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SYSTEMATIC REVIEW Open Access

A systematic review and meta-analysis of the effectiveness of high-intensity interval training for physical fitness in university students

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Abstract

Background Extensive research has demonstrated the effectiveness of high-intensity interval training (HIIT) in children and adults; however, evidence specific to university students remains limited. This study aimed to evaluate the effects of HIIT on promoting physical health in university students and to identify potential factors influencing intervention outcomes.

Method A systematic search was conducted across five electronic databases (Web of Science, Scopus, PubMed, SportDiscus, and MEDLINE) up to December 2024 using Boolean operators and keywords related to HIIT and university students. Inclusion criteria: (1) Experimental studies; (2) Physical-related outcomes; (3) Intervention duration of at least 3 weeks; (4) Meets the definition of high-intensity activity; (5) Participants are general university students. A meta-analysis was conducted using RevMan 5.4 software, comparing intervention and control groups. Effect sizes were calculated using Cohen's d, and heterogeneity was assessed with the I^2 statistic. Subgroup analyses were performed based on intervention duration and rest interval duration.

Results Results showed that HIIT significantly reduced BMI, body fat percentage, waist-to-hip ratio, and heart rate, while significantly improving VO_2max and muscle strength in university students. Interventions lasting longer than eight weeks demonstrated greater improvements in muscle strength compared to those lasting eight weeks or less. However, there are no significant differences in rest interval across any of the groups. Notably, HIIT also has positive effects on agility and speed with varying effect sizes.

Conclusion The unique characteristics of university students make HIIT a time-efficient and effective intervention strategy for this population. Future studies should consider the specific needs of the university environment, incorporating the latest technological advancements and developing tailored intervention strategies that align with students' preferences.

Keywords HIIT, Effectiveness, University students

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Introduction

With the continuous rise in overweight and obesity rates (20.3%) worldwide [1], the health status of young populations is facing severe challenges. University and college students, transitioning from adolescence to early adulthood, are particularly susceptible to health issues such as weight gain, increased body fat percentage, and decreased cardiorespiratory fitness due to factors like academic and social pressures, irregular eating and sleeping habits. Academic pressures often result in prolonged periods of sedentary behavior and reduced participation in physical activities, while social pressures can lead to erratic eating patterns and disrupted sleep schedules. These behavioral patterns—including skipping meals, late-night eating, and inconsistent sleep routines—not only impair metabolic health but also interfere with the body's recovery processes, ultimately contributing to a decline in physical and cardiorespiratory fitness [2–4]. Moreover, unhealthy habits formed during this period may persist into post-graduation life [5].

Given the well-documented link between physical activity and improvements in weight management, body composition, and cardiorespiratory fitness, structured exercise interventions can be particularly beneficial for this population [6, 7]. According to the American College of Sports Medicine (ACSM) guidelines, regular PA plays a critical role in preventing and managing obesity and related conditions, contributing to overall health and well-being [8]. In university settings, where sedentary behavior is prevalent, exercise interventions help mitigate the adverse effects of inactivity, including weight gain and reduced fitness levels. Consequently, exercise not only aids in maintaining or restoring a healthy weight and body composition but also provides a foundation for long-term healthy lifestyle choices, as emphasized by recent systematic reviews and expert recommendations [9–11].

Among various exercise modalities, traditional moderate-intensity continuous training (MICT) is widely promoted for its safety and its ability to induce positive effects, both of which are superior to vigorous exercise [12]. However, given the academic and social pressures faced by university students, their limited time, and low adherence to exercise [13, 14], more efficient and time-saving intervention strategies have garnered increasing attention. High-Intensity Interval Training (HIIT) has garnered significant attention for its efficacy in improving physical performance and cardiorespiratory health within a relatively short timeframe [15, 16]. Extensive research has demonstrated HIIT's notable advantages in enhancing body composition (e.g., reducing body fat, maintaining or increasing lean body mass) and cardiorespiratory fitness (e.g., improving maximal oxygen uptake) [17, 18]. Additionally, HIIT has been shown to improve various dimensions of physical fitness(such as muscle strength, balance, and speed) [19, 20]. Some scholars further argue that compared to MICT, HIIT is more effective in stimulating exercise interest and motivation, achieving results comparable to or even surpassing traditional aerobic training with limited time investment [21, 22].

However, existing literature primarily focuses on children, general adult populations, or athletes, with relatively few studies specifically targeting university students. This stage of life is critical because behaviors adopted during university years can set the trajectory for future health. The transitional nature of university life—marked by flexible schedules, evolving responsibilities, and heightened social pressures—creates distinct challenges and opportunities for intervention. Addressing these challenges with effective exercise strategies is crucial not only for immediate health benefits but also for establishing a foundation for lifelong wellness. Although recent years have seen a growing interest in HIIT interventions for this demographic, inconsistencies remain in research design, intervention protocols (e.g., training duration, work-rest ratios), participant characteristics, and study conclusions [23–26]. In this context, the present study aims to systematically review and meta-analyze HIIT intervention trials and quasi-experimental studies conducted among general university student populations.

The study focuses on evaluating the effectiveness of HIIT on three key dimensions: body composition (BC), cardiorespiratory fitness (CF), and physical fitness (PF). Specifically, it examines the potential impacts of intervention duration (≥ 8 weeks vs. ≥3 and < 8 weeks) and interval format (short-interval [work-rest ratio ≥ 1:1] vs. long-interval [work-rest ratio < 1:1])) on the outcomes. The decision to adopt these subgroup boundaries was based on both theoretical and empirical considerations. Although previous research has used a ≥ 2-week threshold [18], our choice of a ≥ 3-week minimum ensures that interventions are long enough to induce measurable changes, while those lasting ≥ 8 weeks have been shown to yield more robust and stable improvements [27]. Additionally, by examining different work-rest ratios, we aim to account for variations in exercise intensity and recovery, which can further influence the effectiveness of HIIT protocols [28]. Together, these parameters provide a comprehensive framework that not only enhances our understanding of HIIT's benefits in university settings but also offers evidence-based insights for designing tailored physical education programs and health management strategies.

Method

This study was conducted according to The Preferred Reporting Items for Systematic Reviews and Meta-Analyses(PRISMA) [29]. This study was registered with PROSPERO, and the registration number is: CRD42024625867.

