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Original Article

Comparative analysis of ten-week high-intensity interval training, moderate-intensity continuous training, and proprioceptive workouts: Impact on cognitive abilities, body composition, perceived stress and motor skills

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Abstract
Purpose. With the emergence of diverse training methods, it is essential to conduct a comparative analysis of their effects, as each method influences the human body – considered a biopsychosocial entity – differently. Our comparative study aimed to explore the complex effects of proprioceptive training (ProprT), moderate-intensity continuous training (MICT) and high-intensity interval training (HIIT) on cognitive abilities, motor skills, body composition and perceived stress. The goal was to provide insights into effectively integrating these methods into educational and sport programs. **Methods.** One hundred forty-two healthy university students participated in the study. Participants voluntarily engaged in Pilates (n=22), yoga (n=29), functional circuit workouts (n=22), running club (n=23) or boot camp (n=46). Exercises were categorized into ProprT, MICT and HIIT based on established criteria for type and intensity zones. We conducted Hungarofit assessments, which included the Cooper test, push-up test, sit-up test and Flamingo balance test. Participants' body composition was analyzed, and cognitive functions were tested. **Results.** In Cooper test, only the MICT group showed significant improvement during the exercise program. On the other hand, the ProprT group exhibited a significant increase in total body mass, indicating that this training method was associated with the lowest calorie consumption. The most pronounced change in Borg scale values occured in the ProprT group, suggesting that lower-intensity training results in a more significant shift in the subjective level of effort. Changes in VTS COG/S8 test results highlight that exercise generally has a positive effect on cognitive abilities. Additionally, perceived stress levels decreased across all training types. **Conclusion.** Based on our observations, MICT may be the most effective method for improving students' aerobic capacity, while ProprT exercises may be particularly beneficial for enhancing cognitive abilities in public education. Notably, all three training types effectively reduce perceived stress. However, further comprehensive comparative analyses are needed to make personalized recommendations for individuals in public education and recreational athletes to determine which training method is the most optimal choice for their goals.
Key Words: proprioceptive training, moderate-intensity continuous training, high-intensity interval training, motor abilities, cognitive abilities

Introduction

Exercise is a subcategory of physical activity that is planned, structured, repetitive, and purposefully focused on improving or maintaining one or more components of physical fitness (Dasso, 2019). Many new and diverse training methods have appeared, which affect the human body as a biopsychosocial entity in different ways. Therefore, it is very important to know what exercise type should be used to achieve specific goals. Basically, all exercises are functional, as they have a specific purpose. Depending on this, we can distinguish several types based on performance components, such as motor, cognitive or affective factors.

Effects on motor skills, including conditioning and coordination skills, as well as joint mobility, are present in varying proportions throughout all exercises. All exercise methods develop motor skills in a different way. It is well known that endurance training enhances the body's resistance to fatigue and improves the efficiency of aerobic (and anaerobic) metabolism, while strength training primarily results in muscle hypertrophy and increased muscle strength (Egan & Zierath, 2013; Hawley et al., 2014).

Interval training is a form of exercise in which intense work periods and rest periods alternate in a regular and planned manner. Interval training can therefore be placed between the two aforementioned training methods, as it can induce strength, endurance or mixed adaptations in the body with the appropriate dosage of training components (MacInnis & Gibala, 2016; Ayob et al., 2023). High-intensity interval training (HIIT) is a type of interval training, which targets intensities between 80% and 100% of the maximum heart rate, with intervals lasting from 6 sec to 4 min, followed by a short period of reduced oxygen consumption (Weston et al.,

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2014; Araujo, 2024). HIIT can be adapted to the individual conditions, making it suitable for even patients suffering from chronic diseases, like coronary heart disease, chronic heart failure, type 2 diabetes or asthma (Moholdt et al., 2014; Francois & Little, 2015; Rifki et al., 2023). Regular HIIT generates classic physiological adaptations in the body, including an increase in the amount of mitochondria, an improvement in aerobic capacity (VO2max) (MacInnis & Gibala, 2016; Alibrahim & Hassan, 2024). Furthermore, moderate-level evidence indicates that HIIT can improve body composition and insulin sensitivity and in adults at a higher risk of cardiovascular disease and diabetes (Campbell et al., 2019;).

Continuous training, also known as continuous exercise, includes any form of physical exercise performed without rest periods and can be performed at low, moderate, or high exercise intensities. Moderate-intensity continuous training (MICT) is a type of endurance training, which is characterized by exercising at 55–70% of the maximum heart rate, usually for 20-60 minutes (Norton et al., 2010). Traditionally, in most exercise regimens, moderate-intensity continuous training (MICT) is the first choice for fat loss (Yumuk et al., 2015). However, to achieve the benefits, MICT must be maintained for a long period of time, which is time-consuming especially for young people these days, so HIIT is considered a time-saving and effective alternative. Consequently, in recent years, several studies have compared the health effects of HIIT and MICT. Regarding their effects on metabolic and cardiovascular factors, as well as body fat mass and percentage, similar improvements were reported for both interventions in obese adults and sedentary adolescents (Martins et al., 2016; Sanca-Valeriano et al., 2023; Sun et al., 2024). On the other hand, several studies have shown that HIIT may improve maximal oxygen consumption (VO2 max) to a greater extent than MICT (Mekari et al., 2020; Milanovic et al., 2015; Tabata, 2019). However, the effects of HIIT and MICT may vary based on population characteristics (Schmitz et al., 2020). Although both MICT and HIIT have many health benefits, MICT requires longer periods of continuous exercise, which may be challenging for children and adolescents with lower motivation levels. This may affect their long-term commitment to regular physical activity. On the contrary, HIIT is considered to be more time-saving and enjoyable, therefore HIIT may results in a similar or even greater benefits compared with MICT in children and adolescents (Corte de Araujo et al., 2012; Martin-Smith et al., 2020).

