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ORIGINAL ARTICLE

Effect of compound circular exercises on some of the blood parameters and immune system in non-athlete students

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Abstract

Objective This study was conducted to examine the effect of compound circular exercises on hematological variables and immune system of non-athlete female students.

Methods A total of 100 non-athlete female students of Kerman University of Medical Sciences (with an average age of 22 ± 1.62 years, weight of 61.54 ± 8.84 kg, height of 164.1 ± 5.03 cm, systolic blood pressure of 12.31 ± 3.65 and diastolic blood pressure of 8.31 ± 2.02 mmHg), who were eligible to enter the study, were randomly selected from volunteer students. The exercise program consisted of resistance–endurance exercises through the circular method in one session. Hematological variables, including red blood cell (RBC), hematocrit, hemoglobin, mean hemoglobin, mean hemoglobin concentration, mean RBC volume, platelet volume, plasma volume, lymphocyte and neutrophils, were measured before, immediately and 24 h after exercise.

Results ANOVA with repetitive measurements was used for data analysis and post hoc Bonferroni test was performed to study hematologic changes. The results indicated an insignificant increase in RBC, hematocrit and hemoglobin immediately after exercise and significant reduction 24 h after; moreover, lymphocyte and neutrophil percentages increased significantly immediately after exercise and decreased significantly 24 h after exercise ($P \leq 0.05$); however, there were no significant differences in other variables either immediately or 24 h after exercise ($P \leq 0.05$).

Conclusion The results of this study indicated that one session of compound exercises with circular method could affect hematological variables; hence, compound programs of resistance and endurance exercises should be prescribed considering the intensity, duration and other circumstances of the exercise.

Keywords Hematologic variables · Non-athletes · Compound exercises · Immune system

Introduction

Blood is an aqueous tissue and its main task is maintaining a homogenous form of the internal environment of body tissues; in other words, blood protects homeostatic conditions. Various actions are carried out in the body and circulating blood makes it possible for various organs of the body to carry out their tasks within a chemical environment [1]. Like other body organs, the body does not react similarly to all the physical activities. Type of activity, time, intensity and duration are circumstances to which the body shows suitable reaction. Energy supply for active bodies requires cooperation and efficiency of body tissues, especially the blood. Various observations have proved that exercise could change blood composition [2]. In addition, physical activity may create numerous changes in the number and distribution of subgroups as well as proliferation of white blood cells [3]. Many researchers believe that acute exercise will increase blood concentration and vascular resistance and reduce the oxygen supply by reducing the effect on plasma volume and increasing the effect on all the hematological factors, while the oxygen supply in tissue will increase during the recovery after the exercise because large quantities of intracellular water return to the intravascular space, reducing all the hematological factors and blood concentration [4]. On the other hand, some believe that moderate and severe exercises will increase the body's resistance to diseases;

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however, scientific evidences indicate that many athletes suffer from infectious diseases, such as upper respiratory tract infections, after severe exercises and heavy races [5]. Studies on changes in immune cells are increasing, in particular in today's world as there are many competitions, athletic trainers and exercise science professionals are looking for better methods to achieve their goals. The above-mentioned reasons indicate the attention of such individuals toward a number of exercises. However, it is important to be aware of the risks associated with exercise methods and considerations after exercise.

Blood parameters are crucial for diagnosis and control processes in sports medicine and sports might affect blood parameters. Physical and physiological responses play a vital role in hematology; when blood is analyzed, the effect of sports can be seen at different levels of blood, indicating the dependence of such differences on the intensity and duration of sporting activities at different time intervals, in addition to exercise frequency and physical–physiological circumstances [6].

There are contradictory findings in this respect; for instance, the results reported by Nieman et al. [7] implied increased counts of white blood cells after 30 min of walking with 60% of maximum aerobic power on the treadmill. Gleeson et al. [8] also reported increased counts of white blood cells after long activities (more than 90 min) with 55–75% maximum aerobic power. Ghanbari Niaki et al. [9] reported increased counts of white blood cells and platelets after one session of circular endurance exercise; Havil et al. [10] reported the same results after one session of aerobic exercise among young adult athletes and Nemet et al. [11] reported this result after one session of wrestling exercise. On the other hand, Ansley et al. [12] did not report any significant changes white blood cell counts after three sessions of intense interval exercises with endurance. Simonson [13], also, did not report any significant changes in white blood cell counts in powerful athletes after a one-session resistance exercise. Huey-June Wu et al. [14] reported insignificant changes in hemoglobin and hematocrit levels immediately after 24 h of ultra-marathon. Boyadjiev et al. [15] reported a significant reduction in RBC variables in adolescent girls and boys after sports, considering changes in two genders relevant to exercise factor. Amirsasan [16] reported a significant decrease in hemoglobin and hematocrit levels after one session of intense aerobic exercise; Ghanbari Niaki et al. [17] reported significant reductions in hemoglobin and hematocrit levels after 3 days of one-mile running. However, there were no significant changes in blood factors of three trained groups in relation to the effect of duration, intensity and type of one-session exercise [18]. Furthermore, İbiş in 2017 investigated the acute effect of hematological parameters on aerobic and anaerobic exercises. The results of their study showed no significant changes in hematological results after aerobic exercise. However, there were some significant changes in Hb, Hct and WBC just after anaerobic exercises, whereas some significant decrease was observed for 24 h after exercise. As a result, maximal and hard exercises affect hematological values more than moderate exercises [19]. Gaeeni in 2001 also reported a significant increase in hemoglobin and hematocrit levels after maximum exercise [6].