Search strategy

Five electronic databases were searched for relevant literature—Web of Science, Scopus, PubMed, SportDiscus, and MEDLINE—up to December 2024. The search strategy utilized Boolean operators AND and OR along with the following keywords: (high intensity interval training OR high-intensity interval trainings OR high intensity intermittent training OR high intensity interval exercise OR high intensity intermittent exercise OR high intensity circuit training OR high intensity training OR high intensity exercise OR high intensity aerobic interval training OR sprint interval training) AND (university OR college). When using these search strings, the results were further restricted to publications written in English and peer reviewed.

Study inclusion eligibility

The inclusion criteria were as follows: (a) published in English; (b) peer-reviewed article; (c) adopted a randomized controlled trial (RCT) or Controlled trial (CT) design; (d) examined physical-related outcomes, such as cardiovascular health indicators, BMI, and body composition. etc.; (e) intervention duration of at least 3 weeks; (f) met the definition of high-intensity activity [30]; (g) participants were general university/college students (regardless of being overweight or obese, but excluding physical education majors or student-athlete); (h) full-text accessible. The screening process was conducted by H.Y. and ML.L, and any disagreements regarding inclusion or exclusion were resolved by a third author (YJ. Z).

Data extraction

From each included study, the following key details were gathered: first author, publication year, country, number of participants, number or proportion of males and females, age range or mean age, intervention setting, duration of HIT intervals, duration of rest intervals, duration of the intervention, frequency, HIIT dose, physical-related outcomes, study outcomes.

Quality assessment

The Mixed Methods Appraisal Tool (MMAT) [31] was employed to assess the quality of the studies included. Two authors (H. Y And YJ. Z) independently evaluated the articles, and any discrepancies were resolved by consulting a third author (ML. L). While MMAT does not recommend providing an overall quality score, however, if required, scores can be expressed using symbols (e.g., * or %) to describe the results.

Meta-analysis

A meta-analysis was performed with RevMan 5.4 software to assess the effects of HIIT on physical-related outcomes by comparing intervention and control groups. To ensure the feasibility and reliability of the analysis, only studies with at least four datasets reporting the same outcomes were included in the meta-analysis [32]. The analysis utilized the mean changes and standard deviations (SD) of post-test measures to evaluate effectiveness. Employed Cohen's d to evaluate the HR and PF group, due to variations in units used across studies outcomes (e.g., resting HR vs. maximum HR). A random-effects model was applied to account for anticipated heterogeneity across measures. Heterogeneity was assessed using the I^2 statistic, with thresholds of $I^2 < 25\%$, $25\% \leq I^2 < 50\%$, and $I^2 > 75\%$ indicating low, moderate, and high heterogeneity, respectively [33]. Subgroup analyses were performed based on intervention duration (≥ 3 and < 8 weeks vs. ≥8 s.) and rest interval (rest interval ratio ≤ 1:1 vs. >1:1). Statistical significance was defined as $P < 0.1$. This approach ensures a robust and nuanced examination of HIIT's impact on physical-related outcomes, considering both study-level variability and methodological consistency. However, due to the limited number of included studies in each meta-analysis (fewer than 10), publication bias analysis was not conducted.

Result

A total of 4,721 articles were identified through database searches. After removing duplicates ($n = 1{,}250$), 3,441 articles remained for title and abstract screening, followed by full-text review ($n = 17$). Finally, 15 studies reached the inclusion criteria for analysis (as shown in Fig. 1). The main features of the studies included are presented in Table 1.

In brief, 13 of the 15 studies employed a randomized controlled trial (RCT) design. The duration of the interventions ranged from 4 [34] to 16 [35]weeks, with 12 studies reporting an intervention frequency of three sessions per week. Geographically, seven studies were conducted in China [34–40], one in Malaysia [41], one in the United States [42], one in Australia [43], one in Brazil [44], one in South Africa [45], one in Turkey [46], one in Indonesia [47], and one in Colombia [48]. Most interventions involved activities such as running, Tabata, and combined movement exercises, while one study utilized kettlebell and battle rope exercises [42]. The primary outcomes assessed in these studies included body composition [34–36, 39–46, 48], cardiorespiratory fitness [37–41, 43, 45, 47, 48], metabolic health [34, 36, 39], physical