Proprioception, the ability to sense the body's position and movement, is essential for physical well-being (Ribeiro & Oliveira, 2007). Proprioceptive training (ProprT) programs can improve body awareness, balance, coordination, motor learning, which can enhance motor skills and overall physical performance (Yilmaz et al., 2024; Sterkowicz-Przybycień & Kulesza, 2023). Studies have reported the beneficial effects of proprioceptive training on somatosensory and sensorimotor functions, as well as on immune regulation (Aman et al., 2015; Balogh et al., 2022).

Numerous investigations have also been reported in recent years on the effects of physical activity and exercise on cognitive abilities. Studies at the molecular level highlight certain neurotrophic factors that play a central role in neuroplasticity processes and are inevitably involved in the regulation of normal and pathological behavior. Among them, brain-derived neurotrophic factor (BDNF) is a key transducer of neuroplasticity processes because it is critically involved in the control of neuro- and synaptogenesis, protection and maintenance of various populations of neurons. Additionally, this is the most important regulator of memory and thinking (Castrén & Antila, 2017). BDNF levels can be increased by an active social lifestyle and proper and regular physical activity (Makra & Balogh, 2021). A recent study reported significant improvements in cognitive test scores, and BDNF levels after both MICT and HIIT interventions in middle-aged and overweight men (De Lima et al., 2022). Among children with attention-deficit/hyperactivity disorder (ADHD), both MICT and HIIT showed positive effects on cognitive and behavioral outcomes, albeit HIIT demonstrated superior benefits over MICT in improving attention deficits (Sabaghi et al., 2025). Nevertheless, it is not yet clear which type of training is most effective in terms of cognitive abilities in healthy individuals, so further studies are needed. Based on the research of Mekari et al. (2020), improved cardiorespiratory function contributes to increased vascularization of the brain, which positively affects cognitive abilities. Based on this, HIIT training may indeed be the most effective in this area, as this type of training increases VO2 max the most. However, ProprT should also be considered, as it effectively aids perceptual processes, which may increase the activity of the nervous system during training, thereby positively affecting cognitive abilities.

Chronic stress has become a widespread phenomenon today, fundamentally affecting the quality of life of the population, affecting our mental abilities and resulting in numerous psychosomatic illnesses; furthermore, it also impairs physical performance. Of note, the definition of stress according to Selye describes the non-specific reaction of the organism to any stimulus that deviates from its original state of equilibrium and forces it to adapt (Selye, 1946). Stress can therefore be eustress (enhancing performance) or distress (impairing performance), depending on how we adapt to the stressor, to which our cognitive abilities and physical activity also contribute. Numerous studies support and it should now be treated as a fact that physical activity has a stress-regulating effect (Schultchen et al., 2019; Zschucke et al., 2015). However, research on emotional or pleasurable responses to HIIT and MICT is largely ambiguous (Ram et al., 2022). For example, Niven et al. (2021) concluded that compared to MICT, HIIT is experienced less positively, but the post-workout experience

is more enjoyable. While Oliveira et al. (2018) suggested that HIIT may elicit the same or more positive psychological responses as MICT.

Since there is a lack of studies comparing these complex effects of HIIT, MICT and ProprT, we examined the effects of these exercise modalities on cognitive abilities, motor skills, body composition, and perceived stress. In our complex comparative study, we examined the psychosomatic effects of various exercises among young people who attended 60-minute university physical education classes on a weekly basis. It is important that university physical education is the last organized form of physical education and sports that can educate students for a lifelong, physically active lifestyle. Based on the specific effects of these training programs, we can make suggestions for their effective use in education and recreational sports.

Material & methods

Participants

One hundred forty-two healthy university students [55 (38.7 %) men and 87 (61.3 %) women; mean age 21.46 ± 2.28 years] participated in the present study. They participated in general physical education (PE) classes arranged by the Institute of Sport Sciences, University of Debrecen. Each volunteer completed an assessment of dietary and exercise habits questionnaire before and after the exercise program. All participants were non-smokers. They were instructed to refrain from any physical activity, special diet, and vitamin supplementation for at least three months before the investigation. Moreover, exclusion criteria included ongoing viral or bacterial infection, chronic disease treated with continuous drug therapy, cancer, alcohol or drug addiction, pregnancy or breastfeeding, psychiatric illness, insufficient cooperation skills and dietary changes or usage of dietary supplements during the entire study. Informed written consent was obtained from all subjects enrolled in the investigation. The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of the University of Debrecen (protocol number: 6088-2022).

