A 2-week high-intensity interval training intervention improves ejaculation control among men with premature ejaculation

Received: 23 February 2023 | Revised: 25 May 2023 | Accepted: 27 May 2023

DOI: 10.1111/andr.13469

ANDROLOGY

WILEY

ORIGINAL ARTICLE

A 2-week high-intensity interval training intervention improves ejaculation control among men with premature ejaculation

Caoyuan Niu[1,2] | Guangju Wen[1,2] | Daniel Ventus[3] | Yikang Zhang[4] | Patrick Jern[5] | Pekka Santtila[1,2]

[1]School of Psychology and Cognitive Science, East China Normal University, Shanghai, China

[2]Faculty of Arts and Sciences, NYU Shanghai, Shanghai, China

[3]Experience Lab, Faculty of Education and Welfare Studies, Åbo Akademi University, Abo, Finland

[4]Faculty of Psychology and Neuroscience, Maastricht University, Maastricht, The Netherlands

[5]Department of Psychology, Åbo Akademi University, Abo, Finland

Correspondence
Caoyuan Niu, School of Psychology and Cognitive Science, East China Normal University, Shanghai, China.
Email: 52213200016@stu.ecnu.edu.cn

Funding information
The NYU-ECNU Institue for Social Development at NYU Shanghai Internal Fund

Abstract

Background: Premature ejaculation (PE), which leads to substantial distress in men and their partners, is a common male sexual dysfunction worldwide. However, there is still a lack of effective treatments without side effects.

Objectives: We investigated the effect of high-intensity interval training (HIIT) on PE symptoms.

Materials and methods: We recruited 92 Chinese men aged 18–36 to complete the experiment. There were 22 (13 in the control group; 9 in the HIIT group) men diagnosed with PE and 70 (41 in the control group; 29 in the HIIT group) men with normal ejaculatory function. In the HIIT group, participants completed HIIT exercises every morning for 14 days. Participants also completed surveys inquiring about demographic information, erectile function, PE symptoms, body image (including sexual body image), physical activity, and sexual desire. The heart rate was measured before and after each HIIT. In the control group, participants were instructed not to do HIIT, but other procedures were the same as in the HIIT group.

Results: Results indicated that the HIIT intervention alleviated PE symptoms in men with PE. In addition, in the HIIT group, men with PE who had a higher heart-rate increase during the HIIT intervention reported the greatest overall decrements in PE symptoms. In men with normal ejaculatory function, HIIT did not decrease PE symptoms. In addition, increments in the heart rate during the intervention were associated with more pronounced PE symptoms post-intervention in this group. Analyses of secondary outcome measures suggested that the HIIT intervention improved general and sexual body image satisfaction of men with PE compared to before the intervention.

Discussion and conclusion: In summary, HIIT intervention may reduce PE symptoms in men with PE. The heart-rate increase during the intervention may be a key factor influencing the effect of the HIIT intervention on PE symptoms.

KEYWORDS
body image, heart rate, physical exercise, premature ejaculation, sexual desire

1 | INTRODUCTION

Premature ejaculation (PE), which is associated with negative outcomes in men and their partners, is a common sexual complaint worldwide. However, the etiology of PE is not well understood and there are no generally effective interventions available that are also without side effects. Physical exercise interventions have shown some promise to improve the control of ejaculation.[1] However, to our knowledge, no study has investigated the effect of high-intensity interval training (HIIT) on ejaculation control. The present study aimed to explore the effect of HIIT on ejaculation control in men with and without PE.

1.1 | Premature ejaculation

PE is defined as an inability to control the timing of ejaculation and a short ejaculation latency time (i.e., the time between the first vaginal penetration to ejaculation), and subsequent sexual distress.[2–4] PE leads to several negative outcomes for men. Compared to men without PE, men with PE report lower self-confidence and self-esteem,[5,6] higher levels of anxiety and depression,[7] and more interpersonal difficulties.[8,9] Moreover, partners of men with PE report lower relationship and sexual satisfaction and have an increased risk of sexual dysfunctions.[10,11] In addition, a large cross-cultural study found that almost 25% of women reported that they had ended relationships with men because of their early ejaculation problems.[12]

1.2 | Sympathovagal imbalance hypothesis

The etiology of PE is poorly understood.[2] A recent review suggested that a possibly important factor in the etiology of PE may be sympathovagal imbalance.[13] Sympathovagal imbalance reflects an autonomic state with sympathetic overactivation and is associated with stress, cardiac morbidity, and mortality[14] as well as psychopathology.[15]

While the autonomic nervous system's role in the male sexual response is not yet fully understood, a certain balance and timing of the sympathetic and parasympathetic nervous systems are necessary for a well-functioning sexual response.[16] First, the parasympathetic activity enables erection, by eliciting the relaxation of muscles otherwise constricting the flow of blood into the penis. Then, in the ejaculation phase, the sympathetic nervous system has the dominating role, facilitating the emission of seminal fluid.[16] Previous studies suggest that men with PE display earlier and higher levels of sympathetic activation than sexually functional controls in both non-aroused[17] and sexually aroused settings.[18] In addition, Turan and Gürel[19] reported that men with PE had impaired heart-rate recovery compared to a control group with normal ejaculatory function after stress tests, indicating excessive activation of the sympathetic nervous system among men with PE. Also, a recent study found that during a 24-h interval of heart-rate monitoring, men with PE have lower parasympathetic activity and higher sympathetic/parasympathetic ratio, an indicator of the sympathovagal imbalance in the autonomic nervous system, compared with a control group.[13] Finally, a sympathetic/parasympathetic ratio above 2.7 predicted PE with high sensitivity.[13] Therefore, we assumed that sympathovagal imbalance may explain at least some of the etiology of PE.

1.3 | Physical exercise

A recent review indicated that physical exercise has a positive effect on autonomic activity.[20] Brenner and colleagues[21] found that 12 weeks of low-intensity (pain-free walking) exercise increased the parasympathetic and decreased sympathetic activity, and also improved autonomic nervous system regulation in patients with peripheral artery disease. More physical exercise was also associated with fewer PE symptoms.[22,23] Previous studies have also found that regular physical exercise was positively associated with better ejaculation control and longer intravaginal ejaculatory latency time.[23,24] In addition, moderate physical exercise training 5 times a week for 30 days was found to improve the intravaginal ejaculation latency time (IELT) of men with lifelong PE.[1]

1.4 | High-intensity interval training

HIIT, which consists of repeated high-intensity exercises separated by short recovery interval periods, has been used as a time-efficient program to improve physical fitness,[25] autonomic nervous system function,[21,26–28] and cardiovascular function.[29,30] It was demonstrated that HIIT is more effective at decreasing sympathovagal imbalance than moderate-intensity continuous training[27,31] and aerobic training.[30] One study found that 20 min of HIIT and 40 min of moderate-intensity continuous training improve parasympathetic activity after 2 weeks of intervention in physically inactive adults, however, the sample size was small.[26] Nevertheless, only HIIT improved the sympathetic/parasympathetic ratio after the intervention.[26] On the other hand, a previous study suggested that only continuous exercise—not HIIT—improved parasympathetic activity during an exercise rehabilitation program in patients with chronic heart failure.[32] To our knowledge, no studies have directly investigated the effect of HIIT on ejaculation control. Taking into consideration that compared with men without PE, men with PE may have lower parasympathetic and higher sympathetic activity, thus greater sympathovagal imbalance, it seems reasonable to hypothesize that HIIT could alleviate PE symptoms by improving the balance of sympathetic and parasympathetic activity.

In the previous study, we found that men with more PE symptoms tend to have more frequent masturbation and less frequent penile–vaginal sex.[33] In addition, men with PE have less sexual desire than those with normal ejaculatory functions.[11] Therefore, we expected that after HIIT intervention, the ejaculation control would improve which in turn would have a positive impact on sexual motivation and consequently sexual desire for partnered sex.

1.5 | Heart rate

The heart rate and its variability are the results of the complex interplay of sympathetic and parasympathetic activity.[34] Parasympathetic activity decreases the heart rate, while sympathetic activity increases the heart rate.[34] At rest, both sympathetic and parasympathetic systems are active. However, the parasympathetic system plays the main role in modulating heart rate. During physical exercise, the parasympathetic activity withdraws, and the sympathetic activity increases, which in turn leads to the heart-rate rising.[34] The relative roles of the two systems depend on the intensity of exercise.

Higher intensity of physical exercise may trigger more sympathetic activity which in turn contributed to more heart-rate increase,[34] that is, heart rate during exercise can be an indicator of the effort put into the HIIT exercise in the current study. We further expected that heart rate increases during the HIIT intervention would be associated with PE symptom reduction.

1.6 | Body image

Body image, which has been found to be associated with sexual behavior, is a multifaceted construct that refers to the individual's subjective perception and attitude regarding their own body, especially regarding its appearance.[35] Previous studies have found that higher body image satisfaction is associated with higher sexual satisfaction.[36–38] Interestingly, body image self-consciousness during physically intimate interaction was related to a lower level of sexual functioning which includes sexual drive, erectile function, and ejaculatory function.[37]

A recent review indicated that more participation in the physical activity was associated with a more positive body image.[39] Therefore, we expected that after the HIIT intervention, men would have higher general and sexual-related body image satisfaction than before the intervention, also compared with the men without HIIT. We also expected that the relationship between physical activity and PE symptoms would be partly mediated by body image.

1.7 | Aims and hypotheses

We explored whether an HIIT intervention can alleviate PE symptoms in men with PE and improve the ejaculation control in men without PE. We also explored the relationship between heart rate (changes) during the intervention and PE symptoms. In addition, we explored whether the HIIT intervention can enhance sexual desire and improve body image satisfaction.