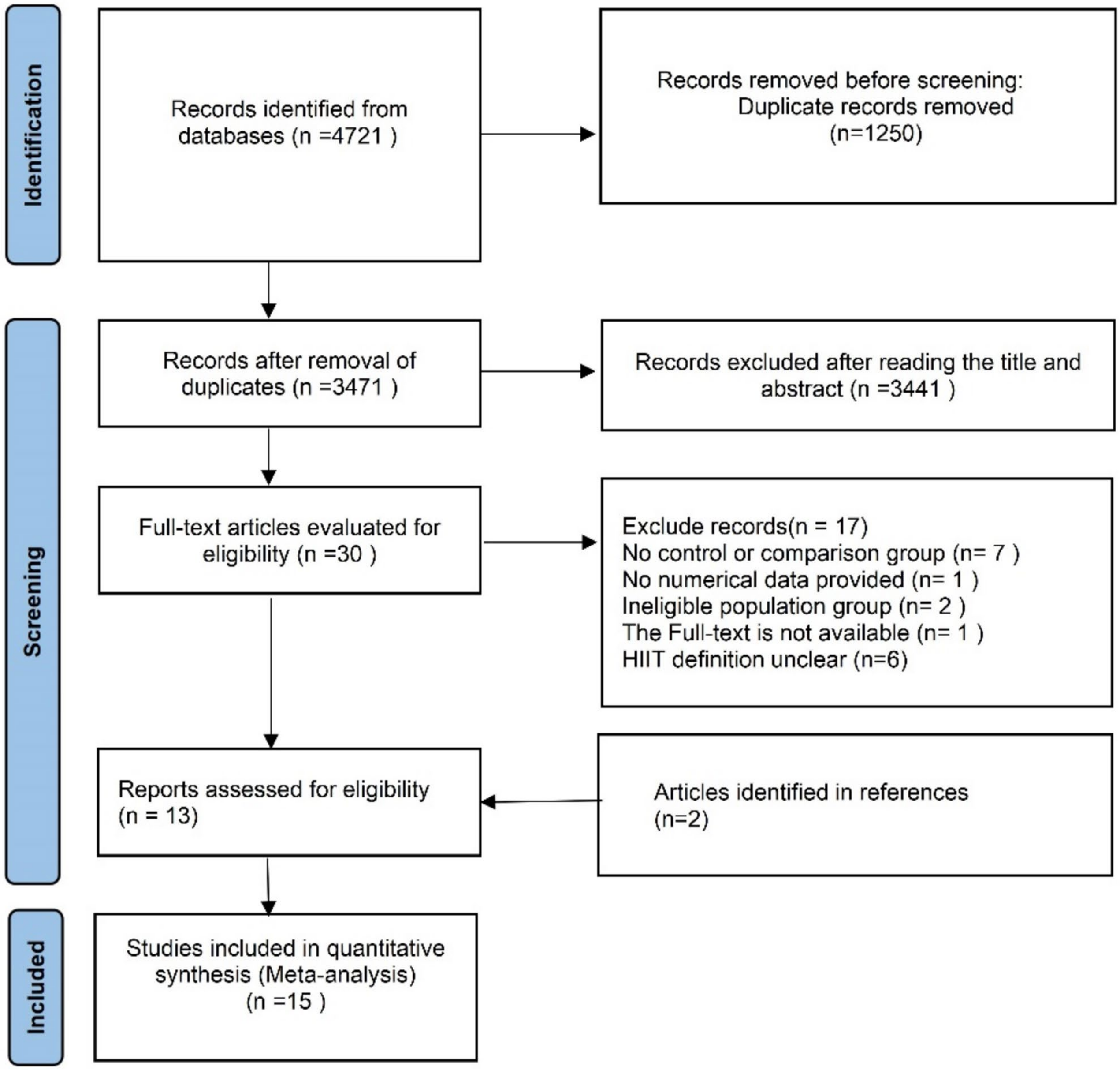

Fig. 1 Flowchart

fitness [35, 37, 40–43, 45, 46], executive function [43], and psychological health [40, 43].

Quality assessment

The quality of the studies was independently assessed by two authors, with any discrepancies resolved through discussion with a third author to ensure a consensus was reached. This rigorous evaluation process aimed to minimize bias and enhance the reliability of the quality assessment. The results of the quality assessment are summarized in Table 1. Symbols *, **, ***, ****, and ***** represent the proportion of quality criteria met, corresponding to 20%, 40%, 60%, 80%, and 100%, respectively.

Of the 15 included studies, 2 studies met ** (40%) of the quality criteria, indicating moderate adherence to methodological standards. The majority of studies ($n=8$) achieved *** (60%), reflecting acceptable but not optimal quality. One study was rated at **** (80%), signifying a high level of methodological rigor, while 4 studies attained ***** (100%), representing the highest standard of quality. The distribution of quality ratings highlights variability in the methodological robustness of the included studies. Studies achieving higher quality ratings often demonstrated greater adherence to key methodological practices, such as randomization, blinding, comprehensive reporting of intervention details, and

Table 1 Characteristics of studies

Study/quality Assessment	Age/gender	Intervention duration/frequency/HIIT approach	Repeated bouts	Exercise: Rest	Protocol duration (including rest)	Total intervention duration	HIIT vs. comparison group	Outcome
Song et al., [36] China RCT/*****	18–25/50% male	8 weeks 3 times weekly Running	Bouts:4	4:3	28 min	11 h and 12 min	HIIT: 85–90% HRmax for 4 min, followed by 50–60% HRmax for 3 min. Comparison: 60–70% HRmax for 35 min.	BC MH
Sukri et al., [41] Malaysia RCT***	21.34 ± 1.29/47.5%male	12 weeks 3 times weekly Tabata	Bouts:5 Sets: 3	3:1	15 min	9 h	HIIT: 5 motions with maximal loading. Comparison: Maintain regular daily activities	BC CF PF
Xu et al., [35] China RCT/*****	20.2 ± 1.0/50% male	16 weeks 5 times weekly Small-sided games	DAW	5:1	DAW	DAW	HIIT: shuttle runs, sprints, passing, jumps, dribbling, and shooting. Comparison: participate in regular physical education classes.	BC PF
Montealegre et al., [48] Colombia NRS/***	18–24/NR	7 weeks 3 times weekly Functional exercises	Bouts:5–6 Sets: 2	15:2	50 min	17 h and 30 min	HIIT: 75-100% HRmax Comparison: treadmill (65% HRmax)	BC CF
Hu et al., [34] China RCT/***	19.8 ± 0.26/100%female	4 weeks 5 times weekly Combined motion	Bouts: 9 Sets: 3	2:1	50 min	16 h and 40 min	HIIT: 90%HRmax. Comparison: participate in one health education each week.	BC MH
Tan [37] China NRS/**	23.49 ± 0.99/100%male	8 weeks 3 times weekly Exercise combined with resistance exercise	Bouts:6 Sets: 3	1:1	30 min	12 h	HIIT: muscle training with HR 150times/min Comparison: 30 min of aerobic exercise	CF PF
Carneiro et al., [44] Brazil RCT/***	NR/100%female	12 weeks 3 times weekly bodyweight training	Bouts:10 Sets: 3	1:1	20 min	12 h	HIIT: HIIBWT (85–90% HRmax) Comparison: aerobic and resistance exercise	BC
Iyakrus et al., [47] Indonesia RCT/***	19–21/NR	16 weeks 2 times weekly Running	Bouts:14–20	2:1	10–15 min	5–8 h	HIIT: Exercises with HRmax greater than 90%. Comparison: as usual	CF
Boer [45] South Africa RCT***	18–25/58.6%male	7 weeks 3 times weekly Running	Bouts 4–5	1:1	32 min	11 h and 12 min	HIIT: four-four min running (90% HRmax) Comparison: normal daily activities	BC CF PF
Quednow et al., [42] USA RCT/***	20.54 ± 1.17/30.8% male	5 weeks 3 times weekly Kettlebells and battle ropes exercise	Bouts:10 Sets: 4	1:1	30 min	7 h and 30 min	HIIT: RPE 8–10 Comparison: normal workout routines	BC PF
Wu et al., [38] China RCT/**	23.57 ± 1.5/NR	8 weeks 3 times weekly Running	Bout: 6	1:1	50 min	20 h	HIIT: 90% VO_2max Comparison: 70%VO_2max	CF
Eather et al., [43] Australia RCT/****	20.38 ± 1.88/34%male	8 weeks 3 times weekly Combined training	DAW	1:1	DAW	30 h and 24 min	HIIT: 85% or above HRmax Comparison: usual PA routines	BC CF PF EF AL