Rama in 2016 evaluated the changes in resting hematological variables in ultra-endurance runners throughout a multi-stage ultra-marathon competition conducted over 5 consecutive days in hot ambient conditions (32–40 °C) and focused on the duration of exercise. A linear increase was observed in leukocyte, monocyte and lymphocyte counts, with increase until the last stage and a decrease thereafter. Hemoglobin and hematocrit showed linear decrease throughout the multi-stage ultra-marathon. No changes in erythrocyte and platelet counts were observed throughout the multi-stage ultra-marathon [20].

Since some of the training sessions, in particular in the race season, are more intense and athletes have to exercise vigorously, there might be changes in their circulatory system and its variables affecting the performance and the result of competition. In this regard, researchers are interested in examining the benefits and risks of changes in the body as well as the structural–biochemical changes and type of physical activity in different exercises. Some believe that regular daily exercises lead to reduction in disease symptoms; hence, many researchers and experts have paid attention to physiological and hematological changes caused by blood activity.

There is little and inconsistent documented data on the changes in hematological and immune parameters after exercise intervention. Obtaining further insight into how exercises affect immunology and hematology biomarkers in non-athlete students is key to understanding how it might alter immunity and hematological activation. This in turn will aid exercise and health professionals in designing appropriate training programs for students. Given the limited data currently available on the effect of circular compound exercise on blood parameters and immune system in students, the primary aim of this study was to examine whether the effect of one compound resistance–endurance training has an effect on blood parameters and immune system in non-athlete students. In addition, these effects were compared before, immediately and 24 h after circular exercise in non-athlete students.

Methodology

Subjects

In this quasi-experimental study, the statistical population consisted of all the 18–25-year-old, female PhD students of Kerman University of Medical Sciences. A total of 120 non-athlete female students volunteered to participate in the study. Inclusion criteria consisted of an age range of 18−25 years, female sex, no severe disease (chronic, autoimmune or neurological diseases, eating disorders, cancer, hepatitis, chronic obstructive pulmonary disease or intellectual disabilities) and without any hematological and infectious diseases, allergic conditions and no use of any medicine for two weeks before exercises, normal BMI ($18 < \text{BMI} < 25$), voluntary participation, keeping the diet, and signing an informed consent form. Participants ($n = 20$) who did not meet inclusion criteria, those who did not complete a demographic questionnaire or informed consent, those who did not keep the diet as stated, and those who were under medication were excluded. Hence, a total of 100 participants were finally included.

Procedures

Explaining the objectives of the project, all the medicinal and sport experiences of respondents were investigated using a medical history questionnaire. According to the scheduled program, the respondents became familiar with the test process, and anthropometric measurements and body parameters, including height, weight and body fat percentage were recorded. A maximum repetition of respondents was determined; then they participated in the main test session. Venous blood samples (2 mL/session) were taken from the respondents before and after exercise and 24 h after exercise with sterile tips and then the blood samples were transferred into specific bottles containing ethylene diamine tetraacetic acid and sent to the medical diagnostic laboratory. Analysis of blood samples was carried out using an electronic counter (ABX Micros 60). According to our research goal and necessity of controlling dietary conditions of the participants in this study, the participants were required to live in dormitories and use self-service meals, so that all the participants acquired similar habits during the study.

We followed the Declaration of Helsinki principles and respected the rights of all the participants. The study was approved by the Ethics Committee of Kerman University of Medical Sciences. Once ethical approval was obtained, a meeting was held with the participants to discuss the research details and expectations of the participants. Written informed consent was obtained during the meeting.