Sympathovagal imbalance may be a factor in the etiology of PE. Previous studies suggest that physical exercise and HIIT could alleviate sympathovagal imbalance.[20,27,31] In addition, moderate physical exercise training has been found to improve the IELT of men with lifelong PE.[1] A 2-week HIIT intervention was found to significantly improve sympathovagal imbalance.[26,30] Therefore, we expected that PE symptoms of men undergoing a 2-week HIIT intervention would decrease during the intervention (Hypothesis 1; main effect of HIIT intervention) and that the changes in PE symptoms of the men with PE would be larger than of the men with normal ejaculatory function (Hypothesis 2; HIIT × Group interaction). In addition, we expected that men undergoing the HIIT intervention would evidence more decreases in PE symptoms over the intervention period than the men without HIIT intervention (Hypothesis 3; HIIT × Time interaction) and the improvement of PE symptoms of the men with PE would be larger than the men with normal ejaculatory function (Hypothesis 4; HIIT × Group × Time interaction).

After regular exercise, the resting heart rate would be lower than before the exercise.[40] Also, the heart-rate increases are associated with sympathetic activity increases and parasympathetic activity decreases during exercise.[34] We expected that resting heart rate, after-intervention heart rate, and heart-rate increase during HIIT would be associated with fewer PE symptoms (Hypothesis 5) and that the heart-rate increase during HIIT would be associated with more improvement in PE symptoms (Hypothesis 6).

PE has been found to impair sexual desire and the frequency of partnered sex.[11,33] Considering the potential positive effect of the HIIT intervention on ejaculation control, this could further affect the desire for partnered sex. We, therefore, expected that men undergoing the HIIT intervention would have a higher dyadic sexual desire and more partnered sex (Hypothesis 7).

Higher body image satisfaction has been found to be associated with better sexual function.[38] More physical activity has also been found to be associated with better body image[39] and ejaculation control.[23,24] We expected that men undergoing the HIIT intervention would have higher general and sexual body image (SBI) satisfaction (Hypothesis 8). We also expected a mediation effect of body image on the relationship between physical activity and PE symptoms (Hypothesis 9).

In addition, we explored the robustness of the effects by also conducting analyses, where pre-intervention work and leisure time physical activity levels were included as covariates.

2 | MATERIALS AND METHODS

2.1 | Preregistration

The sample size, hypotheses, variables, experimental conditions, and planned analyses of the present study were pre-registered on the as-predicted website prior to any data being collected: https://aspredicted.org/JXV_61Y.

2.2 | Participants

To determine the necessary sample size, we conducted a power-analysis for a within-between interaction analysis in G*power,[41] specifically for a 2 (intervention: HIIT vs. control) × 2 (sexual function: PE vs. no PE) ANOVA, with 14 measurements and a moderate effect size (Cohen's *f*) of 0.25. We set our alpha level at 0.05 and our power level at

0.95, and assumed a correlation of 0.5 between the repeated measurements. Based on these parameters, the analysis indicated a minimum sample size of 28 participants. The inclusion criteria of the present study were: (1) Chinese men aged 18—45 years; (2) biological sex at birth being male; (3) being only sexually attracted to women; (4) sexual identity being heterosexual; (5) having a stable sexual partner with whom they have had penile–vaginal sex at least once in the last 2 weeks. Finally, 92 participants aged 18–36 ($M = 22.48$, SD = 3.97) completed the whole experiment. No participants reported that they were currently abusing alcohol or drugs, using selective serotonin reuptake inhibitor (SSRI) medication (e.g., fluoxetine, paroxetine, sertraline, citalopram, and escitalopram), or using medication to delay ejaculation (e.g., dapoxetine). In addition, none of the participants had any history of cardiovascular or endocrine disease, or any history of serious medical, psychiatric, or neurological disorders. The participants were randomly allocated to either the control or the HIIT intervention groups with odd-numbered participants being assigned to the intervention group, while even-numbered participants being assigned to the control group, these numbers being determined based on the order in which the participants signed up for the experiment. Finally, of the men with PE, 13 were randomly allocated into the control group, while 9 participants were allocated into the HIIT group. Of the men without PE, 41 participants were randomly allocated into the control group and 29 participants into the HIIT group. We initially focused on heterosexual men with female partners to control for confounding factors related to the sexual function of same-sex attracted men who also were in sexual relationships with women, which is a relatively common occurrence in China.[42]

2.3 | Measures

2.3.1 | Demographic information

First, participants were instructed to report their age, height, weight, assigned sex at birth, sexual identity, and if they had a stable female sexual partner with whom they had penile–vaginal sex at least once in the last 2 weeks. They reported their sexual identity from the response options: "straight, gay, bisexual, asexual, and unsure." The response options for the sex of the persons they were attracted to had as responses options "men, women, both, neither, unsure."

Body mass index (BMI) was calculated using weight in kilograms divided by the square of the participants' height in meters. A recent study found that self-reported BMI has high accuracy.[43]

2.3.2 | International index of erectile function-5

Erectile dysfunction (ED) of the participants was measured by the International Index of Erectile Function-5 (IIEF-5) on a 5-point Likert scale[44] that was developed from the 15-item version.[45] An example item is: "During sexual (penile–vaginal) intercourse, how often were you able to maintain your erection after you had penetrated (entered) your partner? (1 = almost never/never, 5 = almost always/always)." The sum of the five items was computed to evaluate the severity of ED of each participant. Among Chinese men, a prior study showed the internal consistency assessed with Cronbach's α to be 0.790.[46] Cronbach's α was 0.925 for these items in the present study. Higher values suggest fewer erectile problems.

Before the intervention, participants were instructed to fill in the IIEF-5 for the over 6 months. The sum of the five items considered as the Pre-IIEF score. There are five categories of ED based on IIEF-5 scores: severe (5–7), moderate (8–11), mild to moderate (12–16), mild (17–21), and no ED (22–25).[45]

2.3.3 | Checklist for early ejaculation symptoms

The severity of PE of the participants was measured by the 5-item diagnostic tool checklist for early ejaculation symptoms (CHEES) that was developed from three earlier ejaculation diagnostic tools and has improved validity.[47] Participants responded to items (e.g., "Over the past 6 months, was your control over ejaculation during sexual intercourse?") on a 5-point Likert scale ranging from 1 "very good" to 5 "very poor." The sum of the five items was computed to evaluate the PE severity. In the present study, Cronbach's α was 0.885. A score ranging from 21 to 25 is strongly indicative of fulfilling diagnostic criteria for PE, while a score ranging from 17 to 20 is indicative of PE.

Before the intervention, participants were instructed to fill in the CHEES for the over 6 months. The sum of the five items considered as the pre-CHEES score. To measure participants' PE symptoms for single penile–vaginal intercourse during the last 24 h, we modified CHEES for individual sexual events (CHEES-E) by rephrasing the five items in CHEES so that they were appropriate for assessing individual sexual events. Examples of rephrased items were: "Was your control over ejaculation during this sexual intercourse?", "Did you ejaculate with very little stimulation?", "During this penile–vaginal sexual intercourse, how much time elapsed between when you first entered your partner vaginally with your penis and when you first ejaculated?". In addition, we also created a variable to measure the ejaculation control for men for the individual sexual events during the last 24 h (CONTROL-E), assessing only ejaculation control unrelated to relationship aspects using the sum score of the three items: the feeling of control, ejaculation with little stimulation, and intervaginal ejaculation latency time. During the data analysis, we created a variable to measure the PE symptoms during the intervention (mean-CHEES-E) by calculating the mean-CHEES-E score over the 14 days. In addition, we created a variable to measure the ejaculation control for men during the intervention (mean-CONTROL-E) by calculating the mean-CONTROL-E score over the 14 days. Higher values suggested more PE symptoms or less ejaculation control.

2.3.4 | Body image states scale

The subjective perception of body image was measured by a 6-item questionnaire body image states scale[35] (BISS). The items were

evaluated on a 9-point, bipolar, Likert scale. After reverse-scoring three items, the mean of the six items formed the summary score. An example item is "Right now I feel … with my physical appearance." The response alternatives ranged from extremely dissatisfied to extremely satisfied. In the present study, Cronbach's alpha was 0.868 for these items. Higher values on the scale indicated a more favorable body image.

2.3.5 | Sexual body image

The subjective perception of SBI was measured by 7 items, selected from a previous large-scale study.[48] In the current study, we changed the response scale to correspond with the BISS which ranged from extremely dissatisfied to extremely satisfied. Items included "I am happy with the size of my penis.", "I want to avoid sex because of how my body looks like." (Reverse), "I do not let my partner see myself in the nude during sex." (Reverse), "Because of embarrassment with my body, I avoid certain sexual activities." (Reverse), "I feel that I have a robust, manly body.", "My sexual partners are particularly drawn to my body shape.", "I feel sexy in my body". After reverse-scoring three items, the mean of the seven items formed the summary score. In the present study, Cronbach's alpha was 0.889 for these items. Higher values indicated a more positive SBI.

2.3.6 | Physical activity questionnaire

We used the 5-item physical activity questionnaire that queried the participants about the type of the physical activity, its frequency, duration, intensity, and overall length of participating in different physical activities, and was used to measure the participant's level of physical activity in their free time prior to the intervention.[49] For each item, the response format was a 5-point Likert scale ranging from 1 to 5. In the present study, we added 3 sets of 4 questions. Every set of questions included 4 questions regarding frequency, duration, intensity, and overall length separately for cardiovascular exercise, resistance exercise, and flexibility exercise. An example item was "During a week, how often do you participate in cardiovascular exercise in your free time?". For example, if participants performed two types of physical activity (e.g., cardiovascular exercise, flexibility exercise) they answered two sets of 4 questions regarding frequency, duration, intensity, and overall length separately for the cardiovascular and flexibility exercise, respectively. The score was calculated as follows: first, a sum score was obtained by adding the scores of the frequency, duration, intensity, and overall length for each type of the physical activity. Then, we calculated the mean score of the two types. Finally, the total scale score was calculated by multiplying the mean score by the score "4" of two types of physical activity among the cardiovascular and flexibility exercises. The higher values indicated a higher level of physical activity in their free time.

