Comparison of Physical Effect Between Two Training Methods for Individuals With Substance Use Disorder

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Research article

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Abstract

Background: High-intensity Interval Training (HIIT) has recently been widely used for health promotion in healthy people and patients with chronic diseases. It is not clear whether HIIT can bring better physical rehabilitation benefits to individuals with substance use disorder (SUD) than that of Moderate-intensity continuous Training (MICT). The study aimed to compare the effects of HIIT versus MICT on the physical fitness of individuals with SUD.

Methods: A total 120 individuals with amphetamine-type stimulant dependent from a compulsory drug rehabilitation center voluntarily took part in this study. They were randomly assigned to the HIIT group (experimental group) and MICT group (control group). The subjects in experimental group received HIIT training three times a week (80%-85%HR_{Max}, 60min). The exercise included rope jumping, running, weight training and basketball game. The subjects from control group received MICT 3 times a week (60%HR_{Max}, 60min), including Tai Chi, mind-body exercise and recreation activity. Physical fitness assessment were performed at the baseline, 3 months, 6 months, 9 months and 12 months exercise intervention including blood pressure (BP), vital capacity (VC), hand grip, push-up, sit-and-reach, one-leg-stand with eyes closed and choice reaction time. The craving level was assessed using the visual analog scale (VAS) at the baseline, 6 months and 12 months. A two-way repeated measures analysis of variance (ANOVA) was applied to test whether the intervention were different after 12 months.

Results: The within-group factor displayed significant changes in HIIT and MICT groups in terms of the systolic BP (F_{(4,336)}=12.799), diastolic BP (F_{(4,336)}=9.495), VC (F_{(4,336)}=18.121), hand grip (F_{(4,336)}=34.815), sit-and-reach (F_{(4,336)}=13.871), choice reaction time (F_{(4,336)}=20.603), one-leg-stand with eyes closed (F_{(4,336)}=14.495) and push-up (F_{(4,336)}=28.805). The craving level decreased after 12 months intervention in both groups (F_{(2,168)}=11.25, P<0.001), but there was not significant differences between HIIT and MICT group.

Conclusion: Both HIIT and MICT can promote the physical fitness rehabilitation for individuals with SUD.

Clinical Trials Registry: ChiCTR1900022158 Chinese Clinical Trial Registry

Background

Substance use disorder (SUD) is a highly destructive, chronic and relapsing disease that brings adverse consequences to society and the individuals with SUD’s own psychology and physical, requiring more effective treatment methods (1). The social harm caused by the illicit drug problem is huge. At the same time, how to help individuals rehabilitate from drug abuse and return to normal life have become an important field of rehabilitation. Due to long-term drug abuse, individuals with SUD suffer serious physical and psychological damage, leading to the occurrence of various chronic diseases and complications (2, 3). The individuals with SUD had less protein, muscle mass and fat loss than the general, which resulted in hypertension reflexes, dyskinesia, and gait instability (4). In addition, SUD may lead to physical fitness decline, tachycardia, high blood pressure and chronic cardiovascular diseases (5). Physical and mental injuries affect the life self-confidence of patients with SUD, but also have a negative impact on detoxification. Effective physical health education and exercise guide are the best carrier to promote the integration of individual’s body and mind, the effective form to realize “strengthening the body and civilized the spirit”, and the best way to improve the recovery rate of drug withdrawal and reduce the relapse rate (6). A study showed that exercise may serve to complement other therapy and medication approaches for methamphetamine users, particularly if users are able to more readily utilize relapse prevention skills and incorporate positive behavioral changes consistent with treatment goals (7). Currently, exercise is considered as a potential new treatment for SUD and exercise intervention is also considered as an independent and important supplemental means for SUD (8). Exercise has become one of promising intervention methods for SUD because it is economic, long-term effect.

A growing body of research has demonstrated that aerobic exercise can be an effective and persistent treatment for those with substance use disorders (SUD), which can effectively increase the abstinence rate, ease withdrawal symptoms, and reduce anxiety and depression (9). Study indicates that moderate-intensity aerobic exercise has shown good rehabilitation benefits in assisting detoxification, relieving withdrawal syndrome and inhibiting relapse impulse and relapse behavior, and is considered relatively safe and green (10). Furthermore, a large number of theoretical and empirical studies have found that short-term, medium intensity aerobic exercise, traditional Chinese sports and resistance exercise can significantly improve the brain cognition, psychological behavior and physical function of the new type drug-dependent, improve the quality of life, and reduce the symptom of drug craving
In terms of psychological rehabilitation, many studies have shown that exercise can produce positive emotions for drug users, including emotion regulation, experiencing pleasure, reducing depression symptoms and insomnia (13, 14).

Although the mechanism of exercise detoxification is not clear, it does bring benefits to individuals with SUD. Studies have shown that exercise can improve executive function and brain activity (15), which may be an important reason to curb addiction in individuals with SUD. To further enhance the training effect, it is an important direction to explore the most suitable exercise mode. To date, many articles on drug rehabilitation have talked about benefits of moderate intensity continuous training (MICT). However, future research in the field of exercise intervention should focus on using anaerobic exercise as an intervention to explore whether there is a dose-effect relationship to inhibit relapse (16). Many studies compared the effect of HIIT and MICT. For example, research indicates HIIT have better effect on cognitive ability and cardiopulmonary function than MICT (17, 18). In fact, the results of sports studies show that MICT and HIIT are both beneficial but have different effects on the improvement of body function (19). Moreover, meeting the 2008 Physical Activity Guidelines for Americans minimum by either moderate- or vigorous-intensity activities was associated with nearly the maximum longevity benefit (20).

