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Research Article

The Effects of High-Intensity Interval Training with Different Duration on Fibrinogen and Plasma Viscosity in Sedentary Male College Students

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Abstract

Background: There have been few investigations into the impact of high-intensity interval training on blood rheology.

Objectives: This study aimed to evaluate how high-intensity interval training conducted with different duration affects fibrinogen and plasma viscosity in sedentary young college men.

Methods: For this study, 36 healthy male participants were selected and grouped based on their individual characteristics. The groups included a control group (n = 9), a 45-second training group (tr-45; n = 9), a 30-second training group (tr-30; n = 9), and a 15-second training group (tr-15; n = 9). The training regimen comprised six sessions over two weeks, with varying sets (4, 5, 6, 6, 7, 4 respectively) and durations of 15, 30, and 45 seconds for different groups. There was a fixed 4-minute rest interval between each set, with a consistent load of 0.6 on the Wingate cycle ergometer. Blood samples were collected 48 hours before and after the final session to analyze fibrinogen and plasma viscosity levels.

Results: There were no significant differences between groups in plasma fibrinogen levels ($F3, 32 = 2.303$, $P = 0.96$). However, post-test analysis revealed a significant decrease in plasma fibrinogen in the tr-45 group ($P = 0.027$) compared to pre-test levels. Plasma viscosity did not significantly change between groups ($F3, 32 = 0.651$, $P = 0.058$), but there was a significant interaction between time and group ($F3, 40 = 4.43$, $P = 0.009$). Post-test analysis showed a significant decrease in plasma viscosity in the tr-45 ($P = 0.010$), tr-30 ($P = 0.002$), and tr-15 ($P = 0.003$) groups, while it significantly increased in the control group ($P = 0.004$) compared to pre-test levels.

Conclusions: The findings suggest that high-intensity interval training can effectively decrease blood rheology and factors such as fibrinogen and plasma viscosity, with the 45-second HIIT being more efficient. Therefore, incorporating this training into Physical Activity Programs could be beneficial for inactive men.

Keywords: High Intensity Interval Training; Fibrinogen; Viscosity; Hemorheology; Blood Rheology

1. Background

Hemorheology, also known as blood rheology, is the study of how blood flows and the properties of its protein components in plasma. It examines various flow characteristics of blood, among which fibrinogen and plasma viscosity are two significant factors (1). Various factors affect blood viscosity (BV). Plasma viscosity (PV) is one of the most important variables that determine BV (2). The viscosity of a liquid is its resistance to flow, due to internal friction between molecules and other particles (3). Increased BV can exacerbate morbidity and mortality among cardiovascular patients. Furthermore, abnormal BV is intricately linked to the onset, progression, and prognosis of various life-threatening conditions, including chronic cerebral infarction, transient ischemic attack, diabetes mellitus, hemorrhagic shock, renal disease, and stroke risk factors (4). Changes in blood protein levels, particularly with proteins like albumin and fibrinogen, lead to increased viscosity. The correlation between elevated fibrinogen and heightened plasma and blood viscosity is well-established (5). Among coagulation markers, fibrinogen has been identified as the most reliable indicator in assessing the likelihood of cardiovascular issues (6). Fibrinogen, despite comprising only 5.5% of total plasma protein concentration, is the largest plasma protein. It holds a crucial position in the blood coagulation process and is considered a significant factor influencing blood rheology by affecting the aggregation of red blood cells (7). Elevated plasma fibrinogen levels can potentially exacerbate arteriosclerosis by promoting increased platelet interaction with the vessel wall, enhancing BV, and affecting blood coagulation through non-rheological pathways. Additionally, it may directly impact the vessel wall, contributing to adverse effects in the progression of arteriosclerosis (8). Hematocrit, PV, and BV exhibit inverse relationships with plasma volume. Elevated hematocrit levels lead to increased BV, resulting in decreased blood flow velocity and subsequently reduced oxygen supply to tissues (5).