To measure participants' physical activity level at work, we developed a scale for (Physical Activity Questionnaire at Work) by rephrasing the five items in the original scale so that they were appropriate for assessing physical activity during work. The items included "To what extent do you do physical activity in your job?", "During a week, how often does your job involve physical activity?", "How intense physical activity does your job involve?", "How long periods of physical activity does your job involve?", "How many months have you been performing physical activity in your job?". Higher values indicated a higher level of physical activity in their work time. The responses could range from 1 = not at all to 5 = extremely. The way to calculate the score was the same as for the original scale. Higher values indicated more physical activity at work.

2.3.7 | Sexual desire inventory

The sexual desire inventory (SDI) scale was used to measure the sexual desire level of participants.[50] Six items were used to measure the dyadic sexual desire score. An example item was "When you have sexual thoughts, how strong is your desire to engage in sexual behavior with a partner?". Two items were used to measure the individual sexual desire score including "How strong is your desire to engage in sexual behavior by yourself?" and "How important is it for you to fulfill your desires to behave sexually by yourself?". The mean of the items formed the score. In the present study, Cronbach's alpha was 0.883 for these items. Higher values indicated higher sexual desire.

Two items were used to measure the sexual desire each day including "How strong is your desire to engage in sexual activity with a partner?" and "How strong is your desire to engage in sexual behavior by yourself?". The former indicated a dyadic sexual desire and the latter indicated an individual sexual desire. Higher values indicated higher sexual desire. We created two variables assessing the daily dyadic and individual sexual desire by the mean of the scale during the intervention from the above two items.

2.3.8 | Heart-rate measurement

Participants measured their heart rate twice every morning for 14 days using a heart-rate app program on their smartphones: AFibCheck on Android or Cardiio on iPhone. The heart rate was measured by pressing the forefinger on the rear smartphone camera using the smartphone app that detected changes in the imaging sign of the finger through the rear camera and calculated the heart rate accordingly. A recent study has demonstrated that heart-rate measurements obtained using a smartphone camera are accurate and comparable to those obtained by medically approved oximeters and commercial benchmarks.[51] In the HIIT group, participants measured their heart rates once before the HIIT and another time after the training. In the control group, participants measured their heart rates with a 7 min interval between the two measurements. We calculated the heart-rate increase by subtracting the first heart rate from the second heart rate. We also calculated the mean of the first, and second heart rates and heart-rate increase for 14 days as the resting heart rate, after-intervention heart rate, and heart-rate increase during the intervention.

2.4 | Procedure

Figure 1 shows the procedure of experiment. We recruited the participants by distributing a recruitment poster on online social media, for example, WeChat groups, and the Baidu Tieba (https://tieba.baidu.com/index.html). The potential participants who were interested in participating could scan a QR code on the poster to answer the recruitment questionnaire including questions about demographic information and eligibility criteria. At the end of the survey, only men who met the eligibility criteria were presented with a detailed description of the study. They could then indicate if they were interested in participating. If they agreed, they were instructed to provide their WeChat ID or email address, through which we forwarded them the recruitment questionnaire and made further contact to schedule the experiment.

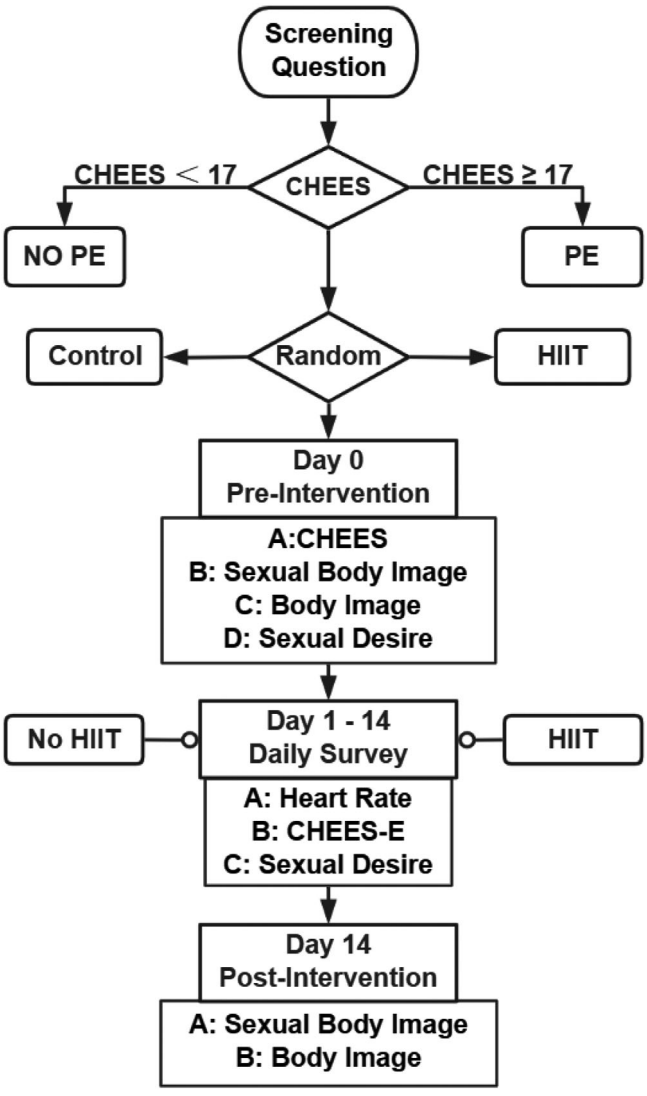

FIGURE 1 Procedure of Experiment. *Notes*. PE, men with premature ejaculation; no PE, men without premature ejaculation; HIIT, men with HIIT; control , men without HIIT; HIIT intervention, high-intensity interval training intervention.

After we had re-checked that the participants fulfilled the screening criteria, they read the information letter online and then decided whether they wanted to participate in the study.

We split the participants into two sexual function groups (PE vs. no PE) by the score of the CHEES measured before the intervention. Participants whose scores were 17 or above were designated to the PE group, and those whose scores were less than 17 were designated to the no PE group. Then, in both groups, participants were randomly assigned to the HIIT or control group. Participants were numbered in the ascending order according to the sequence in which they gave their consent. Subsequently, odd-numbered participants were assigned to the intervention group, while even-numbered participants were assigned to the control group.

Next, the participants were instructed to fill in a pre-intervention questionnaire regarding demographic information, sexual desire, sexual function, (sexual) body image, and physical activity in their free time and at work.

During the intervention, the participants were asked to answer a brief daily survey every morning for 2 weeks. The daily survey contained questions regarding any sexual event during the last day and sexual desire level at the time of responding. If the participant had had penile–vaginal sex with their female sexual partner during the last 24 h, they also answered questions regarding the PE symptoms for this sexual event using the CHEES-E.

In the HIIT group, participants were also instructed to do HIIT exercise for 7 min following an instructional video that was created for LumoWell / LumoFit project by Ego360 (https://www.youtube.com/watch?v = r8cexmYOknI& t = 50s) every day in the morning between 6 a.m. to 10 a.m. from days 1 to 14. As described earlier, the participants measured their heart rates before and after the HIIT using the heart-rate app. Participants were instructed to take a picture of the result and send it to the experimenter to verify the accuracy of their responses to the questionnaire. The HIIT exercise included jumping jacks, wall squats, push-ups, crunches, steps up, squats, triceps dips, plank, high knee run, lunges, side plank, and push-ups with rotation. Each exercise lasted for 30 s followed by a break of 10 s. Participants video-recorded their exercise to ensure compliance. These videos were sent to the researchers and deleted immediately after compliance had been confirmed (the participant was asked to state the date of the exercise at the beginning of the video). There were two versions of the HIIT exercise: a normal level of high-intensity physical exercise and a lower level of physical exercise. The participant chose their version according to their fitness level. Participants were instructed to not participate in other exercise programs for the 2 weeks duration of the study.

In the control group, participants were not instructed to do the HIIT exercise. Participants measured their heart rates two times, with an interval of 7 min. The other procedures were the same as in the HIIT group.

On the morning of the last day of the 2 weeks, participants answered the daily survey regarding a possible sexual event during the last 24 h as well as their sexual desire level at the time of responding, and also the measures for (sexual) body image. Participants received 300 RMB (45 USD) in total via WeChat or Alipay as compensation for their

participation. The present study was reviewed and approved by the New York University Shanghai Institutional Review Board.

2.5 | Statistical analyses

We used IBM SPSS Statistics 25.0 to conduct the data analyses.

We conducted *t*-test analyses to investigate differences in age, BMI, sexual desire, pre-CHEES, and pre-IIEF before the intervention between the Sexual Function (PE vs. No PE) groups. We also conducted *t*-test analyses to investigate differences in age, BMI, sexual desire, physical activity, pre-CHEES, and pre-IIEF before the intervention between the intervention (HIIT vs. control) groups separately for sexual function (PE vs. no PE) groups to ensure that the random allocation had been successful.

We conducted bivariate correlation analyses to explore the relationships between age, BMI, physical activity, sexual desire, (sexual) body image, pre-CHEES, and pre-IIEF before the intervention.

For participants who did not have penile-vaginal sex during the last 24 h, we copied the previous CHEES-E value over. For example, we copied the CHEES-E value on day 10 over to day 11 if the participant on day 11 did not have penile–vaginal sex but did so on day 10.

We calculated the mean CHEES-E score over the 14 days of the intervention as the mean-CHEES-E. Similarly, we also calculated the mean CONTROL-E score over the 14 days of the intervention as the mean-CONTROL-E.

Then, we conducted 2 intervention (HIIT vs. control) × 2 sexual function (PE vs. no PE) ANOVAs to explore differences in the mean-CHEES-E and mean-CONTROL-E, also for the CHEES-E at day 14.

Then, we conducted 14 time × 2 intervention (HIIT vs. control) × 2 sexual function (PE vs. no PE) mixed ANOVAs to explore changes in CHEES-E over the 14 days of the intervention. These were followed by post hoc comparisons at each time point.

We also conducted the *t*-test to explore the difference in the mean-CHEES-E and the mean-CONTROL-E in between the HIIT and control groups separately for the men with and without PE.