While people pay attention to MICT exercise rehabilitation, the emergence of HIIT has attracted much concern. The mental and cognitive health by HIIT, comparing to the traditional high-intensity sports, as an effective way to improve physical, has also attracted great interest in recent years.

There is increasingly evidence that despite a reduction in exercise duration and volume, HIIT resulted in similar or greater physical adaptations relative to MICT, including improvements in body composition, cardiovascular function, and metabolic health (21). Studies also show that compared with the traditional moderate-intensity continuous aerobic training, HIIT has better exercise enjoyment, and provides the same effect in the same effect in aerobic fitness, quality of life, efficiency, safety, tolerance and short-term exercise adherence (22).

HIIT not only brings more effective training to healthy people but also gradually becomes an important means for the rehabilitation of many chronic diseases. In recent years, HIIT has become a form of alternative or complementary aerobic endurance training. In long-term and short-term studies, it has the same value as, if not better than, MICT in terms of fitness, cardiovascular function, quality of life, exercise efficiency, safety, the tolerance and exercise adherence in a short period of time (23). The meta-analysis of 10 studies on patients with Coronary Artery Disease showed that HIIT was more effective in improving patients' mean VO$_2$peak than MICT (24). Studies had confirmed that HIIT can effectively prevent and treat type 2 diabetes and cardiovascular disease, and has great potential in the field of public health (25). Previous study has also found HIIT can improved SUD patients VO$_2$max, indicating that not only will they have a strongly decreased mortality rate, but also a considerable reduced risk of developing cardiovascular disease (26). Because of its time-saving and remarkable effect, HIIT has gradually become an alternative to the traditional training mode and achieved good results. An acute bout of HIIT can also be more enjoyable than an acute bout of MICT (27). Importantly, sedentary young adults report greater enjoyment from a single bout of HIIT and endorsed it as an exercise regime they would chose to continue on their own (27). Furthermore, a six week long-term HIIT and MICT trial for sedentary people also showed that during the six week period, the subjects’ enjoyment of HIIT increased while the pleasure of MICT decreased slightly (22). This seems to show that HIIT has better exercise enjoyment than MICT.

To date, only few articles in the literature discussed the effect of HIIT on substance abuse, one showed that HIIT was feasible for SUD patients in treatment, also, it is reported that HIIT can improve depression and reduce the risk of cardiovascular disease (26). However, the theoretical basis for adopting HIIT has not been fully confirmed in the scientific reports. The effects of MICT on the physical functioning of individuals with SUD have been demonstrated, but it is not clear whether different intensity or form of exercise produces the same or superior results. Considering the benefits and theoretical results of HIIT in the study of many chronic diseases, it is feasible to apply it in SUD. Therefore, the study puts forward the question—which exercise is better for SUD? HIIT or MICT? The purpose of this study was to compare on the physical fitness of HIIT or MICT intervention on the individual with SUD, the hypothesis was the HIIT has better physical fitness recovery effect than MICT for SUD.

**Methods**

**Design**
This single-blind (assessors-blind), two-group randomized controlled trial was conducted from January 2019 to December 2019. The study protocol was approved by the Ethical Committees of the Shanghai University of Sport and the Shanghai Narcotics Control Commission. Written consent was obtained from each participant.

**Participants**

The participants were all male amphetamine-type stimulant (ATS) dependent individuals. At the time of recruitment, a total 1200 individuals with SUD were receiving treatment in a Shanghai Compulsory Rehabilitation Center (SCRC). There were 120 ATS dependent subjects voluntarily participated in this study. The inclusion criteria were 1) age 18-40; 2) subjects who met the diagnosis of MA dependence according to Diagnostic and Statistical Manual of Mental Disorders criteria (DSM-IV); 3) the treatment duration in SCRC should be more than 1 year; 4) no serious medical or mental illness; 5) primary school or above of education. Exclusion criteria: 1) currently diagnosed diseases of the cardiovascular system, respiratory system, and nervous system; 2) anti-social personality disorder and borderline personality disorder; 3) subjects who were unwilling to accept the assigned intervention conditions were excluded.

**Intervention**

The participants were assigned randomly by computer-generated randomization to either the HIIT (n = 60) or MICT groups (n = 60). They participated in exercise sessions three times a week for 12 consecutive months.

**HIIT group**

The training contents in the HIIT group included non-confrontational basketball training, resistance training (weight training and strength machines), rope skipping and running. The exercise intensity was monitored by heart rate monitor (Polar TeamPro), and the heart rate was maintained at 80-85% of the subjects' maximum heart rate (80-85%HR\(_{\text{max}}\)). The duration of each training session was 60 minutes, 10 minutes for warm-up and 10 minutes for cool-down, 3 times a week. Trainings were arranged on Monday, Wednesday and Friday. The main content of each training session was divided into three parts: basketball (15 minutes), weight training (15 minutes) and running (10 minutes) from January to March; basketball (15 minutes), weight training (15 minutes) and rope skipping (10 minutes) from April to June; weight training (15 minutes), strength machines training (15 minutes) and running (10 minutes) from July to September; basketball (15 minutes), weight training (15 minutes) and running (10 minutes) from October to December. The training patterns were short interval training organized by the experienced instructors from Shanghai university of sport. An exercise training expertise team instructed and supervised the training plan of the HIIT group.