The effects of various exercises and physical training on BV and fibrinogen levels have been studied and evaluated. The results indicate a relationship between maximum oxygen consumption and higher levels of physical fitness (9, 10). In recent years, high-intensity interval training (HIIT) has garnered the attention of sports science researchers in enhancing performance and improving cardiovascular fitness (11, 12). High-intensity interval training, while lacking a universal definition, typically involves repeated bouts of short, intermittent exercise performed at maximal or near-maximal effort, eliciting at least 90% of V̇O2peak. These efforts can vary in duration from a few seconds to several minutes, interspersed with periods of rest or low-intensity exercise lasting from minutes to a few minutes, depending on the intensity of the training (13). High-intensity interval training triggers specific physiological adaptations by adhering to predefined exercise formats influenced by factors like intensity, duration, and interval count, as well as activity patterns during recovery periods (12, 14). Research indicates that when traditional endurance training and HIIT are compared based on equal workload or energy expenditure, HIIT emerges as an effective alternative. This is due to its ability to elicit similar or enhanced improvements across various physiological parameters, performance metrics, and health indicators in both healthy individuals and populations with health concerns (15-17). On the other hand, there are also other reports that have indicated no changes and some increases of 28% after resistance training and 34% after aerobic training (18). Long-term exercises are usually not associated with significant changes in hematocrit, but they involve an increase in total plasma proteins, which is one of the mechanisms leading to an increase in PV (9). While PV seems to increase in response to long-term exercises, the lack of a rise in hematocrit in response to these exercises may indicate minimal changes in total viscosity (10). Despite that, investigating the impact of light circuit resistance training on hematological parameters, including platelets, white blood cells, and red blood cell volume (19) and also the impact of circuit resistance training accompanied by saffron supplementation, which led to a reduction in viscosity and fibrinogen in both exercise and saffron groups (20), limited information exists regarding the impact of various physical activities on the viscosity of blood, plasma, and fibrinogen. Nevertheless, in a study using resistance exercise, it was demonstrated that viscosity immediately increased and returned to the initial state after 30 min of recovery. Similar changes were observed in fibrinogen levels, total plasma protein, and albumin, but they returned to baseline levels at the end of the recovery period (21). The increasing evidence indicates that this type of exercise leads to physiological adaptations similar to moderate-intensity continuous training, despite significantly lower time commitment and reduced overall exercise volume (13).

These findings are crucial for public health, given that time constraints are a major barrier to regular exercise participation (22-24). In addition, recent findings indicate that HIIT is perceived as more enjoyable compared to moderate-intensity continuous exercise (25, 26).

2. Objectives

Therefore, considering the positive effects of HIIT exercises and the reduction of metabolic risk factors (27), as well as the positive effect of these exercises on cardiovascular function (11, 28), and on the other hand, there is no study that shows the effect of these exercises on these blood rheological risk factors (fibrinogen and viscosity) and also which of these training durations has a better effect on these indicators. The aim of the present study is to investigate different durations of HIIT training on fibrinogen and viscosity in young university men.

3. Methods

3.1. Participants

The present study, conducted within the framework of a quasi-experimental design on human subjects, consisted of four research groups. Participants for this study were selected from inactive male dormitory residents at Shahid Navab Safavi University of Mazandaran. After announcing the research and providing individuals with information about the study conditions and details, eligible participants were chosen.

Among the eligible individuals, 36 participants meeting the criteria (inclusion criteria: Being sedentary and college students; exclusion criteria: No addiction to drugs or alcohol, non-athletes with no history of regular physical activity for a minimum of 6 months, and absence of any history of kidney, liver, cardiovascular diseases, diabetes, or any physical injury or problem) were randomly assigned to the following groups (see Table 1): Control Group, 15-second HIIT group, 30-second HIIT group, and 45-second HIIT group.

Table 1. Descriptive Characteristics and Features of Participants in Four Groups a

Variable and Group	Control	15-Second HIIT	30-Second HIIT	45-Second HIIT
Age (y)	21.91 ± 4.75	22.00 ± 2.35	21.18 ± 1.72	21.50 ± 1.93
Height (cm)	178.18 ± 4.75	175.10 ± 6.08	175.36 ± 4.6	175.92 ± 5.31
Weight (kg)	69.91 ± 9.40	73.10 ± 10.51	67.36 ± 8.21	67.42 ± 8.46
Body Mass Index (kg/m2)	22.00 ± 2.96	23.90 ± 2.72	21.82 ± 2.60	21.75 ± 1.96

[a] Values are expressed as mean ± SD. HIIT: High-Intensity Interval Training.