We conducted 2 time (first vs. second) × 2 intervention (HIIT vs. control) mixed ANOVAs to explore the differences in first (resting) and second (after intervention) heart rates. Then, we conducted a 2 intervention day (day 1 vs. day 14) × 2 intervention (HIIT vs. control) × 2 sexual function (PE vs. no PE) mixed ANOVAs to explore the differences in separately for the heart rate before exercise and after exercise between days 1 and 14.

Next, we restructured the data file to a long form with repeated measurements for the 14 days of measure, resting heart rate, and after-intervention heart rate, the heart rate increased from resting heart rate to after-intervention by subtracting the value of the former from the latter, and CHEES-E. In addition, we divided the data into 2 weeks: Weeks 1 and 2. We considered days from 1 to 7 as the first week and days from 8 to 14 as the second week. We then conducted two types of correlation analyses,[52] correlations within subjects can answer the question: whether an increase in resting heart rate, after intervention heart rate and heart-rate increase within all the 14 days repeated measurements was associated with a decrease in CHEES-E when removing the variance between participants. Correlations between subjects can answer the question: whether an increase in average value for 14 days measurement of resting heart rate, after-intervention heart rate, and a heart-rate increase of each participant was associated with a decrease in CHEES-E. We conducted the multilevel. cor functions within the R package lavaan.[53]

Finally, for the heart-rate measurement, we split the data file by the median (Md = 26.179) of the heart-rate increase in the HIIT group. Those whose heart-rate increase was lower than 26.179 were allocated to low heart-rate increase group and those whose heart rate increased more than 26.179 into the high heart-rate increase group. We conducted 2 time (pre vs. post) × 2 sexual function (PE vs. no PE) × 2 heart-rate increase (low vs. high) mixed ANOVAs to explore the effect of the heart-rate increase during the HIIT intervention on change from pre-CHEES and the mean-CHEES-E.

Then, we conducted 2 intervention (HIIT vs. control) × 2 sexual function (PE vs. no PE) ANOVAs to explore differences in sexual desire and the total number of sexual intercourses during the intervention.

Finally, we conducted mediation analyses to explore the mediating effect of pre-intervention (sexual) body image on the relationship between pre-intervention physical activity in free time and pre-CHEES. We also conducted 2 time (pre vs. post) × 2 intervention (HIIT vs. control) mixed ANOVAs to explore the differences in pre and post-intervention (sexual) body image.

3 | RESULTS

3.1 | Descriptive statistics

Table 1 shows descriptive statistics for men with and without PE. Results of the *t*-tests showed no significant differences in age ($t(90) = 1.392$, $p = 0.167$), BMI ($t(90) = -1.264$, $p = 0.209$) between the men with PE and men without PE. Men with PE had higher pre-CHEES score ($t(90) = -12.003$, $p < 0.001$) and lower pre-IIEF score ($t(90) = 5.873$, $p < 0.001$) than men without PE which suggested more PE symptoms and erectile problems. In addition, the result indicated that men with PE reported higher values in all items of pre-CHEES than men without PE.

Table 1 also shows descriptive statistics for men in the HIIT and control group separately in men with PE and without PE. Results of the *t*-tests showed no significant differences in age ($t(90) = 0.221$, $p = .825$), BMI ($t(90) = -0.688$, $p = 0.493$), dyadic sexual desire ($t(90) = 0.591$, $p = 0.556$), individual sexual desire ($t(90) = 1.126$, $p = 0.263$), physical activity at work ($t(90) = 1.534$, $p = 0.129$), pre-CHEES score ($t(90) = -0.684$, $p = 0.496$) and pre-IIEF score ($t(90) = 0.975$, $p = 0.332$) between men in the HIIT and control group before the intervention. Men in HIIT (vs. control) group reported less physical activity in the free time ($t(90) = 2.188$, $p = 0.031$) before the intervention. In the HIIT (vs. control) group, men without PE reported less physical activity in the free time before the intervention.

TABLE 1 Descriptive statistics of variables between sexual function and intervention groups.

	No PE						PE					
Pre-intervention (no PE vs. PE)	***M***	**SD**	***M***	**SD**	***t***	***p***	***M***	**SD**	***M***	**SD**	***T***	***p***
Age	22.80	4.12					21.45	3.36			1.392	0.167
BMI	21.87	2.69					22.71	2.86			−1.264	0.209
Pre-CHEES-1	2.23	0.89					4	0.69			−8.572	<0.001
Pre-CHEES-2	1.99	0.88					4	0.69			−9.851	<0.001
Pre-CHEES-3	1.67	0.7					3.23	0.92			−8.431	<0.001
Pre-CHEES-4	2.27	1.03					4.05	0.72			−7.477	<0.001
Pre-CHEES-5	2.94	0.76					4.23	0.87			−6.684	<0.001
Pre-CHEES	11.10	3.05					19.50	2.15			−12.003	<0.001
Pre-IIEF-5	19.43	4.33					13.41	3.70			5.873	< 0.001
Dyadic sexual desire	6.87	1.73					6.33	1.62			1.697	0.093
Individual sexual desire	7.25	1.21					6.66	1.97			1.7	0.093
Pre-intervention (control vs. HIIT)	**Control**		**HIIT**				**Control**		**HIIT**			
	M	**SD**	***M***	**SD**	***t***	***p***	***M***	**SD**	***M***	**SD**	***T***	***P***
Age	22.73	4.21	22.90	4.05	−0.164	0.870	22	4.14	20.67	1.66	0.911	0.373
BMI	21.66	2.06	22.17	3.42	−0.779	0.439	22.69	2.40	22.75	3.58	−0.05	0.961
Pre-CHEES	10.59	2.77	11.82	3.31	−1.704	0.093	19.92	2.18	18.89	2.09	1.113	0.279
Pre-IIEF-5	20.07	4.25	18.52	4.36	1.493	0.140	13.15	3.93	13.78	3.53	−0.381	0.707
Dyadic sexual desire	7.02	1.09	6.66	1.27	1.289	0.202	6.14	1.80	6.61	1.37	−0.66	0.516
Individual sexual desire	7.49	1.15	6.91	1.22	2.004	0.049	6.50	2.24	6.89	1.62	−0.446	0.660
Physical activity (free time)	27.78	11.64	18.91	11.31	3.178	0.002	14.23	8.64	19.11	12.58	−1.082	0.292
Physical activity (work)	34.80	19.68	25.90	17.28	1.960	0.054	23.31	23.61	25.11	16.94	−0.196	0.846
	Control		**HIIT**				**Control**		**HIIT**			
Intervention (control vs. HIIT)	***M***	**SD**	***M***	**SD**	***t***	***p***	***M***	**SD**	***M***	**SD**	***t***	***p***
Mean-CHEES-E	11.44	2.92	12.72	2.72	−1.854	0.068	18.66	1.59	17.01	2.50	1.908	0.071
Mean-CONTROL-E	7.36	1.73	8.21	1.88	−1.957	0.054	11.68	1.25	10.37	1.13	2.523	0.020
Dyadic sexual desire	6.34	1.64	5.92	1.62	1.068	0.289	5.14	2.31	5.33	1.94	−0.194	0.848
Individual sexual desire	6.55	1.68	5.62	1.66	2.278	0.026	5.14	2.28	5.02	2.05	0.134	0.895
Number of sexual intercourse	4.9	4.10	2.34	2.76	2.92	0.005	2.85	2.51	2.22	1.92	0.627	0.538

Note: PE, men with PE; no PE, men without PE. Pre-CHEES-1 is the item to measure the feeling of control. Pre-CHEES-2 is the item to measure the degree of PE cause difficult in relationship. Pre-CHEES-3 is the item to measure the ejaculation with very little stimulation of participants. Pre-CHEES-4 is the item to measure intervaginal ejaculation latency time. Pre-CHEES-5 is the item to measure the frustration because of early ejaculation. Mean-CHEES-E, the mean CHEES-E score over the 14 days of the intervention. Higher values of above CHEES variables suggest more early ejaculation problems. Higher values of mean-CONTROL-E, the mean CONTROL-E score over the 14 days of the intervention suggest less ejaculation control for men. Higher values of Pre-IIEF suggest better erectile function.

Table 2 shows descriptive statistics and the results of correlation analyses between age, BMI as well as (sexual) body image, physical activity in the free time (at work), sexual desire, and pre-CHEES and pre-IIEF before the intervention. There was a strong positive association between pre-CHEES and pre-IIEF score which suggested that more PE symptoms were associated with more erectile problems. Importantly, having more physical activity in free time (at work) was associated with both lower pre-CHEES score and higher pre-IIEF score which suggested fewer PE symptoms and erectile problems. Only having more physical activity at work was associated with higher (dyadic and individual) sexual desire. Higher (sexual) body image satisfaction was associated with lower pre-CHEES score and higher pre-IIEF score which suggested fewer PE symptoms and erectile problems.

Hypotheses 1. *& 2: Overall effects of HIIT on sexual function*

Table 1 shows descriptive statistics of the mean-CHEES-E in the intervention and sexual function groups. A 2 intervention (HIIT vs. control) × 2 sexual function (PE vs. no PE) ANOVA showed a significant interaction effect ($F(1, 88) = 4.879$, $p = 0.03$, partial $\eta^2 = 0.053$), while the main effect of the intervention group was not significant ($F(1, 88) = 0.081$, $p = 0.776$). Post hoc results indicated that no

TABLE 2 Correlations between variables before the intervention.