Exercise protocols

Participants voluntarily engaged in Pilates (n=22), yoga (n=29), functional circuit workout (n=22), running club (n=23) or boot camp (n=46). All sessions were supervised by a physical education professional specialized in the relevant exercise. Each program consisted of one 60-minute session per week for a total of 10 weeks. In accordance with accepted terminology, we have classified these training sessions based on their intensity zones (Table 1).

Table 1. Classification of exercises based on intensity zones

	ProprT		**MICT**		**HIIT**
Type of exercise	Pilates	yoga	functional circuit workout	running club	boot camp
Zone 1 (50-60 % of HRmax)	91 %	95 %	3 %	8 %	0 %
Zone 2 (60-70 % of HRmax)	9 %	5 %	36 %	33 %	8 %
Zone 3 (70-80 % of HRmax)	0 %	0 %	59 %	36 %	20 %
Zone 4 (80-90 % of HRmax)	0 %	0 %	2 %	22 %	47 %
Zone 5 (90-100 % of HRmax)	0 %	0 %	0 %	1 %	25 %

We monitered the intensity of the workouts using a Polar M430 sports watch (Polar Electro Oy, Kempele, Finland) based on the percentage of the individually determined maximum heart rate. Data was recorded on a personal computer using Polar Flow software.

Pilates workouts included floor-based exercises on a mat, focusing on controlled, low-intensity movements, stretching, and breathing, which aimed to improve posture and proprioceptive perception. In Pilates training, unstable training equipment appeared: softball and roller, while in yoga classes, instability was ensured by exercises performed on one leg. The structure of each session was the same: 15 minutes of warm-up and breathing exercises; 35 minutes of main part and 10 minutes of stretching exercises, cool-down time. Both the yoga and Pilates sessions focused on correct posture and learning the breathing technique. During these exercise programs, 91-95 % of the training duration was spent in intensity zone 1 (50-60 % of HRmax).

Functional circuit training served to develop strength endurance and cardiorespiratory endurance. The participants worked in the medium load zone during the main part, on different equipments at the UniFit Fitness and Gym Centre in Debrecen. The participants were divided into 2 groups; one of them took part in a 20-minute cardio workout (intensity level: 70-80 % of HRmax), while the other group developed their strength endurance with fitness equipments, free weights, and free body weight. They developed agonist-antagonist muscle groups alternately, with the same number of repetitions (3x12) during the first 5 weeks. From the 6th week, the number of repetitions increased to 15, while the duration of the cardio part was increased to 25 minutes. In the running club, participants took part in continuous, long-term running trainings. The primary goal of this exercise program was the development of aerobic endurance and the improvement of individual technique. The structure of each session was the same: 15-minute warm-up, running school tasks; 35 minutes of continuous, sustained running in

the main part; and finally, 10 minutes of stretching exercises. The participants performed the exercises with an intensity between 60 and 90 % of HRmax, approximately 70 % of the training duration was spent in zone 2 or 3. Participants in the boot camp class performed interval training with their own body weight. The exercise program was based on general strengthening gymnastic exercises with regularly alternating intensities. The structure of each lesson was different, so the intervals also changed along with the tasks. The general structure of the class was as follows: 15 minutes of warm-up, 35 minutes of the main part, 10 minutes of stretching exercises. Table 2 demonstrates the structures of exercise programs.

Table 2. The structures of exercise programs

	ProprT		**MICT**		**HIIT**
Exercise	Pilates	yoga	functional circuit workout	running club	boot camp
Intensity zone	Zone 1 (50-60 % of HRmax)		Zone 3 (70-80 % of HRmax)		Zone 4 (80-90 % of HRmax)
Total duration	60'	60'	45'-50'	60'	60'
Duration of the warm-up	15'	15'	15'	15'	15'
Duration of the main part	35'	35'	20'-25'	35'	35'
Duration of the streching	10'	10'	10'	10'	10'
Stimulus density	Continuous low intensity exercise		Continuous exercise	moderate-intensity	40 seconds of work and 15 seconds of rest in the main part
Burned calories/min	3.56 kcal	3.46 kcal	9.95 kcal	6.85 kcal	5.45 kcal

Hungarofit assessment

We conducted complex Hungarofit assessments before and after the 10-week exercise program to assess the general fitness of the participants. The assessments included Cooper test (12 minutes of continuous running, measuring the level of aerobic endurance), push-up test (number of push-ups performed in 1 minute, measurement of trunk, abdominal, back and arm muscle strength), sit-up test (number of sit-ups performed in 4 minutes, measurement of abdominal muscle strength) and Flamingo test (balance on one leg on the longitudinal axis of a beam for 1 minute, measuring the state of balance). The Hungarofit assessments were completed by 47 subjects from the ProprT, 44 subjects from the MICT and 40 subjects from the HIIT group.

Analysis of body composition

Body composition analyses were made with TANITA BC-1000 device. We obtained the subjects' weight, BMI, body fat percentage (FatP), body fat mass (FatM), body fat-free mass (FFM), total body water content (TBW), muscle mass (PMM), skeletal muscle mass (SMM), bone mass (BoneM), daily caloric intake (DCI), basal metabolic rate (BMR), visceral fat level (VFatL) and metabolic years (METAGE). TANITA not only examines the body composition, but also shows whether it corresponds to the age, gender, weight and height of the person examined. Body composition analyses were performed in 26 individuals from the ProprT, 42 individuals from MICT, and 36 individuals from HIIT group.