All participants completed a two-week dietary recall questionnaire. Prior to the experiment, they were instructed to maintain their regular dietary habits, exclusively consuming meals from the university cafeteria. Daily activities remained unchanged during training sessions, with a reminder of the study's importance. This study was conducted according to the principles expressed in the latest version of the Declaration of Helsinki.

3.2. Training Protocol

The training protocol, inspired by Burgomaster et al. (29) and incorporating various durations, was implemented over two weeks with three sessions per week, adhering to the same framework of exercise intensity and progressive overload as employed in the 30-second Burgomaster training.

The 15-second training group performed their activities over six sessions. In the first session, they completed four intervals of 15 seconds each, pedaling a Wingate cycle ergometer with an added load of 0.6 at maximum intensity. Each interval was followed by a 4-minute rest period. The second session consisted of five intervals, and the third and fourth sessions included six intervals, all following the same pattern of 15-second pedaling with a 4-minute rest between intervals. The fifth session involved seven intervals, and the sixth session comprised four intervals, maintaining the 15-second pedaling with 4-minute rest intervals and the same added load and maximum intensity on the Wingate cycle ergometer.

The 30-second and 45-second training groups followed the same structure, with the pedaling duration in the 30-second group being 30 seconds and in the 45-second group being 45 seconds. The rest time between intervals remained consistent at 4 minutes, and the load on the Wingate cycle ergometer was maintained at 0.6 throughout all stages of the training. The control group did not engage in any form of training; they solely pursued their regular daily activities (see Figure 1).

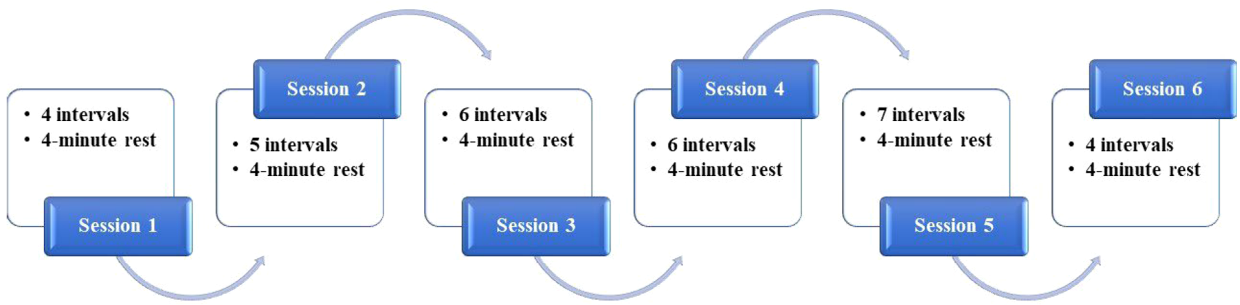

Figure 1. Training protocol

3.3. Blood Sampling

For blood sampling, the following conditions were mandatory: Avoidance of medication or supplements throughout the research period, no alteration in dietary regimen at least two days prior to the experiment, abstaining from any physical activity other than the research exercises during the study, and avoiding prolonged walks at least 72 hours before the research period. Participants were also required to refrain from consuming coffee, strong tea, bananas, grains, and heavy or fatty foods at least 24 hours before the experiment.

Blood samples were collected from the participants' arm veins in the early morning after a 12-hour overnight fast, in two stages: 48 hours before the commencement of the exercises and 48 hours after the last training session. The samples were collected into tubes containing EDTA for laboratory analysis. Subsequently, the blood samples were centrifuged at 3000 revolutions per minute for 10 minutes. The separated plasma was then utilized for analysis. The isolated plasma was employed for analyzing fibrinogen and factors necessary for viscosity calculations. Fibrinogen levels were measured using a LABI TECH device manufactured in Germany. Viscosity was calculated using the following formula Plasma Viscosity = 1.352 + 0.0167 × Total Cholestrol (mmol) + 0.0285 × Fibrinogen (g/L) + 0.0054 × Triglyceride (mmol) + 0.00318 × Hematocrit-0.03 × HDL-c (mmol) (5).