Table 1 (continued)

Study/quality Assessment	Age/gender	Intervention duration/frequency/HIIT approach	Repeated bouts	Exercise: Rest	Protocol duration (including rest)	Total intervention duration	HIIT vs. comparison group	Outcome
Lu et al., [39] China RCT/*****	20.38/100%female	12 weeks 3 times weekly Tabata	Bouts:4 Sets:2	2:1	19 min	11 h and 24 min	HIIT: 90% HRmax; Comparison: normal daily activities	BC CF MH
Cigerci et al., [46] Turkey RCT/***	19.66 ± 1.11/100%male	9 weeks 3 times weekly Sprint	Bouts: DAW	1:12	DAW	DAW	HIIT:90% HRmax; Comparison: no training	BC PF
Wang et al., [40] China RCT/*****	19.75 ± 1.55/26%male	8 weeks 3 times weekly Remote coaching	NR	NR	40 min	16 h	HIIT: Intensity increased Comparison: aerobic resistance training	BC CF PF PH

Note: HIIT, high-intensity interval training; RCT, randomized controlled trials; NRS, non-randomized studies; HRmax, maximum heart rate; BC, body composition; MH, metabolic health; CF, cardiorespiratory fitness; PF, physical fitness; DAW, dynamic adjustments weekly; NR, not report; RPE, rating of perceived exertion; VO_2max, maximal oxygen consumption; EF, executive function; AL, anxiety levels; PH, psychological health

statistical analysis appropriate to the study design. In contrast,

studies with lower quality ratings were generally characterized by limited methodological transparency, incomplete reporting, or potential risks of bias. The detailed evaluation contents are shown in the supplementary materials.

Meta-analysis

Body composition

The pooled mean difference (MD) for BMI was −1.08 (95% CI: -1.87 to -0.29), indicating a statistically significant effect of HIIT interventions ($Z = 2.68$, $P = 0.007$) (as shown in Fig. 2). This result suggests that HIIT has a meaningful impact on reducing BMI. However, there was substantial heterogeneity across studies ($Tau^2 = 1.01$, $Chi^2 = 41.03$, $df = 9$, $P < 0.00001$, $I^2 = 78\%$), reflecting considerable variability in study results. This heterogeneity may stem from differences in study design, population characteristics, or intervention protocols. To address this variability, a random-effects model was applied, which provides a more conservative estimate by accounting for between-study differences. This approach ensures that the pooled estimate is robust despite the observed heterogeneity. Subgroup analyses explored potential sources of heterogeneity. (as seen in supplementary). The analysis examined the impact of intervention duration ($Chi^2 = 0.84$, $df = 1$, $P = 0.36$) and rest interval ($Chi^2 = 0.88$, $df = 1$, $P = 0.36$) on the overall effect. Both analyses suggested no statistically significant interactions, indicating that neither intervention duration nor interval timing substantially influenced the effect of HIIT on BMI.

The MD for BF% was −2.88 (95% CI: -5.66 to -0.09), indicating a statistically significant effect of HIIT interventions ($Z = 2.0.$, $P = 0.04$) (as shown in Fig. 3). This result suggests that HIIT has a meaningful impact on reducing BF%. The heterogeneity was ($Tau^2 = 1.01$, $Chi^2 = 41.03$, $df = 9$, $P < 0.00001$, $I^2 = 78\%$), reflecting considerable variability in study results. The random-effects model was applied. There was no significant effect on intervention duration ($Chi^2 = 0.02$, $df = 1$, $P = 0.88$) and rest interval ($Chi^2 = 3.64$, $df = 1$, $P = 0.06$).

The MD for WHR was −0.02 (95% CI: -0.03 to -0.01), indicating a statistically significant effect of HIIT interventions ($Z = 3.34.$, $P = 0.0008$) (as shown in Fig. 4). This result suggests that HIIT has a meaningful impact on reducing WHR. The heterogeneity was ($Tau^2 = 0.00$, $Chi^2 = 4.96$, $df = 4$, $P = 0.29$, $I^2 = 19\%$), reflecting low heterogeneity across studies. There was no significant effect in intervention duration ($Chi^2 = 0.38$, $df = 1$, $P = 0.54$) and rest interval ($Chi^2 = 0.50$ $df = 1$, $P = 0.48$) (as seen in supplementary).