**MICT group**

The MICT group was trained with Tai Chi, mind-body exercise and recreation activity. The heart rate during the exercise was 55-65% of the maximum heart rate (55-65%HR\(_{\text{max}}\)). The duration of the MICT intervention was similar to that of the HIIT intervention and the training intervention of the two groups was conducted at the same time. The Tai Chi for the MICT group was a kind of modified Tai Chi. The recreation activity was adopted the ninth edition of “Guang Bo Ti Cao” designed by the China General Administration of Sports, while the mind-body exercise was adopted a kind of modified Qi Gong, Tai Chi and Yoga with moderate intensity. Each session in the MICT group included a 10 min recreation activity (Guang Bo Ti Cao), 10 min mind-body exercise and 20 min Tai Chi. The duration of Tai Chi in a training session was increased more than 20 minutes in the second half year, along with the reduction of the training duration of mind-body exercise and recreation activity. One experienced instructor from the Shanghai University of Sport instructed the MICT group.

**Procedure**

The participants were informed of the purpose of this study and signed a consent form during the admission process. The study was performed in accordance with the Declaration of Helsinki II. The HIIT and MICT interventions were performed on a basketball field under fair weather or in an indoor fitness gym. The intervention outcomes of physical fitness were assessed at the baseline, 3 months, 6 months, 9 months and 12 months, the ATS craving level was assessed at the baseline, 6 months and 12 months. The experienced researchers conducted the assessment and were blinded to the two groups.
Outcome measures

The primary outcomes

The physical fitness tests were administered by experienced investigators. Measurements were performed in the morning at the same time. Blood pressure was measured under standardized conditions prior to other tests: participants were asked to rest for 5 min and had not taken any caffeine or tobacco products within 30 minutes. Heart rate of individuals with SUD was monitored with Polar TeamPro.

The fitness test followed the protocol of national physical fitness test. Push-up, sit-and-reach, one-leg stand with eyes closed, vital capacity (VC), height and weight, choice reaction time, hand grip assessment were used the model of BW-FC-9201L (Fitness Assessment System) to test the physical fitness outcomes. All tests were repeated twice and the best performance was recorded. VC measurement requires that subject holds the test instrument and breathes out all the air with maximum force after the maximum inhalation. Muscle strength tests include hand grip and push-up. During the hand grip test, the subjects applied the dominant hand to grasp the grip strength device with the maximum strength. The push-up test was performed on the push-up testers, subjects’ forefoot or toes on floor, hips and back keep straight, the push-up tester placed near subject’s chest, the repetition numbers were counted automatically by push-up tester whenever the torso down-and-up front of the tester sensors. The test index of flexibility is sit and reach. The subject sits in front of the device with slippers and knees straight. Stretch their hands and body forward as far as possible, measuring the maximum distance where subjects’ fingertips can reach. In the choice reaction time test, the subjects used the middle and index fingers of the dominant hand to quickly press the random signal button. The balance function was measured by the duration of standing on one leg with eyes closed. During the test, the subjects stood on the test mat with the dominant leg, eyes closed, then recorded the time of standing on one leg.

The secondary outcome

The craving level was assessed using the visual analog scale (VAS), which is a response scale that measures subjective attitudes that could not be observed directly. Subjects were asked to indicate, on a scale from 0 (no craving for ATS drugs) to 10 (strong craving for ATS drugs), the extent of their craving for ATS drugs, a VAS is considered an appropriate means of assessing cue-induced ATS craving (28).

Statistical analyses

Statistical analyses were performed using SPSS 22.0 (Chicago, USA). Pearson chi-squared test was applied for categorical variables of demography, and independent sample t-test was applied for continuous variables at the baseline comparison. Pearson chi-squared test and independent sample t-test was used to compare the demographic characteristics differences at baseline.

A two-way repeated measures analysis of variance (ANOVA) was applied to test whether the treatments were different after 24 weeks. Time (baseline, 3 month, 6 month, 9 month, 12 month) was the within-group factor, groups (HIIT and MICT) were the between-group factors for the physical fitness comparison. Time (baseline, 6 month, 12 month) was the with-group factor, groups (HIIT and MICT) were there between-group factors for the craving level of VAS comparison. A post hoc test with LSD correction was used to examine which group was different if the ANOVA showed a significant interaction. All data were presented as the mean ± standard deviation and a p-value <0.05 was considered statistically significant.

Results

A total of 120 male individuals with SUD participated in the study, in which, 86 completed the intervention, 34 subjects dropped out because of different reasons. The details were shown in figure 1.

The subjects in the HIIT group were: age, 33.65±4.27 years; height, 172.69±5.65 cm; weight, 76.05±10.95 kg; the years of illicit drug use, 8.90±5.22 years. Subjects in the MICT group were: age, 32.20±5.07 years; height, 174.36±5.70cm; weight, 76.33±9.54kg; the years of illicit drug use, 7.14±4.53years. At baseline, the independent T-test result of the physical fitness and craving level of VAS between the two groups were no significant difference, p>0.05 (Table 1).