Pre-intervention	*n*	*M*	SD	Pre-CHEES	Pre-IIEF	1	2	3	4	5	6	7
Pre-CHEES (PE symptoms)	92	13.11	4.59									
Pre-IIEF (erectile function)	92	17.99	4.90	−0.734**								
Age	92	22.48	3.97	−0.186	0.337**							
BMI	92	22.07	2.74	0.014	0.108	0.065						
Dyadic sexual desire	92	6.74	1.30	−0.170	0.305**	0.138	−0.031					
Individual sexual desire	92	7.11	1.44	−0.229*	0.408**	0.202	0.044	0.720**				
Body image	92	5.55	1.50	−0.512**	0.559**	0.039	−0.238*	0.370**	0.393**			
Sexual body image	92	6.43	1.55	−0.603**	0.705**	0.242*	−0.046	0.350**	0.505**	0.802**		
Physical activity (free time)	92	22.22	12.25	−0.321**	0.330**	0.042	−0.197	0.144	0.091	0.398**	0.396**	
Physical activity (work)	92	29.42	19.63	−0.252*	0.409**	0.028	0.087	0.397**	0.311**	0.401**	0.410**	0.225*

Note: Higher values of Pre-CHEES suggest more early ejaculatory problems. Higher values of Pre-IIEF suggest better erectile function. *$p < 0.05$, **$p < 0.01$.

significant difference in the mean-CHEES-E between the HIIT and control groups for men with ($F(1,88) = 2.042$, $p = 0.157$) and without PE ($F(1,88) = 3.879$, $p = 0.052$). Including physical activity in free time as a covariate, the interaction effect changed from significant to marginally significant for mean-CHEES-E ($F(1,87) = 3.311$, $p = 0.072$). Including physical activity at work as a covariate, results continued to show a significant interaction effect in the mean-CHEES-E ($F(1,87) = 4.432$, $p = 0.038$, partial $\eta^2 = 0.048$).

Table 1 also shows descriptive statistics of the mean-CONTROL-E in the intervention and sexual function groups. A 2 intervention (HIIT vs. control) × 2 sexual function (PE vs. no PE) ANOVA showed a significant interaction effect ($F(1, 88) = 6.759$, $p = 0.011$, partial $\eta^2 = 0.071$), while the main effect of the intervention was not significant ($F(1, 88) = 0.309$, $p = 0.579$). Post hoc results indicated that in men with PE the mean-CONTROL-E score was slightly lower ($F(1, 88) = 3.270$, $p = 0.074$) which suggested fewer PE symptoms and in the men without PE the mean-CONTROL-E score was higher ($F(1, 88) = 4.378$, $p = 0.039$, partial $\eta^2 = 0.047$) which suggested more PE symptoms in the HIIT (vs. control) group. Including physical activity in free time or physical activity at work as a covariate, results continued to show a significant interaction effect in the mean-CONTROL-E ($F(1,87) = 4.565$, $p = 0.035$, partial $\eta^2 = 0.05$; $F(1,87) = 5.899$, $p = 0.017$, partial $\eta^2 = 0.063$).

The results of the *t*-test revealed that, in the HIIT group, men with PE reported lower the mean-CHEES-E score which suggested fewer PE symptoms, while men without PE reported higher the mean-CHEES-E score which suggested more PE symptoms compared to the control group. In addition, among men with PE, the mean-CONTROL-E score was lower in the HIIT group compared to the control group (see Figure 2).

A 2 intervention (HIIT vs. control) × 2 sexual function (PE vs. no PE) ANOVA for CHEES-E at day 14 showed a significant interaction effect ($F(1, 88) = 6.222$, $p = 0.014$, partial $\eta^2 = 0.066$), while the main effect of the Intervention group was not significant ($F(1, 88) = 0.285$, $p = 0.595$). Post hoc results indicated that the effectiveness of HIIT intervention on the CHEES-E at day 14 was positive for men with PE ($F(1, 88) = 2.552$, $p = 0.114$) and negative for men without PE ($F(1, 88) = 1.897$, $p = 0.172$).

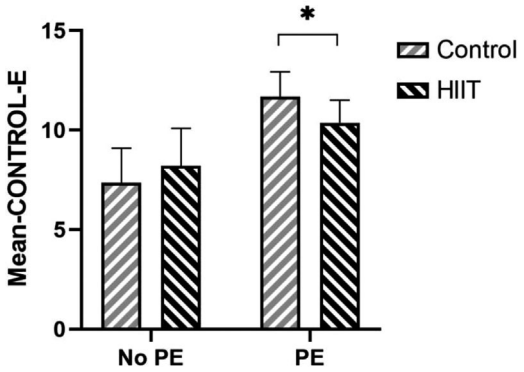

FIGURE 2 Difference in mean-CONTROL-E of men with and without PE in intervention group. *Notes*. PE, men with premature ejaculation; no PE, men without PE; mean-CONTROL-E, the mean of the CONTROL-E for 14 days during the intervention. Higher values of mean-CONTROL-E suggest less ejaculation control.

Hypotheses 3. & 4: Effect of HIIT on sexual function during the intervention

Table 3 shows the changes in the CHEES-E during the intervention divided by PE and HIIT status. A time (14) × 2 intervention (HIIT vs. control) × 2 sexual function (PE vs. no PE) mixed ANOVA showed a significant interaction effect ($F(1, 88) = 2.202$, $p = 0.008$, partial $\eta^2 = .024$), while the main effect of the intervention group was not significant ($F(1, 88) = 0.081$, $p = 0.776$). Post hoc tests indicated that in the HIIT (vs. control) group, the CHEES-E score of men with PE was lower which suggested fewer PE symptoms on days 10, 11, and 12 (see Figure 3). In the HIIT (vs. control) group, the CHEES-E score of men without PE were more frequent which suggested more PE symptoms on days 7, 8, 11, and 13 (see Figure 4).

Hypotheses 5. & 6: HIIT and heart rate and sexual function

The 2 time (first vs. second) × 2 intervention (HIIT vs. control) mixed ANOVA to explore the differences in first (resting) and second

TABLE 3 Descriptive statistics of CHEES-E for 14 days between sexual function and intervention groups.

	No PE						PE					
Intervention	Control		HIIT				Control		HIIT			
Day	*M*	SD	*M*	SD	*t*	*P*	*M*	SD	*M*	SD	*t*	*p*
01	11.39	2.71	11.87	3.23	−0.807	0.422	18.92	1.89	17.33	2.78	1.601	0.125
02	11.63	2.75	12.10	3.32	−0.646	0.521	18.92	2.25	17.44	2.65	1.409	0.174
03	11.49	3.10	12.34	3.11	−1.138	0.259	18.54	2.30	17.44	2.65	1.032	0.314
04	11.61	3.10	12.48	3.20	−1.145	0.256	18.23	2.13	17.44	2.65	0.771	0.450
05	11.24	3.08	12.59	3.08	−1.797	0.077	18.46	2.11	17.56	2.40	0.937	0.360
06	11.10	3.38	12.62	3.08	−1.929	0.058	18.46	2.22	17.78	2.22	0.709	0.486
07	11.15	3.19	12.83	3.12	−2.192*	0.032	18.62	2.22	17.78	2.22	0.870	0.395
08	11.41	3.44	13.07	3.00	−2.090*	0.040	18.54	2.22	17.78	2.22	0.789	0.439
09	11.44	3.48	12.93	2.94	−1.882	0.064	18.62	2.29	16.22	3.49	1.947	0.066
10	11.44	3.33	12.79	2.86	−1.777	0.080	19.00	1.58	16.22	3.56	2.498*	0.021
11	11.46	3.36	13.07	2.88	−2.089*	0.040	19.00	1.58	16.22	3.56	2.498*	0.021
12	11.61	3.35	13.10	2.74	−1.978	0.052	19.00	1.58	16.33	3.46	2.450*	0.024
13	11.54	3.16	13.10	2.55	−2.206*	0.031	18.62	1.90	16.33	3.46	1.996	0.060
14	11.63	3.18	13.03	2.61	−1.952	0.055	18.38	1.94	16.22	3.31	1.936	0.067

Note: PE, men with premature ejaculation; no PE, men without PE. CHEES-E was used to measure the PE symptoms for the individual sexual event during the last 24 h. Higher values of CHEES-E suggest more early ejaculation problems.

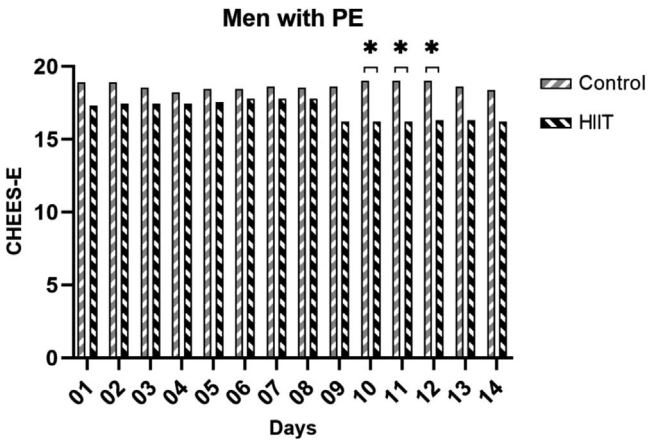

FIGURE 3 Difference in CHEES-E for 14 days between control and HIIT group in men with PE. *Notes.* PE, premature ejaculation; CHEES-E, CHEES for the individual sexual events. Higher values of CHEES-E suggest more PE symptoms.

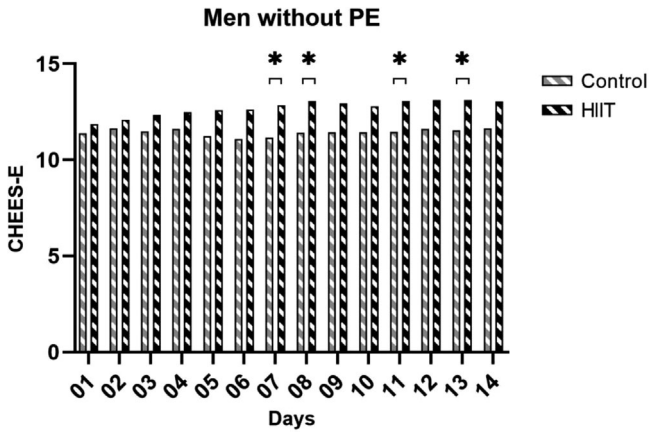

FIGURE 4 Difference in CHEES-E for 14 days between control and HIIT group in men without PE. *Notes.* PE, premature ejaculation; CHEES-E, CHEES for the individual sexual events. Higher values of CHEES-E suggest more PE symptoms.