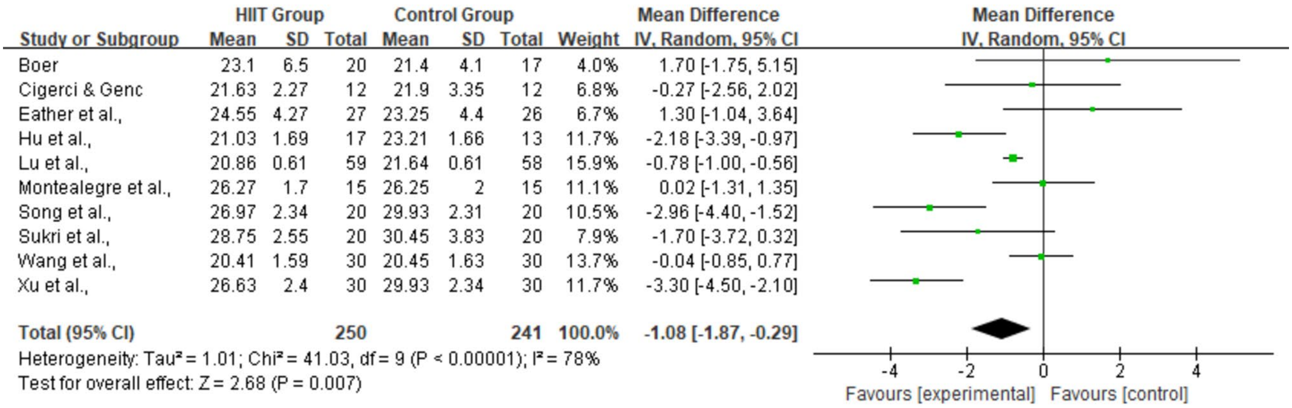

Fig. 2 Forrest plot of HIIT effect on BMI

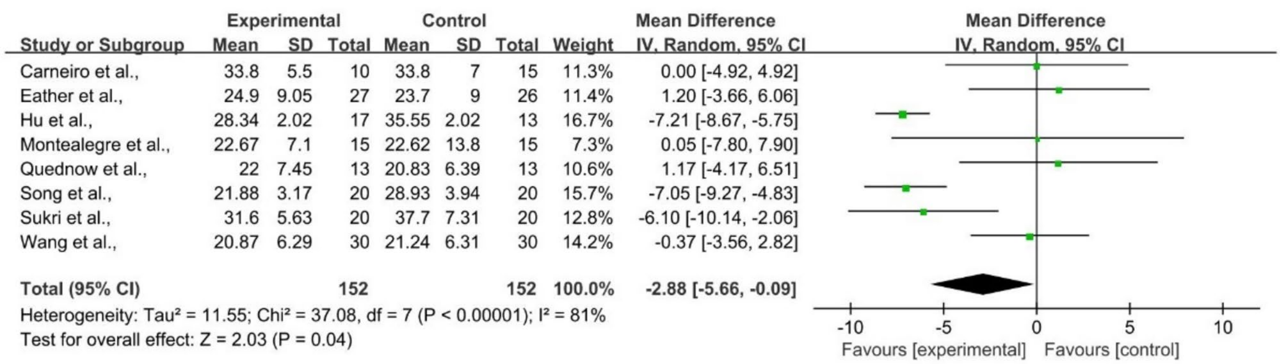

Fig. 3 Forrest plot of HIIT effect on BF%

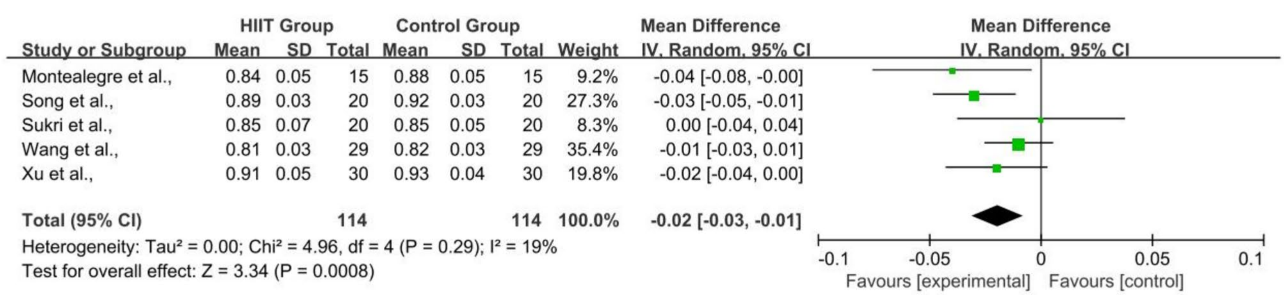

Fig. 4 Forrest plot of HIIT effect on WHR

Cardiorespiratory fitness

The MD for VO_2max was −3.55 (95% CI: 3.39 to 3.72), indicating a statistically significant effect of HIIT interventions (Z = 43.07., $P < 0.00001$) (as shown in Fig. 5). This result suggests that HIIT has a meaningful impact on increasing VO_2max. The heterogeneity was ($Chi^2 = 119.33$, df = 7, $P < 0.00001$, $I^2 = 94\%$), reflecting high heterogeneity across studies. The high heterogeneity observed in the analysis may stem from variations in study design, measurement methods, and data collection processes. Still, the random-effects model was applied. There was no significant effect in intervention duration ($Chi^2 = 1.24$, df = 1, $P = 0.27$) and rest interval ($Chi^2 = 1.53$ df = 1, $P = 0.22$) (as seen in supplementary).

The Cohen's d for HR was −0.41 (95% CI: -0.70 to -0.11), indicating a statistically significant effect of HIIT interventions (Z = 2.72., $P = 0.006$) (as shown in Fig. 6). This result suggests that HIIT has a meaningful impact on reducing HR. The heterogeneity was ($Tau^2 = 0.03$ $Chi^2 = 5.26$, df = 4, $P = 0.26$, $I^2 = 24\%$), reflecting low heterogeneity across studies. There was no significant effect in intervention duration ($Chi^2 = 2.19$, df = 1, $P = 0.14$) and rest interval ($Chi^2 = 2.71$ df = 1, $P = 0.10$) (as seen in supplementary).