Physical fitness
After the 12 months exercise intervention, significant differences were found in the within-group factor in SBP ($F_{(4,336)} = 12.799, \ P<0.001$) and DBP ($F_{(4,336)} = 9.495, \ P<0.001$). No significant interactions of group × time were found in SBP and DBP.

Significant differences were found in the within-group factor in VC ($F_{(4,336)} = 18.121, \ P<0.001$), hand-grip power ($F_{(4,336)} = 34.815, \ P<0.001$), sit-and-reach ($F_{(4,336)} = 13.871, \ P<0.001$), one-leg stand with eyes closed ($F_{(4,336)} = 14.495, \ P<0.001$) and choice reaction time ($F_{(4,336)} = 20.603, \ P<0.001$) tests. No significant interactions of group × time were found in terms of VC, hand-grip power, sit-and-reach, one-leg stand with eyes closed, choice reaction time and push-up test. After 12 months training, the physical fitness change of two groups is shown in table 2.

Although the balance in both groups was improved from the beginning, the both groups was found that the improvement occurred in the first half year, the balance test by one-leg stand with eyes closed was not improved in the second half year. The result indicated that the MICT group had better balance score comparing to the HIIT group (Figure 2).

Subjects both in HIIT and MICT improved the upper-limb strength gradually tested by push-up, although the mean differences of subjects in HIIT group was 4.4 more than subjects in MICT group, there was no significant difference with interaction of group × time found in this test (Figure 3).

**The level of craving**

The craving level of VAS after the 12 months exercise intervention was found significantly decrease ($F_{(2,168)} = 11.25, \ P<0.001$) in both groups, but no significant difference with interactions of group × time were found in VAS (Figure 4).

**Discussion**

**Physical fitness improved in both groups**

In this study, a randomized controlled trial of HIIT and MICT was conducted to explore whether HIIT is more conducive to the rehabilitation of physical functions for individuals with SUD. During the 12 months exercise intervention, HIIT and MICT groups were found significantly improved in VC, grip strength, sit-and-reach, choice reaction time, one-leg stand with eyes closed, push-up. The blood pressure and the craving level in the two groups decreased significantly, but no significant differences were found between the HIIT group and MICT group.

**Choice reaction time declined**

Choice reaction time (CRT) is one of the most important indicators of physical fitness. It reflects the function of the human nervous system to some extent. The smaller the reaction time, the faster the human body responses, the better the function of the nervous system is. Performance in a CRT task is applied as an indicator of cognitive capacity, including aspects of eye-hand reaction time, attentiveness, and processing speed(29). In this study, The CRT in the experimental group decreased by 0.03s, the CRT in the control group decreased by 0.04s. There was no significant difference between groups, whereas, both groups found a significant difference in CRT compared to the baseline. The results are consistent with that physical activity can improve CRT, which indicates that no matter what form of exercise, it is helpful to improve the reaction time. The improvement of reaction time may be explained by the fact that physical exercise can improve the function of central nervous system (Figure 5).

**Balance improved**

The one-leg stand with eyes-closed test was performed to measure the balance control of the subjects. The increase in time spent standing on one foot with eyes closed in individuals with SUD indicated the improvement of their balance ability. Previous study showed an improvement in balance control after long term practice of Tai Chi (30). In this study, the MICT group was able to stand on one leg with eyes closed for 14s longer than baseline while the HIIT group was 11s longer than baseline. The evidence proved that both HIIT and MICT can improve balance ability. However, although there was no significant difference between groups, MICT group seems to have more potential to improve balance than HIIT group because of Tai Chi content arranged.

**Blood pressure decreased**
The subjects in HIIT and MICT group had the same effect on diastolic and systolic blood pressure, both types of training effectively reduced blood pressures for individuals of SUD. A reduction in blood pressure can have a positive effect on the health of individuals. At present, systemic blood pressure is controlled by total peripheral resistance, which is determined by the diameter of small arteries and arterioles (30). The decrease in blood pressure in individuals with SUD may be due to increased flexibility in their blood vessels through training and reduced peripheral resistance. In this study, exercise intervention can significantly reduce blood pressure, which may be due to the Tai Chi and HIIT exercise which improve the cardiac function for subjects, as well as increase stroke output and blood circulation. The relaxation form of exercise may reduce the tension of vascular center and vascular smooth muscle, and accelerate blood flow leading to the reduction of blood pressure. The practice of regular physical exercise can reduce resting blood pressure chronically, as a result, it induce post-exercise hypotension, which is a reduction in blood pressure below resting values after exercise training (31). Therefore, HIIT and MICT have a similar effect to reduce blood pressure. Both HIIT and MICT can be applied as effective exercises for rehabilitation for individuals with SUD in term of reducing blood pressure.

**Flexibility and vital capacity improved**

HIIT, MICT or Tai Chi exercise for different types of participants were all able to improve the flexibility for subjects (32, 33), which is the same as the results of this study. Result shows that the two kinds of exercises have similar promoting effects on muscle flexibility.