3.4. Statistical Method

All data were analyzed using SPSS software version 20. The Kolmogorov-Smirnov test was employed to assess the normality of the data. After confirming the normal distribution, a repeated measures analysis of variance (2 × 4) with a between-group factor was utilized to compare data across the four groups. Additionally, within-group variations in each group were examined using paired t-tests. A significance level of 0.05 was considered ($p < 0.05$).

4. Results

The Kolmogorov-Smirnov test indicated that the data followed a normal distribution ($P > 0.05$). Additionally, Levene's test confirmed the homogeneity of variances ($P > 0.05$).

Statistical analysis of changes in plasma fibrinogen levels before and after exercise, using a repeated measures two-way analysis of variance, did not reveal a significant difference among the groups ($F3,32 = 2.303$, $P = 0.096$). A significant difference was observed between different time points ($F1,32 = 9.508$, $P = 0.004$). The Bonferroni post-hoc test did not reveal a significant difference between the groups ($P > 0.05$). To identify the specific location of the difference within the groups, a paired t-test revealed a significant decrease between pre- and post-exercise data in the 45-second training group ($t8 = 2.712$, $P = 0.027$). In the 30-second and 15-second training groups, a decrease was observed, but this reduction was not statistically significant ($P > 0.05$) (see Figure 2).

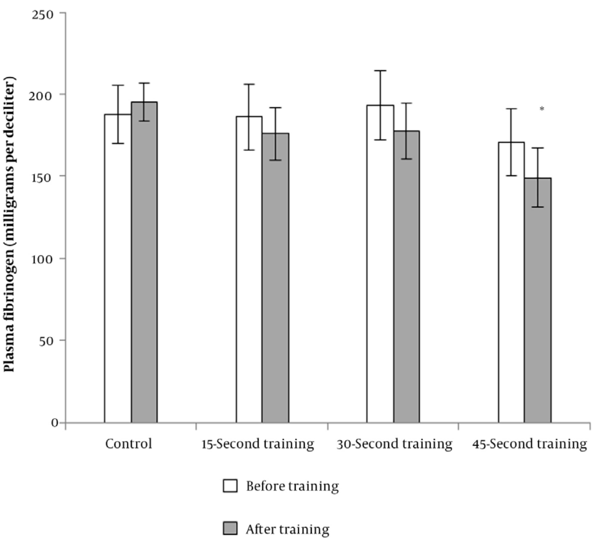

Figure 2. Plasma fibrinogen before and after 6 sessions of high-intensity interval training at different exercise times. * significant difference between pre- and post-training ($P < 0.05$).

Statistical analysis of changes in PV levels among different training groups, using a repeated measures two-way analysis of variance, did not reveal a significant difference between the groups ($F3,32 = 0.651$, $P = 0.058$). A significant difference was observed between different time points ($F1,32 = 33.796$, $P = 0.000$). The results of the Bonferroni post-hoc test did not indicate a significant difference between the groups ($P > 0.05$). To identify the specific location of the difference within the groups, a paired t-test revealed a significant increase in pre- and post-exercise data in the control group ($t8 = 3.992$, $P = 0.004$) and a significant decrease in the 15-second ($t8 = 4.104$, $P = 0.003$) and 30-second ($t8 = 7.123$, $P = 0.002$) training groups. In the 45-second training group ($t8 = 3.384$, $P = 0.010$), a significant reduction was observed (see Figure 3).