Borg scale

The Borg scale is a Likert-type scale on which the test subject can score from 6 to 20 how much effort it took to complete a given exercise. The endpoints of the scale are as follows: 6-No effort, 20-Maximum effort. This measured the extent to which the subjects felt an improvement in themselves as a result of the training and how motivated they were to make the effort. It was completed by the participants in the third, sixth and ninth weeks of the exercise programs. The assessments were carried out in 51 subjects from the ProprT, 45 subjects from the MICT, and 46 subjects from the HIIT group.

COG - Cognitore Test

In the 1st and 10th weeks of the training programs, we used the Vienna Test System (VTS) COG/S8 test to measure cognitive functions, which examined attention and concentration abilities. Based on the theoretical model of Reulecke (1991), the COG test covers three variables: precision, which indicates the quality of performance; the function, as not all tasks require the same amount of energy; and the energy required to complete the task. In the S8 test form, the participants compared four geometric shapes with a reference shape that appears below them, and responded to the stimulus. The reliability value of the test (Cronbach's alpha) is r=0.95. Completion time was 9 minutes (Schuhfried, 2009). A total of 64 participants completed the COG/S8 test, of which 19 participated in ProprT, 29 in MICT, and 18 in HIIT program.

Perceived stress scale PSS14

To assess perceived stress, we used the Hungarian version of the Perceived Stress Scale (PSS14) questionnaire, whith a good reliability (Cronbach-alfa r=0,88) (Stauder & Konkoly-Thege, 2006). The results of the questionnaire are not affected by sex, age and education. The questionnaire contained 14 items, which were scored on a 5-point Likert scale (0-4). After evaluating the stress questionnaire, a numerical value was obtained; the high value indicates high level of perceived stress. The perceived stress questionnaire was completed by 44 participants from the ProprT, 42 from the MICT and 40 from the HIIT group.

Statistical analysis

Data were analysed with TIBCO Statistica® 14.0.1. (TIBCO Software Inc., Palo Alto, CA, USA). To assess the distribution of the data, Shapiro-Wilk normality test was used. In case of Gaussian distribution, two-tail paired t test was used, if the data set differed from normal distribution, Wilcoxon test was performed. Differences were considered statistically significant at $p<0.05$.

Results

Results of the Hungarofit assessment

The participants completed the Hungarofit assessments at baseline and at the end of the 10-week training programs. These assessments included Cooper test, push-up test, sit-up test and Flamingo balance test. In the Cooper test, only the MICT group showed significant improvement during the exercise program (1795.9 ± 507.8 vs. 1991.8 ± 475.4; respectively, $p<0.0001$). In the HIIT group, only a marked, non-significant change occurred (1745.4 ± 429.8 vs. 1886.3 ± 430.7; respectively, $p=0.0739$). There were no changes observed in the results of push-up tests in any groups. However, results of sit-up tests showed a significant improvement in the HIIT group at the end of the training program compared to the baseline values (60.17 ± 21.99 vs. 73.79 ± 24.28; respectively, $p=0.0177$); while in the ProprT group, only a marked improvement was observed (30.06 ± 14.89 vs. 37.05 ± 18.65; respectively, p=0,0771). In the Flamingo test performed with the left leg, significant improvement was observed in two training groups. The number of mistakes within one minute decreased significantly in the ProprT (1,35 ± 1.11 vs. 0.71 ± 0.76; respectively, $p<0.0001$) and the MICT groups (1,73 ± 1.32 vs. 1.09 ± 1.14; respectively, $p=0.0241$). In Flamingo test performed with the right leg, significant improvement was observed only in the ProprT training group (number of mistakes within one minute at baseline compared to the end of 10-week training: 1,39 ± 1.02 vs. 0.57 ± 0.73; respectively, $p<0.0001$).

Evaluation of the changes in body composition

The mean BMI value changed from 22.95 ± 4.46 to 23.67 ± 4.37 in the ProprT group ($p=0.0149$), while in the other groups, no changes occured. In body composition, significant changes were found only in the ProprT group. Total body mass increased (63.57 ± 13.29 kg vs. 65.66 ± 13.44 kg; respectively, $p=0.0159$), while the fat-free mass (47.06 ± 6.37 kg vs. 45.57 ± 6.16 kg; respectively, $p=0.0002$) decreased. There was a marked, but not significant increase in body fat mass, as well (Figure 1).