In this study, vital capacity in HIIT group was increased by 496 ml, whereas, MICT group was increased by 514 ml. The results demonstrated improvements in vital capacity were similar. Some preliminary evidence suggests that Tai Chi exercise may increase lung function (34, 35). One of the explanations is that Tai Chi combines breathing with movement closely to improve breathing efficiency. Furthermore, study shows HIIT and MICT are both effective for improving lung function(36). HIIT is at least as effective as MCT for improving functional capacity and quality of life measures in patients with pulmonary disease (36). Therefore, the experimental results are similar to those of some studies, which prove that both HIIT and MICT have similar effects on improving lung vital capacity.

**HIIT is better in strength development**

In this study, from the data, the grip strength of HIIT group was increased by 5.48kg, while subjects in MICT group was increased by 4.68kg; The number of push-up in HIIT group was increased by 7 repetitions, while subjects in MICT group was increased less than 5 repetitions. The results showed that the improvement of grip strength in the two groups was similar, but the improvement of push up in HIIT group was better than that in MICT group. This demonstrated both groups increased (P < 0.05) muscle strength; whereas, greater muscle strength gains in HIIT group. The possible explanation is the training content of HIIT group includes resistance training (37), which can effectively improve the muscle strength. This result has been supported in the previous study. A study reported HIIT is better at improving upper limb, waist and abdominal strength for individuals with SUD (33).

Interestingly, muscle strength increased was also observed in MICT group. Some preliminary evidence suggests that Tai Chi exercise may increase the body's muscle strength (38, 39). However, study finds Tai Chi has no advantages in improving muscle strength (30). It is not sure whether Tai Chi intervention improved the strength in MICT group, because subjects in MICT group not only practiced Tai Chi, but also engaged in medium intensity broadcast exercise.

**Does HIIT training has better effect than MICT?**

After 12 months exercise training, the results showed HIIT and MICT training have the same effect on the physical fitness for individuals with SUD. The results are not consistent with the previous hypothesis. Generally, the greater the intensity of exercise causing the more profound the stimulation to the human body, the more significant the training effect has. However, the differences of physical fitness and craving level between the two groups were not significant. In terms of standing on one leg with eyes closed, the benefits of the subjects in control group was even better than those of the experimental group. The advantage of HIIT over MICT is mainly in effect of cardiovascular function (40), but there is no evidence that HIIT training is superior to MICT.

Several studies have shown the same effect of HIIT and MICT. In the exercise intervention with HIIT for type 2 diabetes over 12-week, it was found that there was no significant difference in the test indicators of positively altering body fat, increasing peak power output, glucose control, cardiovascular risk, and microvascular complication markers in the HIIT group and the MICT group.
In an exercise intervention for obese men, HIIT was verified as an equally effective exercise mode for improving 24-h glycemic control in overweight and obese adults comparing to MICT (41). However, Haykowsky et al. (42) showed that HIIT was superior to MICT in terms of improving VO$_2$ peak for patients with congestive heart failure, with similar effects on left ventricular function and exercise compliance. Similarly, in patients with coronary heart disease, studies demonstrated HIIT has greater effect on ventilatory threshold and VO$_2$ peak compared to MICT, with similar effects on blood pressure (43, 44).

As can be seen from this, the advantages and disadvantages of HIIT and MICT are still uncertain, many studies believe that these two training methods can produce equal benefits. There may be several reasons for this phenomenon. First, patients with different symptoms are suitable for different training methods, and different training methods can produce different benefits at different stages of the disease. For example, long term continuous aerobic exercise training plays an important role in maintaining the health and well-being of patients with cardiovascular disease, including the potential to maintain ability of self-care and clinical benefits during aging (45-47). Short HIIT is useful in the initial and improved stages of cardiac rehabilitation, while MICT or HIIT regimens seem to be more appropriate for the improvement and maintenance stages, as they have higher physiological stimulation (24).

Secondly, the correlation between the physical benefits and the amount of exercise generated by HIIT and MICT is greater than the intensity of exercise. Martin J. Gibala et al. (48) compared the 6-week HIIT based on Wingate with the traditional endurance training, it was found that although the weekly training amount (90% reduction in HIIT group) and time input (67% decreased in HIIT group), the training had similar improvement on various indexes of skeletal muscle and cardiovascular adaptation. Related studies focus more on the difference between these two training methods and less on the comparison of the total amount of exercise in the same or different situations. Thirdly, there is no exploration of the optimal intensity of HIIT training currently. Different intensity of HIIT training may have different effects on the various subjects.

Conclusion

The HIIT and MICT are both effective training methods to improve physical fitness for individuals with SUD. HIIT training method doesn’t show superior to MICT in terms of physical fitness after 12 months intervention for subjects with SUD.

Limitations

The participants were selected from a Shanghai mandatory detoxification and rehabilitation center. As physical activity is benefit for drug dependents physically and mentally, exercise as a supplementary treatment is one of drug rehabilitation treatments listed in Shanghai detoxification and rehabilitation centers. All substance dependents need to participate in physical activity. Therefore, it is hardly to find any participant does not engage in sports. This is a limitation that we can’t confirm the level of benefits brought by exercise training.

Generally, the exercise intensity of HIIT is 90%-95% HRmax (49, 50), while the exercise intensity of the experimental group in this study was basically around 80%-85%HRmax. This is because most of the subjects belonged to the low-exercise group, their physical conditions were weak after taking illicit drugs. Considering the exercise risk of the subjects, the optimal exercise intensity could not be achieved. The actual exercise intensity in HIIT group may not be the optimal intensity to stimulate the physical function of individuals with SUD, which maybe one of the factors that caused no significant difference between the HIIT group and MICT group.