(after intervention) heart rates found a significant main effect of time ($F(1, 90) = 147.856$, $p < 0.001$, partial $\eta^2 = 0.622$) and intervention ($F(1, 90) = 52.341$, $p < 0.001$, partial $\eta^2 = 0.368$), and a significant interaction effect ($F(1, 90) = 114.156$, $p < 0.001$, partial $\eta^2 = 0.559$). Post hoc analyses indicated that, as expected, the second heart rate was significantly higher than the first heart rate in the HIIT group ($F(1, 90) = 222.268$, $p < 0.001$, partial $\eta^2 = 0.712$). There was no significant difference in the heart rate in the control group ($F(1, 90) = 1.317$, $p = 0.254$). In addition, there was also no significant difference in the first heart rate between the control and HIIT groups ($F(1, 90) = 0.815$, $p = 0.815$). In addition, men in the HIIT (vs. control) group had a higher second heart rate ($F(1, 90) = 96.420$, $p < 0.001$, partial $\eta^2 = 0.517$).

The 2 intervention day (day 1 vs. 14) × 2 intervention (HIIT vs. control) ×2 sexual function (PE vs. no PE) mixed ANOVAs indicated that there was no significant interaction between the intervention day, intervention and sexual function groups separately for the heart rate before exercise ($F(1, 88) = 2.376$, $p = 0.127$) and after exercise ($F(1, 88) = 0.138$, $p = 0.711$). For the heart rate before exercise, the main effect of the intervention day ($F(1, 88) = 5.909$, $p = 0.017$, partial $\eta^2 = 0.063$) and the interaction between the intervention day and

TABLE 4 Descriptive statistics of pre-CHEES and mean-CHEES-E between heart rate increase and the sexual function groups.

			Pre-CHEES		Mean-CHEES-E			
Sexual function	HR increase	*n*	*M*	SD	*M*	SD	*F*	*p*
No PE	Low	16	12.25	3.32	13.07	2.57	4.077	0.051
	High	13	11.31	3.35	12.28	2.94	4.644	0.038
PE	Low	3	18	1	18.11	1.83	0.016	0.900
	High	6	19.33	2.42	16.45	2.89	18.808	<0.001

Note: HR increase, the increase of the heart rate from the before to after the HIIT intervention. Higher values of pre-CHEES or mean-CHEES-E suggest more early ejaculation problems.

sexual function groups were significant ($F(1, 88) = 12.276$, $p < 0.001$, partial $\eta^2 = 0.122$). Post hoc results indicated that in the control group, men with PE reported lower heart rate before exercise at day 14 compared to day 1 ($F(1, 88) = 12.398$, $p < 0.001$, partial $\eta^2 = 0.123$).

For men with PE in the HIIT group, the multilevel correlation results indicated that higher heart rate increases during intervention were associated with fewer the CHEES-E score which suggested fewer PE symptoms (within-group: $r = -0.56$, $p = 0.003$), especially in Week 2 (within-group: $r = -0.8656$, $p = 0.0013$). In Week 2, in the HIIT group, men with and without PE who displayed higher heart-rate increases during the intervention (between-group: $r = -0.63$, $p = 0.007$), and higher after-intervention heart rates (between-group: $r = -0.58$, $p = 0.038$) tended to have fewer the CHEES-E score.

Table 4 shows descriptive statistics for the difference in pre-CHEES and mean-CHEES-E scores between the sexual function and heart-rate increase group in the HIIT group. A 2 time (pre vs. post) × 2 sexual function (PE vs. no PE) × 2 heart rate increase (low vs. high) mixed ANOVA indicated a significant interaction between time, sexual function, and heart-rate increase groups ($F(1, 34) = 5.865$, $p = 0.021$, partial $\eta^2 = 0.147$). Post hoc tests indicated that men without PE in the HIIT group who had a stronger heart-rate increase had more PE symptoms after the intervention compared to before the intervention. In contrast, men with PE in the HIIT group who had a stronger heart-rate increase had fewer PE symptoms after the intervention compared to before the intervention.

Hypothesis 7. : Effects of HIIT on sexual desire and sexual activity

Table 1 also shows descriptive statistics of sexual desire and the total number of sexual intercourses during the intervention in the intervention and sexual function groups. A 2 intervention (HIIT vs. control) × 2 sexual function (PE vs. no PE) multivariate ANOVA showed no significant main effect of the intervention ($F(1, 87) = 0.154$, $p = 0.858$) and the sexual function groups ($F(1, 87) = 1.205$, $p = 0.305$) and the interaction effect were not significant ($F(1, 87) = 1.041$, $p = 0.35$).

Results of a 2 intervention (HIIT vs. control) × 2 sexual function (PE vs. no PE) ANOVA indicated no significant interaction ($F(1,88) = 1.344$, $p = 0.249$). The main effect of the intervention was close to significant ($F(1,87) = 3.639$, $p = 0.06$). Post hoc tests indicated that in the HIIT (vs. control) group, men without PE had fewer sexual intercourses during the intervention ($F(1,88) = 9.862$, $p = 0.002$, partial $\eta^2 = 0.101$). The total number of sexual intercourses during the intervention was not significant difference ($F(1,88) = 0.184$, $p = 0.669$) in men with PE in the HIIT (vs. control) group.

Hypothesis 8. : Effect of HIIT on (sexual) body image

Table 5 shows the descriptive statistics of pre and post-intervention (sexual) body image for men in the intervention and sexual function groups. A 2 intervention (HIIT vs. control) × 2 time (pre vs. post) mixed ANOVAs showed that the main effect of the time was significant ($F(1, 90) = 7.770$, $p = 0.006$, partial $\eta^2 = 0.079$) for body image. However, the main effect of the intervention was not significant ($F(1, 90) = 1.298$, $p = 0.258$). Importantly, there was a significant interaction effect ($F(1, 90) = 4.515$, $p = 0.036$, partial $\eta^2 = 0.048$). Post hoc tests showed that compared to before the intervention after the intervention men had better body image satisfaction in the HIIT group ($F(1, 90) = 10.278$, $p = 0.002$, partial $\eta^2 = 0.102$).

A 2 intervention (HIIT vs. control) × 2 time (pre vs. post) mixed ANOVA showed that the main effect of time ($F(1, 90) = 2.787$, $p = 0.098$) and intervention group ($F(1, 90) = 0.994$, $p = 0.321$) were not significant for SBI. There also was no significant interaction effect ($F(1, 90) = 3.306$, $p = 0.072$). However, post hoc tests showed that compared to before the intervention after the intervention men had better SBI in the HIIT group ($F(1, 90) = 5.181$, $p = 0.025$, partial $\eta^2 = 0.054$).

Hypothesis 9. : Mediation effect of body image on the relationship between physical activity and sexual function

See Figure 5 for the mediating effect of (sexual) body image on the relationship between physical activity in free time and pre-CHEES score before the intervention. Table 6 shows the indirect effect of physical activity in free time on pre-CHEES score via (sexual) body image. The result indicated that the higher level of the physical activity in free time was associated with better (sexual) body image which in turn was associated with lower pre-CHEES score which suggested fewer PE symptoms before the intervention. However, the level of the physical activity in free time had no significant direct effect on the pre-CHEES. The indirect effect of the mediation from the physical activity in free time via (sexual) body image satisfaction to the pre-CHEES was significant.

TABLE 5 Descriptive statistics of (sexual) body image between time and the intervention groups.

		Control intervention							HIIT intervention					
		Pre		Post					Pre		Post			
	n	*M*	SD	*M*	SD	*t*	*p*	*N*	*M*	SD	*M*	SD	*t*	*p*
Body image	54	5.78	1.62	5.85	1.62	0.287	0.594	38	5.23	1.26	5.75	0.91	9.279	0.004
Sexual body image	54	6.63	1.70	6.61	1.57	0.014	0.906	38	6.15	1.26	6.52	1.13	4.779	0.035

FIGURE 5 The diagram of the mediating effect of (sexual) body image on the relationship between physical activity in free time and pre-CHEES before the intervention. *Note*. Higher values of pre-CHEES suggest PE symptoms. PE, premature ejaculation.

TABLE 6 Indirect effect of physical activity in free time on pre-CHEES via (sexual) body image before the intervention.

	BISS score			SBI score		
	Indirect effect	SE	95% CI	Indirect effect	SE	95% CI
Physical activity (free time)	−0.**068**	0.02	−0.112, −0.032	−**0.084**	0.024	−0.134, −0.041

Note: The significant indirect effects were shown in bold. BISS, Body image states scale; SBI, sexual body image. The significant indirect effects were shown in bold.

4 | DISCUSSION

The present study investigated the effect of a 7-minute HIIT intervention for 2 weeks on the ejaculation control in men with PE and men without PE. The result showed that the short-term HIIT intervention had different effects on the ejaculation control between men with PE and men without PE. Specifically, on the one hand, after the HIIT intervention, men with PE had fewer PE symptoms compared with the control group. On the other hand, after the HIIT intervention, men without PE had more PE symptoms than the control group. However, there was a significant association between the higher heart-rate increase during the HIIT intervention and fewer PE symptoms. In men with and without PE, men with higher heart-rate increases during the HIIT intervention would have fewer PE symptoms. In addition, the HIIT intervention had a positive effect on general and SBI satisfaction.

A previous study demonstrated that regular moderate physical exercise (30 min of moderate running) and dapoxetine (30 mg) can reduce PE symptoms and increase the IELT in men with PE compared with minimal physical activity intervention after 10 days of treatment.[1] Similarly, in our study, we found that a short-term HIIT intervention for 2 weeks also can reduce PE symptoms compared with the control group. Compared with previous studies,[1] the 7 min of HIIT intervention had the advantage of being time effective. We conclude that an HIIT intervention may have clinical utility in the treatment of PE.