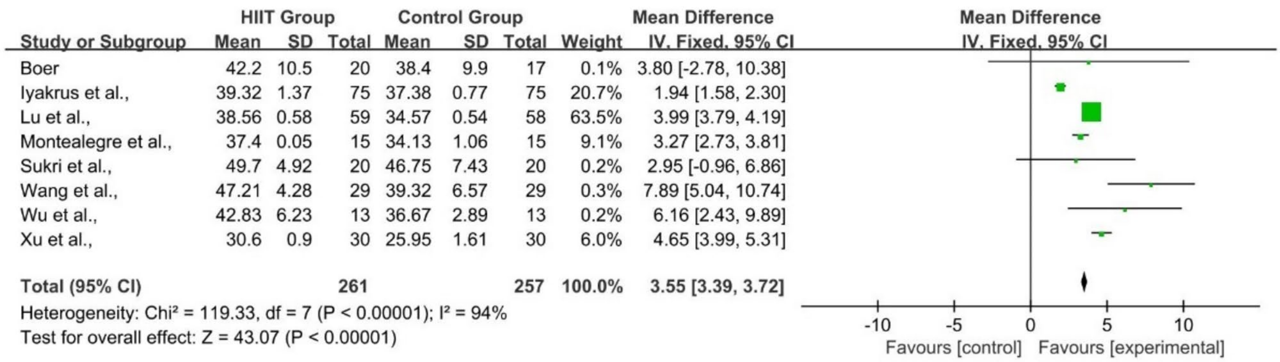

Fig. 5 Forrest plot of HIIT effect on VO_2max

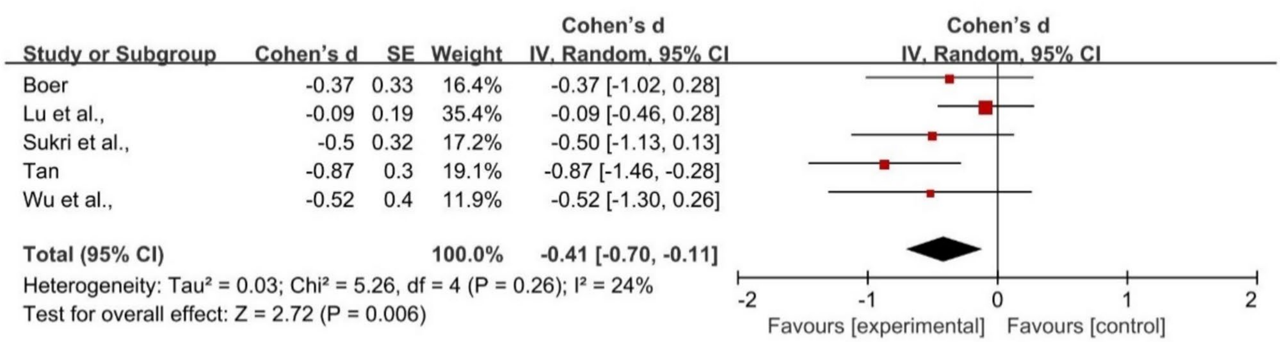

Fig. 6 Forrest plot of HIIT effect on HR

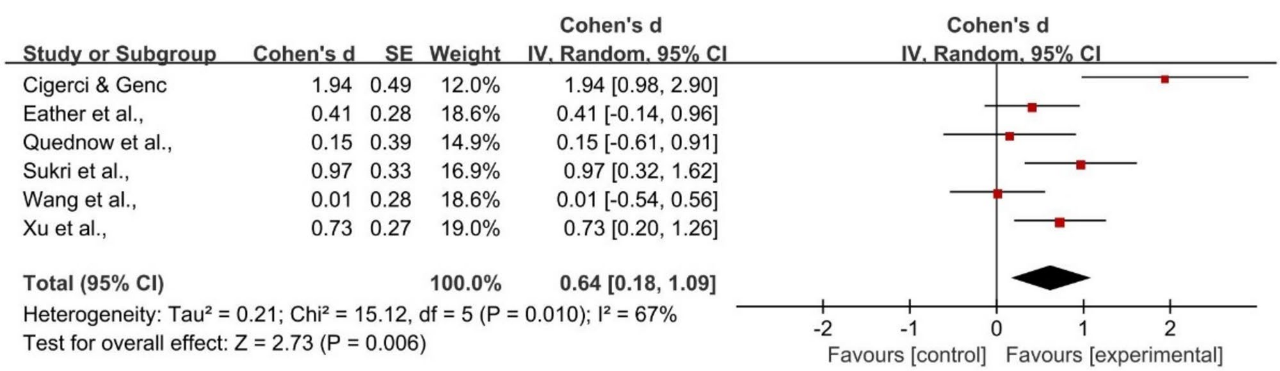

Fig. 7 Forrest plot of HIIT effect on muscle strength

Physical fitness

The Cohen's d for muscle strength was 0.64(95% CI:0.18 to 1.09), indicating a statistically significant effect of HIIT interventions (Z = 2.73., P = 0.006) (as shown in Fig. 7). This result suggests that HIIT has a meaningful impact on improving muscle strength. The heterogeneity was ($Tau^2 = 0.21$ $Chi^2 = 15.12$, df = 5, P = 0.01, $I^2 = 67\%$), reflecting high heterogeneity across studies. The random-effects model was applied to address this variability. There was a significant effect in intervention duration ($Chi^2 = 6.43$, df = 1, P = 0.01), indicating that interventions lasting longer than eight weeks are more effective for improving muscle strength. No significant effect between interval groups ($Chi^2 = 0.01$, P = 0.92) (as seen in supplementary).

Additionally, two studies found that HIIT significantly improved agility (cohen's d = 0.43 and 0.18) [40, 45]. One study reported a significant speed improvement (cohen's d = -1.13) [46].

Discussion

To our knowledge, this study is the first systematic review and meta-analysis to evaluate the effectiveness of HIIT specifically among university students. Fifteen studies reaching the criteria were identified, with data extracted and synthesized for meta-analysis. The results indicate that, compared to aerobic training, moderate-intensity training, or no training controls, HIIT significantly reduces BMI, BF%, WHR, and HR, and significantly improves VO_2max and muscle strength. Furthermore, Intervention duration played a significant role in enhancing muscle strength, with durations longer than eight weeks showing greater benefits compared to interventions lasting eight weeks or less.

However, the methodological quality of the included studies varied. Of the 15 studies, only 4 were rated as high quality. Many studies did not report whether blinding was implemented during outcome assessments, failed to describe participants' adherence to the intervention protocols, or lacked information on follow-up data. Additionally, the sample sizes in these studies were generally small, limiting the generalizability of the findings.

The studies we reviewed employed a range of modalities, including running, sprint, bodyweight exercises, battle ropes with kettlebell combinations, and Tabata. Each of these protocols emphasizes different aspects of fitness. For example, running and sprint-based protocols predominantly target cardiovascular capacity and improve VO_2max, whereas bodyweight training and combined modalities engage both muscular endurance and strength alongside aerobic benefits. Tabata protocols, characterized by very brief, high-intensity bursts with short recovery periods, offer a balanced approach that can simultaneously stimulate metabolic and neuromuscular adaptations. Additionally, small-sided games (SSGs), a novel HIIT strategy, integrate multiple fitness components—enhancing agility, coordination, and tactical skills along with cardiovascular function—by simulating sport-specific activities in a competitive, team-based setting. Recognizing these distinctions can inform the design of HIIT programs that are specifically tailored to target the diverse health and fitness needs of university students, ensuring that the chosen modality aligns with desired outcomes while considering factors such as exercise intensity, duration, and baseline fitness levels.