The long-term effect of HIIT training for individuals with SUD is still unclear, the mechanism of HIIT training needs further confirmation. In the future study of exercise intervention, the exercise intensity of the HIIT will be further enhanced to maintain at 90%HRmax or higher, and the interval time will be strictly controlled.

Abbreviations

HIIT: High-intensity Interval Training; MICT: Moderate-intensity Continuous Training; SUD: Substance Use Disorder; BP: Blood Pressure; SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; VC: Vital Capacity; VAS: Visual Analog Scale; ATS: Amphetamine-type Stimulant; MA: Methamphetamine; SCRC: Shanghai Compulsory Rehabilitation Center; DSM-IV: Diagnostic and Statistical Manual of Mental Disorders Criteria; CRT: Choice Reaction Time
Declarations

Acknowledgement

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Authors contributions

Dong Zhu, Yan-guang Yang and Jing-yi Chen contributed to design of the study, analysis and interpretation of the data and writing of the manuscript. Xiao-Wu Pang, Meng-lu Shen, Tian-yuan Wang and Jia-bin Wang designed the training plan, guided the participants in exercise and tested the participants. Su-yong Yang, Ding Xu and Ke Xiao collected data and approved final version of manuscript. All authors read and approved the manuscript and have given consent for the submission of the final article.

Ethics approval and consent to participate

Ethics approval was obtained from the Ethical Committees of the Shanghai University of Sport and the Shanghai Narcotics Control Commission (SNCC). All subjects provided written informed consent to participate in the study and to have their results analyzed.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analysed during the current study are available from corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Conflicts of Interest

The authors declare no conflicts of interest. The results of the present study do not constitute endorsement by ACSM. The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation.