In line with findings regarding the role of HIIT in achieving the balance between sympathetic and parasympathetic activity,[26,29] it is plausible that the underlying mechanism is such that HIIT improves the PE symptoms in men by improving the sympathovagal imbalance, at least in men with PE.[13,17]

For the daily PE symptoms measurement of CHEES-E for sexual events, first, in the first 7 days, there was no significant difference observed in CHEES-E between the HIIT intervention group and control group regardless of participants' PE status. Interestingly, after 7 days of intervention, in men with PE, the HIIT intervention group showed fewer PE symptoms than the control group. Therefore, one plausible explanation is that this HIIT intervention might at least need 7 days of continuous participation to observe the effect on the ejaculation function.

During the HIIT intervention, the heart rate increased due to the parasympathetic activity withdrawal and the sympathetic activity enhanced.[34] The heart-rate increase during the intervention, an indicator of the exercise intensity, was associated with the reduction of PE symptoms. The correlation analyses result showed a positive effect of the HIIT intervention on ejaculation control. First, in men with PE, the heart-rate increase during the intervention was associated with fewer PE symptoms for the daily sexual event, especially after a 1-week intervention. In week 2, participants on average put more effort into the HIIT intervention, resulting in more heart-rate increase, and lower scores on the measure of PE symptoms. This was true for both men with and without PE. These results indicated that the sympathetic activity increase during intervention was closely associated with the reduction of PE symptoms. In addition, we found that only men with higher heart rates increased during the intervention which may indicate that higher intensity of effort exerted and more sympathetic activity in the HIIT intervention has significant PE symptoms improvement compared with those with low heart rates increased during the intervention. All in all, continuous participation and physical exercise intensity were critical for the effect of the HIIT intervention on PE symptom improvement.

HIIT intervention improved not only general body satisfaction but also improved SBI, which was consistent with the previous studies.[39] In addition, better SBI was associated with better ejaculation control and erectile function. We considered that the regular HIIT intervention may improve the participant's physical condition and even body shape which in turn improves satisfaction with their body image. In addition, the release of beta-endorphin during exercise, which plays a role in the body's inhibitory response to pain which in turn increases the positive mood,[54] may also increase the body image satisfaction.

Interestingly, there also were results that showed that in the pre-intervention test, men with more physical activity in their free time had higher SBI and body image satisfaction which in turn was associated with fewer PE symptoms. The physical activity may be associated with better physical condition and therefore higher body image and SBI satisfaction. Higher body image satisfaction especially related to the sexual activity would lead to more confidence during sex as well as less sexual performance anxiety.[55,56] Excessive anxiety will impair the parasympathetic activity and lead to earlier sympathetic overactivity[57–59] resulting in a sympathovagal imbalance which may be a cause of a poorer ejaculation control in men. In this way, the physical activity was associated with fewer PE symptoms via higher SBI satisfaction.

However, the HIIT intervention might have a negative effect on ejaculation control compared with the control group in men without PE. It was hard to explain this opposite result. In addition, the observed increase in PE symptoms in men without PE was small and unstable. The result may be the random variation in measured scores. Future studies should aim for a larger sample size and investigate additional details (i.e., testosterone levels) related to the effects of HIIT interventions on the control of ejaculation in both men with PE and without PE. Some previous studies have found that physical exercise increased acute testosterone levels,[60,61] including high-intensity interval activity.[60]

4.1 | Limitations and future directions

There are some limitations to the study. First, there was a limited sample size of participants with PE. Future studies should have a bigger sample size of participants with PE. Second, there was no measurement to identify the participants' exertion other than the speculated heart-rate increase during HIIT. Insufficient exertion might also affect the effectiveness of the intervention. Further studies should have a rating of perceived exertion scale to measure the participant's effort during the HIIT intervention. Third, the validity of some surveys has not been tested in the Chinese population, including CHEES. Future research should test the validity of these instruments. Fourth, the observations were made on a relatively short timescale. Further studies should take a longer time to observe the effects of lifestyle changes. Last but not least, heart rates were measured by the app via the rear smartphone camera. The validity and reliability of the app were limited. Further studies could use devices with a heart-rate sensor to reduce measurement errors (e.g., Embrace 4).

5 | CONCLUSION

The effect of HIIT was complex for men with and without PE. The 2-week HIIT intervention may reduce PE symptoms in men with PE. However, the HIIT intervention may increase early ejaculation symptoms in men without PE. The heart-rate increase during the intervention is a key factor that was related to the reduction of PE symptoms.

AUTHOR CONTRIBUTIONS

Pekka Santtila, Daniel Ventus, and Caoyuan Niu conceived the idea for the manuscript. Pekka Santtila had oversight and leadership responsibility for the research activity planning and execution. Caoyuan Niu performed the experiment and data collection. Caoyuan Niu, Guangju Wen, and Yikang Zhang analyzed the study data. Caoyuan Niu wrote the initial draft and prepared the draft for publication. All authors reviewed and edited the manuscript before submission.

FUNDING INFORMATION

The original data collections were funded by the NYU-ECNU Institue for Social Development at NYU Shanghai Internal Fund to the last author.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in OSFHOME at https://osf.io/dashboard.

ORCID

Caoyuan Niu https://orcid.org/0000-0003-2195-0710

REFERENCES

1. Kilinc MF, Aydogmus Y, Yildiz Y, Doluoglu OG. Impact of physical activity on patient self-reported outcomes of lifelong premature ejaculation patients: results of a prospective, randomised, sham-controlled trial. *Andrologia*. 2018;50(1):e12799. doi:10.1111/and.12799
2. Althof SE, McMahon CG, Waldinger MD, et al. An update of the International Society of Sexual Medicine's Guidelines for the diagnosis and treatment of premature ejaculation (PE). *Sex Med*. 2014;2(2):60-90. doi:10.1002/sm2.28
3. Colonnello E, Ciocca G, Limoncin E, Sansone A, Jannini EA. Redefining a sexual medicine paradigm: subclinical premature ejaculation as a new taxonomic entity. *Nat Rev Urol*. 2021;18(2):115-127. doi:10.1038/s41585-020-00417-1
4. Sansone A, Aversa A, Corona G, et al. Management of premature ejaculation: a clinical guideline from the Italian Society of Andrology and Sexual Medicine (SIAMS). *J Endocrinol Invest*. 2021;44(5):1103-1118. doi:10.1007/s40618-020-01458-4
5. Rowland DL, Patrick DL, Rothman M, Gagnon DD. The psychological burden of premature ejaculation. *J Urol*. 2007;177(3):1065-1070. doi:10.1016/j.juro.2006.10.025
6. Symonds T, Roblin D, Hart K, Althof S. How does premature ejaculation impact a man's life? *J Sex Marital Ther*. 2003;29(5):361-370. doi:10.1080/00926230390224738
7. Porst H, Montorsi F, Rosen RC, Gaynor L, Grupe S, Alexander J. The Premature Ejaculation Prevalence and Attitudes (PEPA) survey: prevalence, comorbidities, and professional help-seeking. *Eur Urol*. 2007;51(3):816-824. doi:10.1016/j.eururo.2006.07.004
8. Giuliano F, Patrick DL, Porst H, et al. Premature ejaculation: results from a five-country European observational study. *Eur Urol*. 2008;53(5):1048-1057. doi:10.1016/j.eururo.2007.10.015
9. Patrick DL, Althof SE, Pryor JL, et al. Premature ejaculation: an observational study of men and their partners. *J Sex Med*. 2005;2(3):358-367. doi:10.1111/j.1743-6109.2005.20353.x
10. Jern P, Sola IM, Ventus D. Do women's relationship satisfaction and sexual functioning vary as a function of their male partners' premature ejaculation symptoms? *J Sex Marital Ther*. 2020;46(7):630-638. doi:10.1080/0092623X.2020.1766612
11. Zhang Y, Zhou B, Qiu J, Zhang L, Zou Z. Heart rate variability changes in patients with panic disorder. *J Affect Disord*. 2020;267:297-306. doi:10.1016/j.jad.2020.01.132
12. Burri A, Giuliano F, McMahon C, Porst H. Female partner's perception of premature ejaculation and its impact on relationship breakups, relationship quality, and sexual satisfaction. *J Sex Med*. 2014;11(9):2243-2255. doi:10.1111/jsm.12551
13. Erbay G, Ceyhun G. Is heart rate variability a risk factor for premature ejaculation? *Int J Clin Pract*. 2021;75(10):e14699. doi:10.1111/ijcp.14699
14. Dekker JM, Crow RS, Folsom AR, et al. Low heart rate variability in a 2-minute rhythm strip predicts risk of coronary heart disease and mortality from several causes: the ARIC study. *Circulation*. 2000;102(11):1239-1244. doi:10.1161/01.CIR.102.11.1239
15. Alvares GA, Quintana DS, Hickie IB, Guastella AJ. Autonomic nervous system dysfunction in psychiatric disorders and the impact of psychotropic medications: a systematic review and meta-analysis. *jpn*. 2016;41(2):89-104. doi:10.1503/jpn.140217
16. Alwaal A, Breyer BN, Lue TF. Normal male sexual function: emphasis on orgasm and ejaculation. *Fertil Steril*. 2015;104(5):1051-1060. doi:10.1016/j.fertnstert.2015.08.033
17. Xia JD, Han YF, Zhou LH, Xu ZP, Chen Y, Dai YT. Sympathetic skin response in patients with primary premature ejaculation. *Int J Impot Res*. 2014;26(1):31-34. doi:10.1038/ijir.2013.23
18. Rowland DL. Genital and heart rate response to erotic stimulation in men with and without premature ejaculation. *Int J Impot Res*. 2010;22(5):318-324. doi:10.1038/ijir.2010.22
19. Turan Y, Gürel A. The heart rate recovery is impaired in participants with premature ejaculation. *Andrologia*. 2020;52(5):e13573. doi:10.1111/and.13573
20. Daniela M, Catalina L, Ilie O, Paula M, Daniel-Andrei I, Ioana B. Effects of exercise training on the autonomic nervous system with a focus on anti-inflammatory and antioxidants effects. *Antioxidants*. 2022;11(2):350. doi:10.3390/antiox11020350
21. Brenner IKM, Brown CA, Hains SJM, Tranmer J, Zelt DT, Brown PM. Low-intensity exercise training increases heart rate variability in patients with peripheral artery disease. *Biol Res Nurs*. 2020;22(1):24-33. doi:10.1177/1099800419884642
22. Ventus D, Jern P. Lifestyle factors and premature ejaculation: are physical exercise, alcohol consumption, and body mass index associated with premature ejaculation and comorbid erectile problems? *J Sex Med*. 2016;13(10):1482-1487. doi:10.1016/j.jsxm.2016.08.007
23. Yildiz Y, Kilinc MF, Doluoglu OG. Is there any association between regular physical activity and ejaculation. *Urol J*. 2018;15(5):285-289.
24. Fergus KB, Gaither TW, Baradaran N, Glidden DV, Cohen AJ, Breyer BN. Exercise improves self-reported sexual function among physically active adults. *J Sex Med*. 2019;16(8):1236-1245. doi:10.1016/j.jsxm.2019.04.020
25. Kilpatrick MW, Jung ME, Little JP. High-intensity interval training: A review of physiological and psychological responses. *ACSMs Health Fit J*. 2014;18(5):11-16.
26. Alansare A, Alford K, Lee S, Church T, Jung H. The effects of high-intensity interval training vs. moderate-intensity continuous training on heart rate variability in physically inactive adults. *Int J Environ Res Public Health*. 2018;15(7):1508. doi:10.3390/ijerph15071508
27. Besnier F, Labrunée M, Richard L, et al. Short-term effects of a 3-week interval training program on heart rate variability in chronic heart failure. A randomised controlled trial. *Ann Phys Rehabil Med*. 2019;62(5):321-328. doi:10.1016/j.rehab.2019.06.013
28. Heydari M, Boutcher YN, Boutcher SH. High-intensity intermittent exercise and cardiovascular and autonomic function. *Clin Auton Res*. 2013;23(1):57-65. doi:10.1007/s10286-012-0179-1
29. Abreu RM, de, Rehder-Santos P, Simões RP, Catai AM. Can high-intensity interval training change cardiac autonomic control? A systematic review. *Braz J Phys Ther*. 2019;23(4):279-289. doi:10.1016/j.bjpt.2018.09.010
30. Kiviniemi AM, Tulppo MP, Eskelinen JJ, et al. Cardiac autonomic function and high-intensity interval training in middle-age men. *Med Sci Sports Exercise*. 2014;46(10):1960-1967. doi:10.1249/MSS.0000000000000307
31. Ito S. High-intensity interval training for health benefits and care of cardiac diseases: the key to an efficient exercise protocol. *World J Cardiol*. 2019;11(7):171-188. doi:10.4330/wjc.v11.i7.171
32. Dimopoulos S, Anastasiou-Nana M, Sakellariou D, et al. Effects of exercise rehabilitation program on heart rate recovery in patients with chronic heart failure. *Eur J Cardiovasc Prev Rehabil*. 2006;13(1):67-73.
33. Niu C, Ventus D, Jern P, Santtila P. Premature ejaculation among Chinese urban men: prevalence and correlates. *Sex Med*. 2023;11(1):qfac015. doi:10.1093/sexmed/qfac015