Body composition

The findings demonstrate that HIIT significantly improves body composition metrics among university students, including reductions in body mass index (BMI), body fat percentage (BF%), and waist-to-hip ratio (WHR), findings that are consistent with previous studies [26, 49, 50]. From a physiological perspective, HIIT promotes energy expenditure both during and after exercise (EPOC effect) through repeated high-intensity efforts in a short period, enhancing fat oxidation rates and basal metabolic levels [51]. Furthermore, compared to MICT, HIIT offers a more appealing and practical option for time-constrained university students who are particularly sensitive to the effectiveness of exercise, supporting its broader application in health management [52].

A notable finding of this study is that subgroup analysis approached significance($P = 0.06$), suggesting that short-interval HIIT may be more effective in reducing BF% compared to long-interval HIIT, which is consistent with findings from previous studies [53]. This outcome may be attributed to the short rest intervals reducing the reliance on glycolysis for energy production, thereby increasing the proportion of energy derived from aerobic metabolism [54]. This shift may enhance overall metabolic efficiency, promoting greater fat oxidation and improved endurance capacity. The increased aerobic contribution during shorter rest intervals allows participants to sustain exercise intensity for longer periods, potentially amplifying the physiological benefits of HIIT. Therefore, for college students whose main goal is to lose fat, if their physical foundation and health status allow, they can moderately adopt the short-interval HIIT mode within a safe range to obtain higher fat oxidation efficiency per unit time. Moreover, given the academic pressures and time constraints commonly faced by university students, short-interval HIIT offers greater flexibility in terms of duration and intensity, making it easier to integrate into campus health education or physical education programs. However, when intervening, it is necessary to consider personal physical ability, sports experience, and tolerance to high-intensity training; excessively shortening rest time or blindly extending working hours may lead to excessive fatigue or sports injuries. Finally, given the relatively small sample size in this study, this result should be interpreted with caution.

Cardiorespiratory fitness

HIIT interventions significantly improve VO_2max and reduce resting or exercise-related heart rate (HR), further supporting the notion that HIIT is effective in enhancing cardiorespiratory fitness [25]. VO_2max is a core indicator of an individual's aerobic capacity and cardiorespiratory function, while HR serves as a critical parameter for monitoring exercise intensity and cardiovascular load. During each high-intensity interval of HIIT, HR rapidly elevates to higher zones, requiring the heart to efficiently supply oxygen-rich blood within a short time. This process not only strengthens myocardial contraction but also improves the compliance of peripheral blood vessels [55]. During overextended intervention periods, these physiological adaptations become more pronounced, leading to significant improvements in both VO_2max and HR.

For university students, enhanced cardiorespiratory fitness contributes to better athletic performance and offers potential protective effects against chronic conditions such as cardiovascular diseases and metabolic syndrome [56]. Incorporating HIIT-based cardiorespiratory training into university physical education programs or exercise guidance can provide students with an efficient and diverse workout experience within limited time constraints, while also promoting overall health in the young adult population [57]. Additionally, individual differences in fitness levels must be considered. For students with weaker baseline cardiorespiratory function or underlying cardiovascular risks, HIIT protocols should be carefully tailored, including adjustments to work duration, rest intervals, and exercise intensity, to prevent excessive fatigue or exercise-related injuries. Tailoring such interventions ensures both the safety and effectiveness of HIIT for diverse student populations.

Physical fitness

The meta-analysis in this study highlights the significant effects of HIIT on improving the muscle strength of university students, Additionally, two studies reported enhancements in agility, while one study demonstrated speed improvements. HIIT exerts substantial stimuli on the neuromuscular and energy metabolism systems by achieving high-intensity loads repeatedly in a short period, facilitating rapid and efficient improvements in physical performance and fitness metrics [58].

Notably, the study found that HIIT protocols lasting longer than eight weeks demonstrated more pronounced improvements in muscle strength among university students. Extended intervention durations provide sufficient time for physiological adaptations such as mitochondrial biogenesis, muscle fiber type transformation, and enhanced neuromuscular conduction efficiency [59]. Over these longer training cycles, the students' physical capacities adapt more effectively to high-intensity loads, resulting in greater gains in metrics such as maximal strength, speed, and aerobic-anaerobic metabolic efficiency. However, in the subgroup analysis of rest intervals, no significant differences were found in the effects of HIIT on muscle strength. This suggests that variations in rest interval duration alone may not be a decisive factor in determining strength adaptations within HIIT protocols. One possible explanation is that muscle strength improvements depend more on overall training volume, intensity, and resistance load [60]. While shorter rest intervals are often associated with greater metabolic stress and endurance adaptations, longer rest intervals may allow for higher force production and better neuromuscular recovery, potentially benefiting strength development. However, since the overall effect of rest intervals on muscle strength was not significant, it is possible that other training variables—such as exercise selection, resistance level, and total workload—play a more dominant role in strength gains. Moreover, the nature of HIIT exercises used in the included studies may have influenced these findings. Many HIIT protocols prioritize aerobic-based or bodyweight exercises (e.g., jumping jacks, burpees, and sprints) rather than high-resistance strength exercises, which are traditionally more effective for increasing maximal muscle strength. Consequently, the rest interval duration within these HIIT sessions may not have been a limiting factor for strength development.

Unique characteristics and novel insights in university students

An important consideration in interpreting our findings is the distinct nature of university students compared to other adult groups. University students experience more flexible schedules, unique academic pressures, and rapid developmental changes that can influence their physiological and psychological responses to exercise. Unlike many working adults with established routines, students face fluctuating stress levels, variable social engagements, and intermittent periods of intense study—all of which may enhance their neuroplasticity and metabolic responsiveness to time-efficient, high-intensity training protocols [61]. Additionally, the communal university environment, with its strong social support and group dynamics, tends to boost adherence and motivation, potentially amplifying the positive outcomes of HIIT. Recognizing these unique lifestyle attributes underscores the need for tailored HIIT interventions that optimize both short-term performance gains and long-term health outcomes in university students, distinguishing their responses from those of the broader adult population.