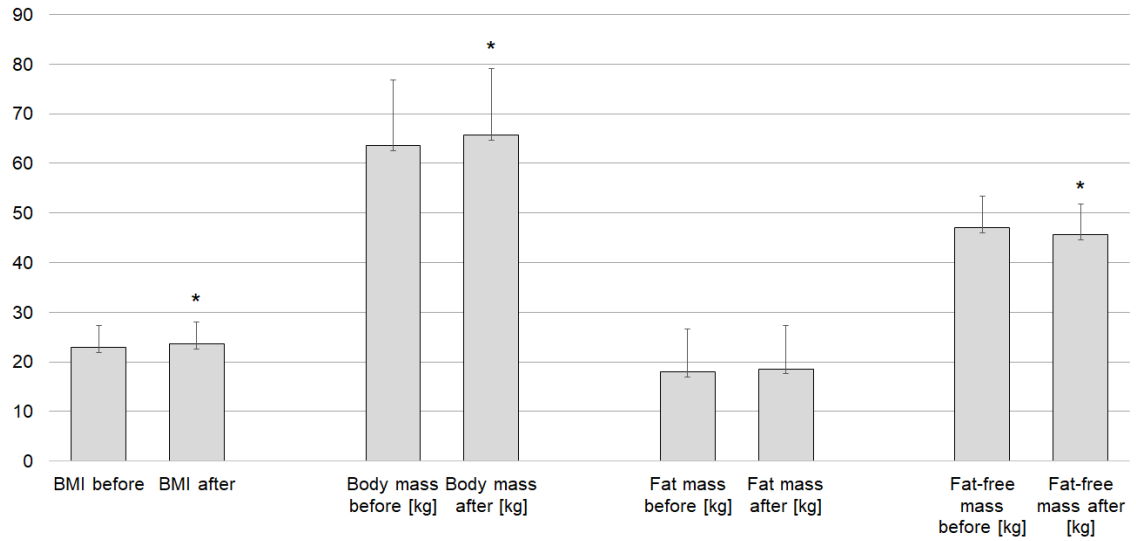

Figure 1. *Effects of ProprT training type on BMI, body weight, body fat mass (FatM) and fat-free mass (FFM)* Bars show the mean and the standard deviation (SD). Statistically significant differences are indicated by * ($p<0.05$).

Assessment of the Borg scale values

The most pronounced change in Borg scale values occurred in the ProprT group. The change in this group was significant between each time of measurements (between week 3 and 6: $p=0.0377$; between week 6 and 9: $p<0.0001$, between weeks 3 and 9: $p<0.0001$). Regarding the HIIT group, we observed significant differences between week 3 and 9 ($p<0.0001$) and between week 6 and 9 ($p=0.0002$). On the contrary, in the MICT group no changes occured.

Changes in cognitive functions

The changes in VTS COG/S8 test results were significant only for SUMR and SUMGES values. The SUMR increased significantly in all training types (PropT: 489.78 ± 89.77 vs. 628.06 ± 82.72; respectively, $p<0.0001$; CMIT: 445.82 ± 79.40 vs. 551.29 ± 99.93; respectively, $p<0.0001$; HIIT: 447.18 ± 95.52 vs. 559.47 ±

128.07; respectively, p<0.0001). The changes in SUMGES values indicated the positive effect of the trainings on cognitive abilities. We observed significant improvement in each training group (ProprT: 483.53 ± 100.47 vs. 638.11 ± 113.23; respectively, p=0.0005; CMIT: 450.06 ± 96.77 vs. 566.13 ± 105.17; respectively, p=0.0002; HIIT: 457.04 ± 97.06 vs. 566.62 ± 135.26; respectively, p=0.0001). There was no significant change in SUMF and PRF values.

Assessment of the perceived stress

Figure 2 shows that the level of perceived stress decreased in all training types. The changes in final scores were particularly significant (p<0.0001).

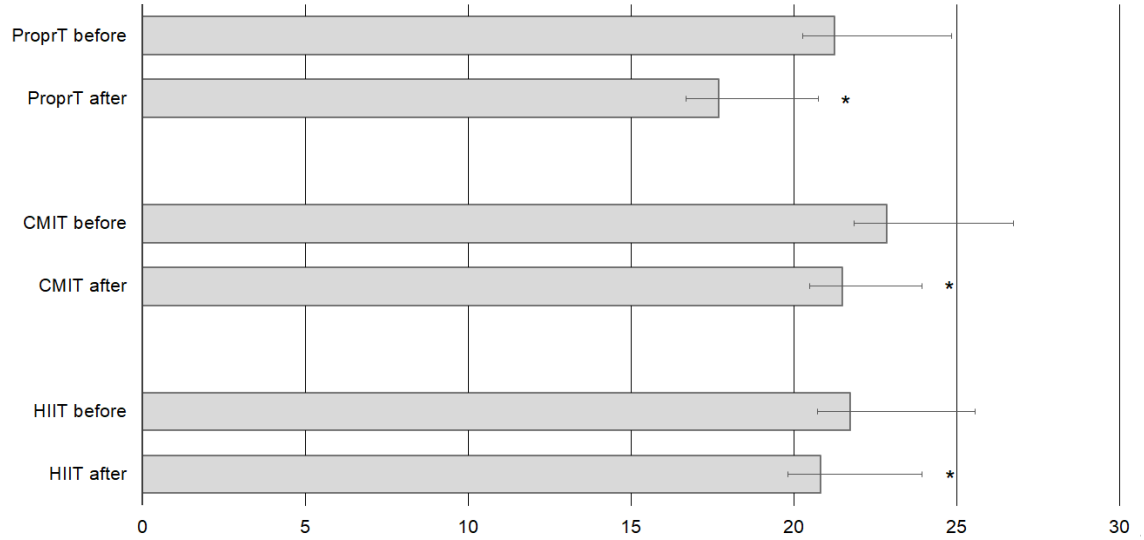

Figure 2: *Changes in the final scores of the perceived stress questionnaire*

Bars show the mean and the standard deviation (SD). Statistically significant differences are indicated by * (p<0.05).