References

1. Bellamoli E, Manganotti P, Schwartz RP, et al. rTMS in the Treatment of Drug Addiction: An Update about Human Studies. Behav Neurol. 2014;2014:11.
2. Kolodny A, Courtwright DT, Hwang CS, et al. The prescription opioid and heroin crisis: a public health approach to an epidemic of addiction. Annu Rev Public Health. 2015;36:559-74.
3. Vowles KE, McEntee ML, Julnes PS, et al. Rates of opioid misuse, abuse, and addiction in chronic pain: a systematic review and data synthesis. Pain. 2015;156(4):569-76.
4. Liu QQ, Gericke CA. Yulu Shequ - a unique rehabilitation program for illicit drug users in Kaiyuan in southwest China. Harm Reduct J. 2011;8:4.
5. Cruickshank CC, Dyer KR. A review of the clinical pharmacology of methamphetamine. Addiction. 2009;104(7):1085-99.
6. Magill M, Ray LA. Cognitive-behavioral treatment with adult alcohol and illicit drug users: a meta-analysis of randomized controlled trials. Journal of studies on alcohol and drugs. 2009;70(4):516-27.
7. Mooney LJ, Cooper C, London ED, et al. Exercise for methamphetamine dependence: rationale, design, and methodology. Contemp Clin Trials. 2014;37(1):139-47.
8. Lynch WJ, Peterson AB, Sanchez V, et al. Exercise as a novel treatment for drug addiction: a neurobiological and stage-dependent hypothesis. Neurosci Biobehav Rev. 2013;37(8):1622-44.
9. McLachlan CD, Hay M, Coleman GJ. The effects of exercise on the oral consumption of morphine and methadone in rats. Pharmacology, biochemistry, and behavior. 1994;48(2):563-8.
10. McNamara J, McCabe MP. Striving for success or addiction? Exercise dependence among elite Australian athletes. J Sports Sci. 2012;30(8):755-66.
11. Zhu D, Dai G, Xu D, et al. Long-Term Effects of Tai Chi Intervention on Sleep and Mental Health of Female Individuals With Dependence on Amphetamine-Type Stimulants. Front Psychol. 2018;9:1476.
12. Wang D, Zhou C, Chang YK. Acute exercise ameliorates craving and inhibitory deficits in methamphetamine: An ERP study. Physiol Behav. 2015;147:38-46.
13. de Oliveira MS, da Silva Fernandes MJ, Scorza FA, et al. Acute and chronic exercise modulates the expression of MOR opioid receptors in the hippocampal formation of rats. Brain Res Bull. 2010;83(5):278-83.
14. Brown RA, Abrantes AM, Read JP, et al. A Pilot Study of Aerobic Exercise as an Adjunctive Treatment for Drug Dependence. Ment Health Phys Act. 2010;3(1):27-34.
15. D'Souza MS. Brain and Cognition for Addiction Medicine: From Prevention to Recovery Neural Substrates for Treatment of Psychostimulant-Induced Cognitive Deficits. Front Psychiatry. 2019;10:509.
16. Colledge F, Gerber M, Puhse U, et al. Anaerobic Exercise Training in the Therapy of Substance Use Disorders: A Systematic Review. Front Psychiatry. 2018;9:644.
17. Ismail H, McFarlane JR, Nojoumian AH, et al. Clinical outcomes and cardiovascular responses to different exercise training intensities in patients with heart failure: a systematic review and meta-analysis. JACC Heart Fail. 2013;1(6):514-22.
18. Chang YK, Labban JD, Gapin JI, et al. The effects of acute exercise on cognitive performance: a meta-analysis. Brain Res. 2012;1453:87-101.
19. Terada T, Friesen A, Chahal BS, et al. Feasibility and preliminary efficacy of high intensity interval training in type 2 diabetes. Diabetes Res Clin Pract. 2013;99(2):120-9.
20. Arem H, Moore SC, Patel A, et al. Leisure time physical activity and mortality: a detailed pooled analysis of the dose-response relationship. JAMA Intern Med. 2015;175(6):959-67.
21. Pentz MA, Riggs NR. Longitudinal relationships of executive cognitive function and parent influence to child substance use and physical activity. Prevention science: the official journal of the Society for Prevention Research. 2013;14(3):229-37.
22. Heisz JJ, Tejada MGM, Paolucci EM, et al. Enjoyment for High-Intensity Interval Exercise Increases during the First Six Weeks of Training: Implications for Promoting Exercise Adherence in Sedentary Adults. PLoS One. 2016;11(12):10.
23. Gayda M, Ribeiro PA, Juneau M, et al. Comparison of Different Forms of Exercise Training in Patients With Cardiac Disease: Where Does High-Intensity Interval Training Fit? Can J Cardiol. 2016;32(4):485-94.
24. Liou K, Ho S, Fildes J, et al. High Intensity Interval versus Moderate Intensity Continuous Training in Patients with Coronary Artery Disease: A Meta-analysis of Physiological and Clinical Parameters. Heart Lung Circ. 2016;25(2):166-74.
25. Biddle SJ, Batterham AM. High-intensity interval exercise training for public health: a big HIT or shall we HIT it on the head? Int J Behav Nutr Phys Act. 2015;12:95.
26. Flemmen G, Unhjem R, Wang E. High-Intensity Interval Training in Patients with Substance Use Disorder. Biomed Res Int. 2014;2014:8.
27. Jung ME, Bourne JE, Little JP. Where Does HIT Fit? An Examination of the Affective Response to High-Intensity Intervals in Comparison to Continuous Moderate- and Continuous Vigorous-Intensity Exercise in the Exercise Intensity-Affect Continuum. PLoS One. 2014;9(12):18.
28. Du J, Sun H, Huang D, et al. Use trajectories of amphetamine-type stimulants (ATS) in Shanghai, China. Drug and alcohol dependence. 2014;143:44-50.
29. Deary IJ, Liewald D, Nissan J. A free, easy-to-use, computer-based simple and four-choice reaction time programme: the Deary-Liewald reaction time task. Behav Res Methods. 2011;43(1):258-68.
30. Zhu D, Xu D, Dai G, et al. Beneficial effects of Tai Chi for amphetamine-type stimulant dependence: a pilot study. Am J Drug Alcohol Abuse. 2016;42(4):469-78.
31. Amaral AL, Mariano IM, Carrijo VHV, et al. A Single Dose of Beetroot Juice Does Not Change Blood Pressure Response Mediated by Acute Aerobic Exercise in Hypertensive Postmenopausal Women. Nutrients. 2019;11(6):1327.
32. Rand D, Miller WC, Yiu J, et al. Interventions for addressing low balance confidence in older adults: a systematic review and meta-analysis. Age Ageing. 2011;40(3):297-306.
33. da Silva MR, Waclawovsky G, Perin L, et al. Effects of high-intensity interval training on endothelial function, lipid profile, body composition and physical fitness in normal-weight and overweight-obese adolescents: A clinical trial. Physiol Behav. 2020;213:8.
34. Niu R, He R, Luo BL, et al. The effect of tai chi on chronic obstructive pulmonary disease: a pilot randomised study of lung function, exercise capacity and diaphragm strength. Heart Lung Circ. 2014;23(4):347-52.
35. Ngai SPC, Jones AYM, Tam WWS. Tai Chi for chronic obstructive pulmonary disease (COPD). Cochrane Database Syst Rev. 2016(6):97.
36. Ross LM, Porter RR, Durstine JL. High-intensity interval training (HIIT) for patients with chronic diseases. J Sport Health Sci. 2016;5(2):139-44.
37. Carneiro MAS, de Oliveira AA, Martins FM, et al. High-intensity interval body weight training promotes different adaptations to combined training in body composition and muscle strength in young women. Science & Sports. 2018;33(3):e105-e13.
38. Li JX, Xu DQ, Hong Y. Changes in muscle strength, endurance, and reaction of the lower extremities with Tai Chi intervention. J Biomech. 2009;42(8):967-71.
39. Tsang WW, Hui-Chan CW. Comparison of muscle torque, balance, and confidence in older tai chi and healthy adults. Med Sci Sports Exerc. 2005;37(2):280-9.
40. Locke SR, Bourne JE, Beauchamp MR, et al. High-Intensity Interval or Continuous Moderate Exercise: A 24-Week Pilot Trial. Med Sci Sports Exerc. 2018;50(10):2067-75.
41. Parker L, Shaw CS, Banting L, et al. Acute Low-Volume High-Intensity Interval Exercise and Continuous Moderate-Intensity Exercise Elicit a Similar Improvement in 24-h Glycemic Control in Overweight and Obese Adults. Front Physiol. 2016;7:661.
42. Haykowsky MJ, Timmons MP, Kruger C, et al. Meta-analysis of aerobic interval training on exercise capacity and systolic function in patients with heart failure and reduced ejection fractions. Am J Cardiol. 2013;111(10):1466-9.
43. Pattyn N, Coeckelberghs E, Buys R, et al. Aerobic interval training vs. moderate continuous training in coronary artery disease patients: a systematic review and meta-analysis. Sports Med. 2014;44(5):687-700.
44. Elliott AD, Rajopadhyaya K, Bentley DJ, et al. Interval training versus continuous exercise in patients with coronary artery disease: a meta-analysis. Heart Lung Circ. 2015;24(2):149-57.
45. Mandic S, Stevens E, Hodge C, et al. Long-term effects of cardiac rehabilitation in elderly individuals with stable coronary artery disease. Disabil Rehabil. 2016;38(9):837-43.
46. Magalhães S, Miguel Ribeiro M, Barreira A, et al. Long-term effects of a cardiac rehabilitation program in the control of cardiovascular risk factors. Revista Portuguesa de Cardiologia (English Edition). 2013;32(3):191-9.
47. Goel K, Pack QR, Lahr B, et al. Cardiac rehabilitation is associated with reduced long-term mortality in patients undergoing combined heart valve and CABG surgery. Eur J Prev Cardiol. 2015;22(2):159-68.
48. Gibala MJ, Little JP, Macdonald MJ, et al. Physiological adaptations to low-volume, high-intensity interval training in health and disease. J Physiol. 2012;590(5):1077-84.
49. Weston KS, Wisloff U, Coombes JS. High-intensity interval training in patients with lifestyle-induced cardiometabolic disease: a systematic review and meta-analysis. Br J Sports Med. 2014;48(16):1227-34.
50. Williams DM, Dunsiger S, Whiteley JA, et al. Acute effects of moderate intensity aerobic exercise on affective withdrawal symptoms and cravings among women smokers. Addict Behav. 2011;36(8):894-7.