This study diverges from previous research in several key ways. While numerous recent studies have established the benefits of HIIT for reducing body fat and enhancing cardiorespiratory fitness [17, 62], our meta-analysis specifically examines university students—a group with distinct lifestyle patterns and adherence challenges. In doing so, we uncovered a novel, duration-dependent effect on muscle strength, with interventions lasting more than eight weeks eliciting significantly greater neuromuscular adaptations, an outcome that has not been prominently reported in prior literature [17, 63, 64]. Additionally, our analysis distinguishes between different HIIT modalities—ranging from traditional running and sprint-based protocols to Tabata and small-sided games, thereby offering fresh insights into how specific exercise formats can be strategically tailored to optimize both physical and functional outcomes in a university setting. These nuanced findings suggest that, beyond the established benefits, HIIT programs for young adults may need to be customized not only in terms of intensity and duration but also by selecting the modality that best aligns with the unique demands and preferences of the academic environment.

This study also uncovered an intriguing finding regarding work-rest ratios. In our subgroup analysis, no significant differences emerged across any physical indicators—such as BF%, VO_2max, or muscle strength—when comparing various work-rest ratios. This contrasts with earlier studies that have reported variable physiological adaptations with different work-rest configurations in HIIT protocols [28]. One possible explanation is that, within the university student population, factors like overall adherence, baseline fitness, and external stressors (e.g., academic pressures) may overshadow the effects of work-rest ratio modifications. Alternatively, the range of work-rest ratios employed in the studies we reviewed might have been too narrow to reveal distinct differences. Further investigation is warranted to elucidate how work-rest configurations interact with the unique lifestyle and physiological characteristics of university students.

Incorporating HIIT into student health initiatives

The practical applications of our findings for university settings are multifaceted and warrant a tailored approach that leverages the unique characteristics of the campus environment. First, universities inherently foster a communal and group-oriented atmosphere. This social structure can be harnessed by implementing group-based HIIT programs, which not only promote adherence through peer support and accountability but also enhance the overall enjoyment and motivation of exercise sessions. Organized group HIIT classes or intramural competitions can capitalize on the inherent group dynamics of student life, transforming physical activity into a social event that reinforces campus community.

Second, the high receptivity of university students to novel and technology-driven initiatives presents another opportunity. Integrating HIIT programs with advanced wearable technologies, mobile applications, or even gamification elements can increase engagement and provide real-time feedback. For instance, using wearable devices to monitor heart rate and track progress, coupled with app-based challenges and rewards, can appeal to tech-savvy students and create a more interactive and personalized exercise experience.

Given the flexible nature of university schedules, HIIT can be woven throughout campus life to promote consistent physical activity. For example, brief HIIT sessions—or "exercise snacks" [65]—can be integrated into physical education classes, orientation events, or even during short breaks between lectures to interrupt sedentary periods. Rather than presenting these short bouts as a complete intervention on their own, it is more effective to position them within a comprehensive movement strategy that considers variations in intensity, frequency, and individual fitness levels. By tailoring these flexible exercise opportunities to meet the diverse needs of students, universities can cultivate a proactive health management culture that supports sustained engagement and overall well-being.

Finally, collaboration between university athletic departments, student health centers, and academic units can facilitate the development of comprehensive health initiatives that include HIIT as a core component. Such partnerships could support research-based adjustments to HIIT protocols tailored specifically for student populations, continuously optimizing program design based on feedback and emerging evidence. In doing so, universities not only promote physical health but also contribute to improved mental well-being and academic performance, thereby enhancing the overall student experience.

Future direction

Although this study demonstrated that intervention duration effectively improved muscle strength in university students—further research is needed to identify the optimal configurations of intervention frequency and training duration. Moreover, when investigating these parameters, it is crucial to control confounding factors such as participants' baseline health status. Tailoring protocols to specific subgroups (e.g., beginners versus experienced individuals or across different genders and age ranges) may maximize training efficacy while ensuring safety. Such refined protocols would provide actionable guidelines for designing effective and inclusive HIIT interventions for university populations.

In addition, future studies should focus on observing the long-term maintenance of health outcomes following the completion of HIIT interventions. Particular attention should be given to changes in lifestyle, exercise habits, and physical function during the post-intervention period. Longitudinal studies with follow-up periods of six months, one year, or longer would provide valuable insights into the sustained effects of HIIT on health management in university students. Moreover, these studies could identify intervention strategies that help participants retain the health benefits initially gained through HIIT.

Lastly, With the increasing prevalence of wearable devices and digital exercise platforms, future research could explore the integration of technologies such as heart rate monitoring, motion tracking, virtual reality (VR), and gamification into HIIT interventions. These advancements could provide real-time monitoring and instant feedback, potentially enhancing university students' interest and adherence to exercise programs.

Strengths and limitations

This is the first study that provides a systematic and comprehensive meta-analysis of HIIT interventions targeting university students (specific population, such as academic stress and limited time), synthesizing findings across diverse studies to identify overall trends and effects. Furthermore, the study's subgroup analyses, examining factors such as intervention duration and rest interval, provide nuanced insights into how specific HIIT configurations influence outcomes, aiding in the development of optimized protocols. Findings emphasize the potential of HIIT as a time-efficient and versatile exercise strategy, particularly suited to university settings, with applications in physical education and health promotion programs.

However, there are some limitations in this study. Significant heterogeneity was observed among included studies, likely due to variations in protocols, participant characteristics, and measurement methods, which may affect the reliability of pooled results. In addition, many studies had methodological limitations, such as inadequate blinding, small sample sizes, and a lack of adherence or follow-up data, which may introduce bias into the results. These strengths and limitations underline the importance of further research to address gaps and build upon the foundational insights provided by this study.

Conclusion

HIIT was shown to be an effective, time-efficient intervention, particularly when intervention durations exceed eight weeks, with better results on muscle strength. Overall, the findings support the inclusion of HIIT in university health promotion programs, with the potential to improve not only physical health outcomes but also the overall well-being of students. Addressing the identified limitations in future studies will further strengthen the evidence base and inform the development of optimized, inclusive HIIT interventions.

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

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Author contributions

H.Y was responsible for drafting the manuscript. H.Y, YJ.Z, and ML.L conducted the search and screening of articles and evaluated the selected articles. J.Z supervised the overall work and provided revision suggestions. All authors have read and approved the final manuscript for publication.

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Data availability

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

Declarations

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Consent for publication

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Competing interests

The authors declare no competing interests.

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