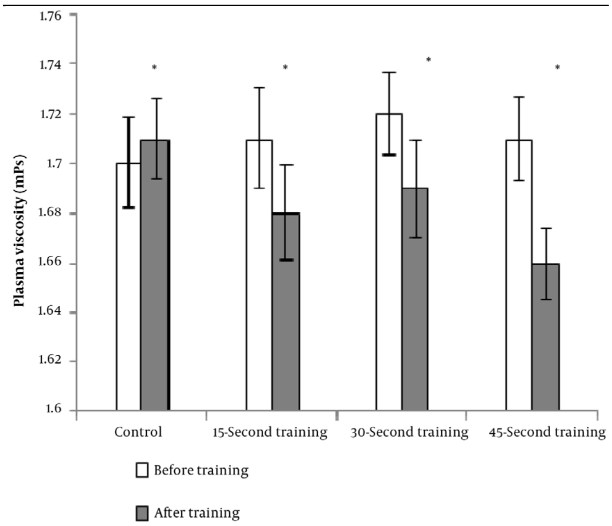

Figure 3. Plasma viscosity before and after 6 sessions of high-intensity interval training at different exercise times. * significant difference between pre- and post-training ($P < 0.05$).

5. Discussion

Exercise, based on its type, duration, intensity, and the individual's physical fitness level, induces changes in blood rheology (30). Few studies have been conducted on the impact of HIIT on fibrinogen and plasma viscosity (PV). However, previous studies have demonstrated alterations in blood hemorheology with resistance exercises. Intensive resistance training increased the PV and fibrinogen (21). In the present study, the impact of various HIIT exercises, concerning the duration of activity, on plasma fibrinogen and viscosity was investigated in inactive men. Plasma fibrinogen decreased by 12% after six sessions of 45-second HIIT, by 8% after 30-second HIIT, and by 5% after 15-second HIIT. In this context, Ahmadizad and El-Sayed (21) demonstrated that intense resistance activity leads to an increase in plasma fibrinogen levels, and this increase returns to baseline levels within 30 minutes of recovery. They suggested that the mechanism behind this increase is likely related to a reduction in blood plasma volume. Furthermore, Ghanbari-Niaki et al. (5) did not observe any change in fibrinogen levels in response to progressive aerobic exercises over a period of four weeks, which contradicts the findings of the present study. However, the present study is consistent with the findings of the Kilic-Toprak et al. (31) study, which demonstrated a reduction in fibrinogen levels after three weeks of progressive resistance exercises. Nevertheless, with continued exercises for twelve weeks, plasma fibrinogen levels increased compared to pre-training levels (32), which is not in line with the findings of the present study. This contradiction is likely attributable to the duration, intensity, and nature of the resistance exercises, as the present study utilized HIIT. When comparing traditional endurance exercises with HIIT based on equal work volume or equivalent energy expenditure, HIIT can be considered an effective alternative to traditional endurance training. This is because HIIT has demonstrated similar or even superior changes in a wide range of physiological conditions, performance measures, and health-related indicators in both healthy individuals and patient populations (15-17). Therefore, considering the nature of HIIT, the potential mechanism for the reduction in fibrinogen levels is likely associated with increased plasma volume and improved cardiovascular system function.

Other potential mechanisms for the reduction in fibrinogen include increased activity of the nervous system and alterations in lipid profiles (32, 33). It has been demonstrated that lipid profiles, the percentage of body fat, BMI, LDL, and cholesterol decrease, while HDL increases in response to HIIT (34). The reduction in lipid profile plays a role in decreasing fibrinogen, as fibrinogen has a direct correlation with LDL and an inverse correlation with HDL (5). High-intensity interval training, by increasing aerobic capacity, VO2MAX, peak power, average power, and minimum power, as well as enhancing muscle mass, can contribute to the improvement of lipid metabolism (11). Several mechanisms can justify the reduction in fibrinogen observed in this study. The normal range for fibrinogen levels is between 200 to 400 milligrams per deciliter. Considering controlled dietary intake before blood sampling, these changes could be attributed to exercise. Regular aerobic exercises may reduce catecholamine stimuli, increase blood flow to muscles, and enhance overall blood volume, contributing to a decrease in fibrinogen concentration in the blood (35). The reduction in fat percentage can lead to a decrease in IL-6 produced in adipose tissue. Considering that IL-6 is a stimulator of fibrinogen synthesis, its reduction results in decreased fibrinogen (35). The reduction in the fractional synthesis rate (FSR) of fibrinogen is another mechanism resulting from long-term exercise, contributing to the decrease in fibrinogen levels (35). After six sessions (two weeks) of HIIT with different durations, fibrinogen levels decreased, with the reductions being more prominent in the 45-second group, followed by the 30-second and the 15-second training groups.