Discussion

Regular exercise is a very important part of the healthy lifestyle, therefore, the World Health Organization (WHO) and the American College of Sports Medicine (ACSM) recommend that adults should perform phisical activity for least 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity in a week to maintain and improve health conditions (Garber et al., 2011). However, based on a study conducted on university students, a large number of young individuals failed to reach the recommended level of physical activity (Clemente et al., 2016). Thus, one of the main concerns of exercise scientists is to develop exercise programs that can be both effective and popular. For this purpose, we compared the complex effects of ProprT, MICT and HIIT on cognitive abilities, motor skills, body composition and perceived stress among university students.

In order to assess the changes in the general fitness of the participants, we conducted Hungarofit assessments, which included the Cooper test, push-up test, sit-up test, and Flamingo balance test. In the Cooper test, only the MICT group showed significant improvement during the exercise program. In the HIIT group, only a marked, non-significant change occurred, while there was no change in the ProprT group. The latter is not surprising, since the goal of this workout was not to increase aerobic capacity. Notably, the effectiveness of the exercise programs is fundamentally influenced by individual characteristics such as motivation, athletic background, anthropometric features, health status, etc.; therefore, more comprehensive studies are needed to get a clear picture of the differences between the the MICT and the HIIT groups. In the push-up tests, no changes were observed in any groups, while the sit-up tests showed a significant improvement in HIIT the group. The reason for this is probably to be found in the trained muscle groups. In the ProprT group, a marked improvement was observed in the sit-up test, which can be explained by the many posture exercises in ProprT workouts. These exercises strengthen the core muscles, which play an important role in maintaining balance (Yilmaz et al., 2024), and help subjects perform the sit-up test with the best possible results. Based on these results, primarily the HIIT and the ProprT workouts could be effectively incorporated into physical education classes, helping to develop, maintain, and restore correct posture if necessary. The results of the Flamingo test suggest that the ProprT training achieved its goal and the subjects' balance ability improved significantly at the end of the training program. The ProprT group exhibited a significant increase in BMI and total body mass, while the fat-free mass decreased significantly. These indicate that this training method was associated with the lowest calorie consumption.

The most pronounced changes in Borg scale values occured in the ProprT group. We assume that lower intensity training results in a more marked change in subjective effort levels, thereby leading to a greater sense of achievement, which makes sport engagement more likely. Therefore, this type of training could be recommended to beginners in the sport. This observation can also be useful in education, as children are more motivated to participate in sports in which they have a sense of success.

Regarding the changes in cognitive functions, SUMR values increased significantly in all training types. This highlights that exercise generally has a positive effect on cognitive abilities. The SUMR value provides information on the amount of all correct answers of the tested subject. These changes indicate that the cognitive abilities developed and the quality of solving the tasks improved. Consequently, school physical education can have a particularly beneficial effect on students' cognitive abilities. Similarly, SUMGES values also improved significantly in each training group. The SUMGES value represents the amount of all responses, and provides information about the speed of stimulus processing of the examined subject; the higher the speed, the greater the value. These observations suggest that the stimulus processing speed of an individual can be increased through sports. Based on these results, the MICT, HIIT and ProprT workouts had positive effects on cognitive abilities, but these changes were not significant in all areas.

Perceived stress levels decreased across all training types, indicating that physical activity is generally effective in reducing perceived stress. The ProprT training could be one of the most effective technique for reducing perceived stress. However, considering the methods, we cannot say that ProprT, by its nature, had a positive effect on reducing perceived stress, since one of the training programs was yoga and the other was Pilates, both types of training that promote stress reduction and relaxation. The MICT exercise program also had a similarly good effect on reducing perceived stress. This means that all three types of exercise significantly affect the perception of stress in everyday life.

Conclusions

Based on our observations, ProprT exercise may be the most useful sports method for developing cognitive skills in public education. On the other hand, any type of training is beneficial, as each type improves cognitive abilities in certain areas, which can affect student performance. All three types of training were effective in reducing perceived stress. If the goal is to improve students' aerobic capacity, the most effective method is MICT. However, HIIT training was the most beneficial for strength development, which is important for students because physical development is rapid during school age, and proper core muscles are needed to develop correct posture.

In summary, HIIT, MICT, and ProprT workouts are useful and effective for recreational sports as well. However, further comprehensive comparative analyses are needed to make personalized recommendations for individuals in public education and recreational athletes to determine which training method is the most optimal choice for their goals.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

References

Alibrahim, M. S., & Hassan, A. K. (2024). Effect of high-intensity interval training on physical and biological indicators in individual sports Athletes. *Journal of Physical Education and Sport*, 24(9), 1245–1252.

Aman JE, Elangovan N, Yeh IL, Konczak J. (2015). The effectiveness of proprioceptive training for improving motor function: a systematic review. *Frontiers in Human Neuroscience*, 8, 1075.