34. Vitale JA, Bonato M, La Torre AL, Banfi G. Heart rate variability in sport performance: do time of day and chronotype play a role? *J Clin Med*. 2019;8(5):723. doi:10.3390/jcm8050723
35. Cash T, Fleming E, Alindogan J, Steadman L, Whitehead A. Beyond body image as a trait: the development and validation of the body image states scale. *UEDI*. 2002;10(2):103-113. doi:10.1080/10640260290081678
36. Holt A, Lyness KP. Body image and sexual satisfaction: implications for couple therapy. *J Couple Relatsh Ther*. 2007;6(3):45-68. doi:10.1300/J398v06n03_03
37. Milhausen RR, Buchholz AC, Opperman EA, Benson LE. Relationships between body image, body composition, sexual functioning, and sexual satisfaction among heterosexual young adults. *Arch Sex Behav*. 2015;44(6):1621-1633. doi:10.1007/s10508-014-0328-9
38. van den Brink F, Vollmann M, Smeets MAM, Hessen DJ, Woertman L. Relationships between body image, sexual satisfaction, and relationship quality in romantic couples. *J Fam Psychol*. 2018;32(4):466-474. doi:10.1037/fam0000407
39. Sabiston CM, Pila E, Vani M, Thogersen-Ntoumani C. Body image, physical activity, and sport: a scoping review. *Psychol Sport Exerc*. 2019;42:48-57. doi:10.1016/j.psychsport.2018.12.010
40. Reimers A, Knapp G, Reimers CD. Effects of exercise on the resting heart rate: a systematic review and meta-analysis of interventional studies. *J Clin Med*. 2018;7(12):503. doi:10.3390/jcm7120503
41. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods*. 2007;39(2):175-191. doi:10.3758/BF03193146
42. Li X, Zhang B, Li Y, Antonio ALM, Chen Y, Williams AB. Mental health and suicidal ideation among Chinese women who have sex with men who have sex with men (MSM). *Women Health*. 2016;56(8):940-956. doi:10.1080/03630242.2016.1145171
43. Chia YC, Ching SM, Ooi PB, et al. Measurement accuracy and reliability of self-reported versus measured weight and height among adults in Malaysia: findings from a nationwide blood pressure screening programme. Yon DK, ed. *PLoS One*. 2023;18(1):e0280483. doi:10.1371/journal.pone.0280483
44. Rosen R, Cappelleri J, Smith M, Lipsky J, Peña B. Development and evaluation of an abridged, 5-item version of the international index of erectile function (IIEF-5) as a diagnostic tool for erectile dysfunction. *Int J Impot Res*. 1999;11(6):319-326. doi:10.1038/sj.ijir.3900472
45. Rosen RC, Riley A, Wagner G, Osterloh IH, Kirkpatrick J, Mishra A. The international index of erectile function (IIEF): a multidimensional scale for assessment of erectile dysfunction. *Urology*. 1997;49(6):822-830. doi:10.1016/S0090-4295(97)00238-0
46. Gao J, Peng D, Zhang X, et al. Prevalence and associated factors of premature ejaculation in the anhui male population in china: evidence-based unified definition of lifelong and acquired premature ejaculation. *Sex Med*. 2017;5(1):e37-e43. doi:10.1016/j.esxm.2016.11.002
47. Jern P, Piha J, Santtila P. Validation of three early ejaculation diagnostic tools: a composite measure is accurate and more adequate for diagnosis by updated diagnostic criteria. Speybroeck N, ed. *PLoS One*. 2013;8(10):e77676. doi:10.1371/journal.pone.0077676
48. Ålgars M, Santtila P, Jern P, Johansson A, Westerlund M, Sandnabba NK. Sexual body image and its correlates: a population-based study of Finnish women and men. *Int J of Sexual Hlth*. 2011;23(1):26-34. doi:10.1080/19317611.2010.509692
49. Cho MH. Preliminary reliability of the five item physical activity questionnaire. *J Phys Ther Sci*. 2016;28(12):3393-3397. doi:10.1589/jpts.28.3393
50. Spector IP, Carey MP, Steinberg L. The sexual desire inventory: development, factor structure, and evidence of reliability. *J Sex Marital Ther*. 1996;22(3):175-190. doi:10.1080/00926239608414655
51. Antoniou P, Nestoros M, Polycarpou AC. Calculation of heartbeat rate and SpO_2 parameters using a smartphone camera: analysis and testing. *Sensors*. 2023;23(2):737. doi:10.3390/s23020737
52. Bland JM, Altman DG. Statistics notes: calculating correlation coefficients with repeated observations: Part 2–correlation between subjects. *BMJ*. 1995;310(6980):633-633. doi:10.1136/bmj.310.6980.633
53. Rosseel Y. lavaan: an R package for structural equation modeling. *J Stat Soft*. 2012;48(2). 10.18637/jss.v048.i02
54. Flora R, Zulkarnain M, Sukirno. β-endorphin response to aerobic and anaerobic exercises in Wistar male rats. *Med J Indones*. 2020;29(3):245-249. 10.13181/mji.oa.203569
55. Holwerda SW, Luehrs RE, Gremaud AL, et al. Relative burst amplitude of muscle sympathetic nerve activity is an indicator of altered sympathetic outflow in chronic anxiety. *J Neurophysiol*. 2018;120(1):11-22. doi:10.1152/jn.00064.2018
56. Pyke RE. Sexual performance anxiety. *Sex Med Rev*. 2020;8(2):183-190. doi:10.1016/j.sxmr.2019.07.001
57. Chalmers JA, Quintana DS, Abbott MJA, Kemp AH. Anxiety disorders are associated with reduced heart rate variability: a meta-analysis. *Front Psychiatry*. 2014;5:80. doi:10.3389/fpsyt.2014.00080
58. Goessl VC, Curtiss JE, Hofmann SG. The effect of heart rate variability biofeedback training on stress and anxiety: a meta-analysis. *Psychol Med*. 2017;47(15):2578-2586. doi:10.1017/S0033291717001003
59. Rowland DL, van Lankveld JJDM. Anxiety and performance in sex, sport, and stage: identifying common ground. *Front Psychol*. 2019;10:1615. doi:10.3389/fpsyg.2019.01615
60. Cofré-Bolados C, Reuquen-López P, Herrera-Valenzuela T, Orihuela-Diaz P, Garcia-Hermoso A, Hackney AC. Testosterone and cortisol responses to hiit and continuous aerobic exercise in active young men. *Sustainability*. 2019;11(21):6069. doi:10.3390/su11216069
61. Kowal M, Sorokowski P, Żelaźniewicz A, et al. A positive relationship between body height and the testosterone response to physical exercise. *Evol Hum Behav*. 2021;42(3):179-185. doi:10.1016/j.evolhumbehav.2020.08.012

How to cite this article: Niu C, Wen G, Ventus D, Zhang Y, Jern P, Santtila P. A 2-week high-intensity interval training intervention improves ejaculation control among men with premature ejaculation. *Andrology*. 2024;12:164–178. https://doi.org/10.1111/andr.13469