Exercise program

The training protocol in this research was a combination of resistance and endurance exercises designed as a circular exercise within two consecutive sessions. After 10 min of warm-up, compound exercises were performed (for 20 min). Stations of this exercise consisted of horizontal bar movements (20 s), jumping over obstacles (540 cm obstacles with 1 m distance), Swedish swimming (12 repetitions), sit-ups with a medicine ball (30 s), chest press with a barbell (70% one progressive repetition $\times 8 \times 1$), foot press (70% one progressive repetition $\times 8 \times 1$), waist fillet movement (15 repetitions), shin movements (70% one progressive repetition $\times 8 \times 1$), zigzag jump over obstacles (20 repetitions), and 6×10 m Illinois running, and 5 min of cool-down. The warm-up and cool-down phases included dynamic movements and stretching. Two well-trained teachers, who were familiar with the research objectives and practice stages, supervised the training sessions in 1 day (each day, 5 sessions, with 20 students in every session).

Statistical analysis

Descriptive statistics were used to analyze data, classify data and design tables. Then, ANOVA repetitive measurements were employed in intragroup studies obtained from triple steps of test (pretest and posttests 1 and 2). In addition, post hoc Bonferroni test was used to analyze significance of differences in the results and means. Statistically significant difference was considered at $P \leq 0.05$. SPSS 18 was employed for analyses.

Results

All the data collection and analysis steps were performed in Kerman University of Medical Sciences. The characteristics of the subjects are presented in Table 1.

Comparisons of average hematological changes in non-athlete students before, immediately and 24 h after compound exercises are presented in Table 2.

In Table 2, data are reported as means ± SD; the differences between means before exercise, immediately after exercise and 24 h after exercise were significant ($P \leq 0.05$) (Table 2). There were statistically significant differences between the red blood cell (RBC), hematocrit (HCT), lymphocyte and neutrophil variables before exercise and immediately after exercise ($P < 0.05$). No differences were found in mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin

Table 1 Means and standard deviations (SD) of subjects' individual characteristics

Characteristics of statistical index	Age	Height (cm)	Weight (kg)	BMI	Systolic blood pressure (mmHg)	Diastolic blood pressure (mmHg)
Mean ± SD	22 ± 1.62	164.1 ± 5.03	61.54 ± 8.84	23.1 ± 2.09	12.31 ± 3.65	8.31 ± 2.02

concentration (MCHC), mean cell volume (MCV) and platelet and plasma volume between the different time intervals.

Post hoc Bonferroni test was used to compare variables at different time intervals (Table 3). The results showed the significant differences between the periods before exercise and immediately after exercise in red blood cell counts ($P < 0.05$). No significant differences were detected in hematocrit, hemoglobin, lymphocyte and neutrophil variables before exercise and immediately after exercise ($P > 0.05$).

Discussion

Several studies have examined the effects of exercise on increasing mental and physical health [21, 22]. In this research, we considered hematological changes, including MCH, HB, MCHC, MCV, PLT, HCT, RBC, lymphocytes and neutrophils in non-athlete female subjects when responding to one-session compound exercises with circular method.

The results indicated no significant differences in blood plasma volume (PV) of the subjects before, immediately after and 24 h after one-session endurance exercise. This finding implied absence of dilution or concentration of plasma and its relative stability of volume. Respondents were allowed, during exercises, to drink water. On the other hand, they did exercises with low intensity. Therefore, drinking enough water and doing exercises with low intensity justified the absence of changes in plasma volume. In the Azarbayjani study, PLT decreased immediately after one-session aerobic and anaerobic exercise in young men kickboxing.

According to the results of the study, RBC counts increased immediately after the exercise, while HCT and HB increased insignificantly. Varlet-Marie et al. [23] reported a significant increase in whole blood viscosity and hematocrit after exercise. RBCs will sustain more damage during

Table 2 Changes in variables in non-athlete students before, immediately and 24 h after exercise

Hematological variables	Before exercise	Immediately after exercise	24 h after exercise	ANOVA *F* statistic	*P* value
Red blood cell/10^6 μL × (RBC)	5.28 ± 0.11	5.38 ± 0.10	5.21 ± 0.12	6.89	0.01*
Hematocrit (HCT)%	46.98 ± 0.73	47.62 ± 0.63	45.53 ± 0.78	7.49	0.006*
Hemoglobin (HB) g/l	15.78 ± 0.29	16 ± 0.27	15.42 ± 0.3	12.22	0.001*
Mean Corpuscular Hemoglobin (MCH) Pg	29.98 ± 0.86	29.87 ± 0.82	29.71 ± 0.89	2.39	0.1
Mean corpuscular hemoglobin concentration (MCHC) dl/g	33.61 ± 0.26	33.58 ± 0.25	33.57 ± 0.3	0.029	0.9
Mean cell volume (MCV) Femtolite	89.02 ± 2.1	88.76 ± 2.2	82.80 ± 5.08	1.21	0.3
Platelet/10^3 μL × (PLT)	217.12 ± 16.64	225.25 ± 17.04	214.25 ± 13.81	0.65	0.5
Plasma volume (PV)%	53.02 ± 0.73	52.38 ± 0.63	54.07 ± 0.78	0.9	0.5
Lymphocytes (%)	46.53 ± 9.56	50.36 ± 9.63	47.07 ± 5.78	4.75	0.03*
Neutrophils (%)	47.71 ± 10.07	52.97 ± 9.95	48.09 ± 6.18	5.98	0.02*