Ayob, A. L., Malik, A. A., Hashim, H. A., & Muhamad, A. S. (2023). Effects of five weeks of self-paced and prescribed high-intensity interval exercise on perceptual responses, body composition, aerobic capacity, blood glucose, and lipid profile in overweight-to-obese adults. *Journal of Physical Education and Sport*, 23(3), 637–647.

Araujo, F. D. S., Freire, H. P., Candido, W. A., & Carvalho, R. G. D. S. (2024). Perceptual and performance responses after a body-weight high-intensity interval exercise session in adult men. *Journal of Physical Education and Sport*, 24(6), 1479–1486.

Balogh, L., Szabó, K., Pucsok, J.M., Jámbor, I., Gyetvai, Á., Mile, M., Barna, L., Szodoray, P., Tarr, T., Csiki, Z., Papp, G. (2022). The Effect of Aerobic Exercise and Low-Impact Pilates Workout on the Adaptive Immune System. *Journal of Clinical Medicine*, 11(22), 6814.

Campbell, W. W., Kraus, W. E., Powell, K. E., Haskell, W. L., Janz, K. F., Jakicic, J. M., Troiano, R. P., Sprow, K., Torres, A., Piercy, K. L., Bartlett, D. B.; 2018 Physical Activity Guidelines Advisory Committee. (2019). High-intensity interval training for cardiometabolic disease prevention. *Medicine & Science in Sports & Exercise*, 51(6), 1220–1226.

Castrén, E., & Antila, H. (2017). Neuronal Plasticity and Neurotrophic Factors in Drug Responses. *Molecular Psychiatry*, 22(8), 1085–1095.

Clemente, F. M., Nikolaidis, P. T., Martins, F. M. L., & Mendes, R. S. (2016). Physical activity patterns in university students: do they follow the public health guidelines? *PLoS One,* 11(3), e0152516.

Corte de Araujo, A. C., Roschel, H., Picanço, A. R., do Prado, D. M. L., Villares, S. M. F., de Sa Pinto, A. L., & Gualano, B. (2012). Similar health benefits of endurance and highintensity interval training in obese children. *PLoS One,* 7, e42747.

Dasso, N. A. (2019). How is exercise different from physical activity? A concept analysis. *Nursing Forum*, 54(1), 45–52.

De Lima, N. S., De Sousa, R. A. L., Amorim, F. T., Gripp, F., Diniz E Magalhães, C. O., Henrique Pinto, S., Peixoto, M. F. D., Monteiro-Junior, R. S., Bourbeau, K., & Cassilhas, R. C. (2022). Moderate-intensity continuous training and high-intensity interval training improve cognition, and BDNF levels of middle-aged overweight men. *Metabolic Brain Disease*, 37(2), 463–471.

Egan, B., & Zierath, J. R. (2013). Exercise metabolism and the molecular regulation of skeletal muscle adaptation. *Cell Metabolism*, 17(2), 162-184.

Francois, M. E., & Little, J. P. (2015). Effectiveness and safety of high-intensity interval training in patients with type 2 diabetes. *Diabetes Spectrum*, 28(1), 39–44.

Garber, C. E., Blissmer, B., Deschenes, M. R., Franklin, B. A., Lamonte, M. J., Lee, I. M., & Swain, D. P. (2011). Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults. *Medicine & Science in Sports & Exercise*, 43(7), 1334–1359.

Hawley, J. A., Hargreaves, M., Joyner, M. J., & Zierath, J. R. (2014). Integrative biology of exercise. *Cell*, 159(4), 738–749.

MacInnis, M. J., & Gibala, M. J. (2017). Physiological adaptations to interval training and the role of exercise intensity. *The Journal of Physiology*, 595(9), 2915–2930.

Makra, G., & Balogh, L. (2021). Examination of the relationship between physical activity and cognitive skills. *Stadium - Hungarian Journal of Sport Sciences*, 1(1).

Martin-Smith, R., Cox, A., Buchan, D. S., Baker, J. S., Grace, F., & Sculthorpe, N. (2020). High intensity interval training (HIIT) improves cardiorespiratory fitness (CRF) in healthy, overweight and obese adolescents: a systematic review and meta-analysis of controlled studies. *International Journal of Environmental Research and Public Health*, 17, 2955.

Martins, C., Kazakova, I., Ludviksen, M., Mehus, I., Wisloff, U., Kulseng, B., Morgan, L., & King, N. (2016). High-intensity interval training and isocaloric moderate-intensity continuous training result in similar improvements in body composition and fitness in obese individuals. *International Journal of Sport Nutrition and Exercise Metabolism*, 26(3), 197–204.

Mekari, S., Earle, M., Martins, R., Drisdelle, S., Killen, M., Bouffard-Levasseur, V., & Dupuy, O. (2020). Effect of high intensity interval training compared to continuous training on cognitive performance in young healthy adults: a pilot study. *Brain Sciences*, 10(2), 81.

Milanović, Z., Sporiš, G., & Weston, M. (2015). Effectiveness of high-intensity interval training (HIT) and continuous endurance training for VO2max improvements: a systematic review and meta-analysis of controlled trials. *Sports Medicine*, 45(10), 1469–1481.

Moholdt, T., Madssen, E., Rognmo, Ø., & Aamot, I. L. (2014). The higher the better? Interval training intensity in coronary heart disease, *Journal of Science and Medicine in Sport*, 17(5), 506–510.

