, 18]. Previous research has proven that sports can improve individuals' executive functions and that moderate-intensity sporting activities are the most effective in this regard [19-23]. This study created a 16-week basketball sports intervention program that aimed to improve the executive functions of attendees at a compulsory-isolation drug rehabilitation center. In theory, playing basketball can effectively improve executive functions. First, executive functions are developed through sporting activities; frequent use of these functions while playing sports and practicing moves can improve or strengthen an individual's executive functions. Consequently, specific and targeted exercises can be beneficial in enhancing executive functions [24]. Second, as a sport, basketball involves diverse exercises and techniques and necessitates the use of wide-ranging executive functions. Playing and practicing this sport continuously can effectively improve executive functions. For instance, stationary dribbling and shooting require the player to block out irrelevant noise and control ball speed, angle, and wrist strength. Inhibition has a vital role in these processes. Another example is changing direction while dribbling or passing; the uncertainty involved requires the player to continuously update their working memory and switch movements promptly. Thus, such exercises are beneficial in enhancing the updating and shifting functions [22, 24]. This study found that in line with expectations, the basketball intervention positively impacted the executive functions of the participating attendees at the center. Wang et al. [25] observed that engaging in moderately intense aerobic exercise three times a week for 12 weeks can improve the inhibitive control of individuals with methamphetamine dependency and lower their desire for the stimulant. Rong et al. [26] also found that 30 mins of moderate and high-intensity aerobic exercise can improve the executive control of persons addicted to methamphetamine. In addition, Lv et al. [6] discovered that resistance training can significantly improve the inhibition of persons addicted to heroin. Previous studies have provided evidence that healthy individuals receive a boost to their executive functions when they engage in resistance training, aerobic exercises, soccer jump rope, and basketball [20, 27-32]. This study's results align with those of previous research and present further evidence that sports and exercise are beneficial for improving the executive functions of those with drug use disorders and helping them control their addictions.

Neuroscientists hold that both simple and complex sports require nervous system regulation, especially the brain's regulatory function. Existing neuroscience research has shown that sports can modify the activation patterns in the brain region, including the frontal lobe (dorsolateral and ventrolateral prefrontal cortex), cingulate gyrus (mainly the anterior cingulate gyrus), cerebellum, parietal lobe, and striatum (ventral). This modification increases the functional connectivity in the brain region, improving the inhibition, updating, and shifting functions [9]. Basketball is an open-skill sport, characterised by innovative, diverse, and targeted movements, as well as sporting scenarios. As such, the entire practice process involves inhibitory control, updating, and shifting functions. Playing basketball can facilitate the activation processes in the brain region associated with these three functions, thereby enhancing the executive functions. Additionally, from a molecular physiological perspective, exercising can stimulate the release of hormones, growth factors, and neurotransmitters. Meanwhile, exercise can also enhance both the gene expression of related brain regions and the antioxidant capacity of brain tissues. These changes to molecular physiological indicators can promote improvements in executive functions [5, 33, 34]. Studies have shown that endorphins play a regulating role in various brain regions that are involved in drug addiction circuitry and in improving the inhibitory control of persons with drug use disorder, weakening addiction memory [35]. Considering the sporting activity itself, complex technical exercises and diverse sporting scenarios involve participation from more parts of the brain. By stimulating and activating more neural circuits and elevating the activity level of the frontal lobe, executive functions can be improved. Moderately intense sports can induce the optimal release of catecholamine (such as dopamine, norepinephrine, and serotonin) and activate the central nervous system, thereby improving cognitive and executive functions. Long-term exercise can also increase the oxygen saturation and cerebral blood flow in the frontal lobe, parietal lobe, parts of the temporal lobe, and other brain regions, which can directly impact the executive functions [36]. In addition, participating in long-term basketball training can have stimulatory and cumulative effects on the executive functions.

In summary, this study provides evidence for the effectiveness of basketball in improving the executive functions of male attendees at a compulsory-isolation drug rehabilitation center. Nevertheless, it has certain limitations. First, owing to recruitment constraints, only male attendees were considered. However, extant research has shown that sports interventions affect the recovery of men and women with drug use disorder differently; therefore, subsequent studies should examine the effects of sports interventions on female attendees [36]. Second, this study only examined the effects of moderately intense basketball activities on the executive functions of male attendees. Future studies can focus on sports interventions of different intensity, quantity, and frequency. Third, this study only considered the effects of basketball intervention on executive functions [37]. Subsequent research should explore the benefits of basketball for physical and mental health and sleep quality, among other areas.

CONCLUSION

Finally, this study only demonstrated the immediate effects of the sports intervention, and subsequent studies should examine any delayed effects. Long-term basketball training can effectively improve executive functioning and encourage positive changes in the nervous systems of patients at compulsory-isolation drug rehabilitation centres.

FUNDING

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

AUTHORS CONTRIBUTIONS

Conceptualization, Resources, Supervision, Investigation, Formal Analysis, and Writing-Review and Editing: Leqin Chen; Data Curation, Writing-Review and Editing: Yini Wu; Visualization, Writing-Review and Editing: Yanjun He; Conceptualization, Methodology, Software, Writing-Original Draft: Qianqian Li.All authors have read and agreed to the published version of the manuscript.

INSTITUTIONAL REVIEW BOARD STATEMENT

This study was approved by the Sports Science Experimental Ethics Committee of China Institute of Sport Science (Ethical code: CISSIRB-2016006). The study was conducted in accordance with the principles of the Declaration of Helsinki.

INFORMED CONSENT STATEMENT

Any research article describing a study involving humans should contain this statement.

DATA AVAILABILITY STATEMENT

All data generated or analyzed during this study are included in this published article and its supplementary information files.

ACKNOWLEDGMENTS

The authors would like to thank the compulsory-isolation drug rehabilitation center at Linfen, Shanxi Province and all participants for their participation.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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