Tables

Table 1. Demographic characteristics

|                   | HIIT group     | MICT group     | P-value |
|-------------------|----------------|----------------|---------|
| (n=60)            | (n=60)         |                |         |
| Means             | Means          |                |         |
| Height [cm]       | 172.69         | 174.36         | 0.889   |
| Weight [kg]       | 76.05          | 76.34          | 0.109   |
| Age [y]           | 33.65          | 32.2           | 0.093   |
| Year of illicit drug use [y] | 8.9            | 7.14           | 0.417   |
| Systolic BP [mmHg] | 127.9          | 128.22         | 0.328   |
| Diastolic BP [mmHg] | 74.9           | 73.41          | 0.29    |
| Vital capacity [ml] | 3983.74        | 4116.93        | 0.059   |
| Hand grip [Kg]    | 47.24          | 48.08          | 0.801   |
| Push up (Rep)     | 26.26          | 21.66          | 0.173   |
| Sit-and-reach [cm] | 15.11          | 15.57          | 0.173   |
| One-leg stand with eyes closed [s] | 23.71          | 22.82          | 0.74    |
| Choice reaction time [ms] | 0.5409         | 0.5331         | 0.074   |
| Craving level of VAS | 2.16           | 2.54           | 0.37    |

BP: blood pressure; VAS: visual analogue scale;

Table 2. The physical fitness comparison between HIIT and MICT group
|                          | HIIT \(n=40\) | MICT \(n=46\) | Within-group | Between-group | Time Group |
|--------------------------|---------------|---------------|--------------|---------------|------------|
|                          | Baseline      | 12 months     | Baseline     | 12 months     | F value    | F value    | F value    |
| Systolic BP [mmHg]       | 129.40±16.39  | 123.03±15.34  | 124.32±20.53 | 123.5±16.28   | 12.799**   | 0.384      | 1.647      |
| Diastolic BP [mmHg]      | 75.10±11.75   | 70.90±8.81    | 70.32±11.94  | 71.55±14.69   | 9.495**    | 0.796      | 1.665      |
| Vital capacity [ml]      | 3891.53±779.25| 4475.83±853.85| 4192.93±538.29| 4647.39±1032.35| 18.121**   | 1.117      | 0.519      |
| Grip strength [Kg]       | 47.21±7.24    | 51.75±7.22    | 48.08±7.72   | 52.23±7.41    | 34.815**   | 0.315      | 0.058      |
| Push up (Rep)            | 23.67±17.08   | 43.40±21.12   | 20.87±13.65  | 37.03±20.08   | 28.805**   | 3.017      | 0.587      |
| Sit and reach [cm]       | 15.41±5.92    | 15.88±7.98    | 14.76±6.55   | 13.97±7.74    | 13.871**   | 1.654      | 0.277      |
| One-leg stand with eyes closed [s] | 21.61±14.32 | 30.33±24.09 | 21.22±16.38 | 37.02±27.75 | 14.495**   | 1.102      | 1.112      |
| Choice reaction time [s] | 0.55±0.10     | 0.47±0.06     | 0.52±0.07    | 0.48±0.06     | 20.603**   | 0.639      | 1.662      |

Rep: repetition; BP: blood pressure; *p<0.05; **p<0.01.