Norton, K., Norton, L., & Sadgrove, D. (2010). Position statement on physical activity and exercise intensity terminology. *Journal of Science and Medicine in Sport*, 13(5), 496–502.

Niven, A., Laird, Y., Saunders, D. H., & Phillips, S. M. (2021). A systematic review and meta-analysis of affective responses to acute high intensity interval exercise compared with continuous moderate-and high-intensity exercise. *Health Psychology Review*, 15, 540–573.

Oliveira, B. R. R., Santos, T. M., Kilpatrick, M., Pires, F. O., & Deslandes, A. C. (2018). Affective and enjoyment responses in high intensity interval training and continuous training: A systematic review and meta-analysis. *PLoS One*, 13(6), e0197124.

Ram, A., Marcos, L., Morey, R., Clark, T., Hakansson, S., Ristov, M., Franklin, A., McCarthy, C., De Carli, L., Jones, M. D., Ward, R. E., & Keech, A. (2022). Exercise for affect and enjoyment in overweight or obese males: a comparison of high-intensity interval training and moderate-intensity continuous training. *Psychology, Health & Medicine*, 27(5), 1154–1167.

Reulecke, J. (1991): Cognitrone test. In: Schuhfried (eds.): Vienna Test System Psychological Assessment. Schuhfried, Moedling, 67–78.

Ribeiro, F., & Oliveira, J. (2007). Aging effects on joint proprioception: the role of physical activity in proprioception preservation. *European Review of Aging and Physical Activity*, 4(2), 71–76.

Rifki, M. S., Ndayisenga, I. J., & Zakaria, J. B. (2023). The effect of combined continuous run, circuit training, and high-intensity interval training on lung function, asthma control, and VO2max in asthma patients: A quasi-experimental study. *Journal of Physical Education and Sport*, 23(12), 3264–3270.

Sabaghi, A., Ebrahimi, B., Yousofvand, N., & Hoseini, R. (2025). Comparative effects of moderate-intensity continuous training and high-intensity interval training on ADHD symptoms and behavioral inhibition in children. *European Journal of Pediatrics*, 184(2), 183.

Sanca-Valeriano, S., Espinola-Sánchez, M., Caballero-Alvarado, J., & Canelo-Aybar, C. (2023). Effect of high-intensity interval training compared to moderate-intensity continuous training on body composition and insulin sensitivity in overweight and obese adults: A systematic review and meta-analysis. *Heliyon*, 9(10), e20402.

Schmitz, B., Niehues, H., Thorwesten, L., Klose, A., Krüger, M., & Brand, S. M. (2020). Sex differences in high-intensity interval training-are HIIT protocols interchangeable between females and males, *Frontiers in Physiology*, 11, 38.

Schuhfried (2009): Vienna Test System. Psychological Assessment. Schuhfried, Moedling.

Schultchen, D., Reichenberger, J., Mittl, T., Weh, T. R. M., Smyth, J. M., Blechert, J., & Pollatos, O. (2019). Bidirectional relationship of stress and affect with physical activity and healthy eating. *British Journal of Health Psychology*, 24(2), 315–333.

Selye, H. (1946). The general adaptation syndrome and the diseases of adaptation. *Journal of Allergy*, 17(4), 231–247.

Stauder, A., & Konkoly-Thege, B. (2006). [Characteristics of the Hungarian version of the Perceived Stress Scale (PSS)]. *Mentálhigiéné és Pszichoszomatika*, 7(3), 203–216.

Sterkowicz-Przybycień, K., & Kulesza, M. (2023). Physical activity and wellness in Polish older women practicing Pilates and non-exercising women: a cross-sectional analysis. *Journal of Physical Education and Sport*, 23(9), 2435–2444.

Sun, F., Williams, C. A., Sun, Q., Hu, F., & Zhang, T. (2024). Effect of eight-week high-intensity interval training versus moderate-intensity continuous training programme on body composition, cardiometabolic risk factors in sedentary adolescents. *Frontiers in Physiology*, 15, 1450341.

Tabata, I. (2019). Tabata training: one of the most energetically effective high-intensity intermittent training methods. *The Journal of Physiological Sciences*, 69(4), 559–572.

Weston, K. S., Wisløff, U., & Coombes, J. S. (2014). High-intensity interval training in patients with lifestyle-induced cardiometabolic disease: a systematic review and metaanalysis. *British Journal of Sports Medicine*, 48, 1227–1234.

Yilmaz, O., Soylu, Y., Erkmen, N., Kaplan, T., & Batalik L. (2024). Effects of proprioceptive training on sports performance: a systematic review. *BMC Sports Science, Medicine and Rehabilitation*, 16, 149.

Yumuk, V., Tsigos, C., Fried, M., Schindler, K., Busetto, L., Micic, D., & Toplak, H. (2016). European Guidelines for Obesity Management in Adults. *Obesity Facts*, 8, 402–424.

Zschucke, E., Renneberg, B., Dimeo, F., Wüstenberg, T., & Ströhle, A. (2015). The stress-buffering effect of acute exercise: Evidence for HPA axis negative feedback. *Psychoneuroendocrinology*, 51, 414–425.