In general, blood flow during exercise decreases due to a reduction in plasma volume and an increase in blood hematocrit (7). Following exercise sessions, blood hematocrit decreases due to an increase in plasma volume (36). Hematocrit is one of the main determinants of blood viscosity (BV) (7). Fibrinogen, as the largest plasma protein and one of the main determinants of blood and plasma viscosity, decreased in all groups except the control group in this study. The reduction was more significant in the 45-second exercise group. In this study, HIIT led to a reduction in PV. This reduction was 2.93% in the 45-second exercise group, 1.73% in the 30-second exercise group, and 1.72% in the 15-second exercise group. There is no study directly related to the impact of HIIT on PV. However, consistent with the findings of this study, Kilic-Toprak et al. (31) demonstrated an 11% reduction in PV after three weeks of progressive resistance training. The difference in the degree of reduction is likely due to the duration, intensity, and nature of the training period. Plasma viscosity is dependent on plasma proteins such as fibrinogen and globulins (37). One of the possible mechanisms for the reduction in PV is the decrease in fibrinogen. Fibrinogen, constituting approximately 5% of the plasma protein concentration, when increased, can lead to enhanced platelet interaction with vascular walls and exacerbate hemodynamic disturbances, resulting in increased blood and plasma viscosity (7). It is well-established that an increase in platelet aggregation leads to an elevation in BV (38). In this study, HIIT with a duration of 45 seconds demonstrated a 12% reduction in fibrinogen, while exercises with durations of 30 and 15 seconds showed an 8% and 5% reduction, respectively. This decrease in fibrinogen may contribute to the observed 2.93% reduction in PV in the 45-second exercise group, a 1.73% reduction in the 30-second exercise group, and a 1.72% reduction in the 15-second exercise group.

Researchers have demonstrated that high-intensity resistance training leads to an increase in platelet aggregation. However, regular exercise, which increases plasma volume and reduces the hematocrit-to-blood volume ratio, results in a decrease in PV (39). Furthermore, studies have shown a significant correlation between PV and physical fitness, as well as cardiovascular performance. On the other hand, the positive impact of HIIT on the cardiovascular system and physical fitness has been well established (11). In individuals engaged in exercise, part of the reduction in PV was attributed to the decrease in gamma globulin levels. Additionally, marathon runners exhibited lower levels of PV and fibrinogen compared to non-exercisers, and this reduction in viscosity was due to an increase in plasma volume in athletes (7). Considering the increase in maximal oxygen consumption following a period of HIIT (11) and the association of elevated fitness levels with VO2MAX (9, 10), along with the established fact that plasma volume is higher in individuals with better fitness (7), it is likely that one of the reasons for the reduction in PV in this study is the increase in blood plasma.

5.1. Conclusions

In general, HIIT with various durations resulted in a reduction in fibrinogen and plasma viscosity, with the greatest reduction observed in the 45-second group, followed by the 30-second and 15-second exercise groups. Therefore, considering the decrease in these factors associated with cardiovascular diseases, these exercises can be incorporated into health programs for inactive young individuals. One of the limitations of this study is the intervention period; a longer intervention would provide insight into the sustained effects of high-intensity interval training on blood rheology. Longitudinal studies with extended intervention periods and exploration of underlying mechanisms could deepen understanding.

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Critical manuscript revision for important intellectual content: S.M.Tayebi

Study supervision: A.Ghanbari-Niaki & S.M.Tayebi

Conflict of Interests: The authors reported no potential conflict of interest.

Data Reproducibility: Datasets are available through the corresponding author upon request.

Ethical Approval: (a) informed consent was obtained from each patient included in the study and (b) the study protocol conforms to the ethical guidelines of the 1975 Declaration of Helsinki as reflected in a priori approval by the institution's human research committee.

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