*Significance level of $P \leq 0.05$

Table 3 Post hoc Bonferroni test to compare hematological variables at different time intervals

Hematological variables	Post hoc test		Mean difference	Standard error	*P* value
Red blood cell/10^6 μL × (RBC)	Before exercise	Immediately after exercise	−0.08	0.03	0.04*
	Before exercise	24 h after exercise	0.07	0.05	0.6
Hematocrit (HCT)%	Before exercise	Immediately after exercise	0.66	0.29	0.2
	Before exercise	24 h after exercise	1.61	0.47	0.03*
Hemoglobin (HB) g/l	Before exercise	Immediately after exercise	−0.22	0.01	0.2
	Before exercise	24 h after exercise	0.56	0.1	0.007*
Lymphocytes (%)	Before exercise	Immediately after exercise	3.83	1.2	0.03
	Before exercise	24 h after exercise	0.54	0.1	0.006*
Neutrophils (%)	Before exercise	Immediately after exercise	5.26	2.43	0.01
	Before exercise	24 h after exercise	0.38	0.17	0.02*

*Significance level of $P \leq 0.05$

intense exercise since they more intensely hit the walls of blood vessels. In case of severe rupture of RBC membrane, there will be greater amounts of Hb and proteins in urine. In addition, acidosis might occur in some heavy physical activities, leading to vulnerability and faster decomposition of RBCs. Despite the absence of changes in RBC counts in blood, RBCs will increase in active tissues during physical activities due to increased blood flow in active tissues, i.e., in line with increase in RBC counts, there is a minor increase in hematocrit and HB immediately after the exercise. Other research findings demonstrated that despite the increase in RBC, HCT and Hb immediately after the exercise, these variables decreased 24 h after the exercise, consistent with the results of previous studies [16, 17]. Camacho-Cardenosa [24] evaluated the effects of 8 training sessions (2 sets of 5 repeated sprints for 10 s with a recovery of 20 s between sprints and a recovery period of 10 min between sets), in 24 active adults and reported that this dose of exercise with maximal-intensity interval training in hypoxia improved HCT and Hb parameters significantly in healthy and active adults. Moreover, Belviranli [25] reported that acute high-intensity interval training caused an inflammatory response in blood by increasing hematocrit percentages, hemoglobin values, red cell counts, mean cell volume, platelet counts, total white blood cell counts, and counts of white blood cell subgroups immediately after HIT and their values began to return to resting levels 3 h after exercise.

This phenomenon can be attributed to some factors such as intensity, duration and compound nature of exercises, as well as inadequate rest between exercises, which effectively reduce important parameters of gas exchange and oxygen transfer to active muscles. If PV is not changed physiologically, the oxygen available to active muscles will decrease, making muscles use anaerobic energy reserves. Use of energy reserves causes glycogen depletion, pH reduction, and lactate accumulation in the blood, leading to fatigue and poor performance of the athlete.

Some researchers have reported no changes in erythrocyte metabolism and morphology in relation to MCH, MCHC, MCV and PLT factors after short-term physical activities and fatigue in studies on the effect of sports on RBC and hematological system. Furthermore, many studies have shown no significant changes in concentration of blood parameters of subjects after exercise [14, 26], confirming the findings of the present study on insignificant changes in MCH, MCHC, MCV and PLT parameters immediately and 24 h after one-session exercise. This can be attributed to blood compatibility.

Previous studies have shown improvements in immune function after exercise. In this context, Passos [27] in patients with chronic primary insomnia, Starzak in male African youths [28], and Borges [29] showed that a single bout of street dancing induced inflammation and reduced neutrophil migration and adhesion molecule expression. In addition, Escribano [30] concluded that moderate exercise improves the response of the nonspecific immune system to future infections. The results of the present study showed a significant increase in neutrophil and lymphocyte counts immediately after the activity, consistent with the results reported by Gaeeni et al. [6], Natale et al. [21] and Ghanbari Niaki et al. [9], who reported a significant increase in the indices mentioned above. However, the results reported by Suzuki et al. [31], on the impact of a competitive marathon race on systemic cytokine and neutrophil responses, were not consistent with the results of this study. Two reasons can be presented to explain the results of this study; first, severe contraction is one of reasons for muscular damage. After the muscular damage, release of a chemotactic factor from damaged cells leads to absorption, accumulation and migration of white blood cells to the damaged part. The number of circulating white blood cells might increase four times greater than the normal after exercise and remain at a high level after the end of the physical activity; then this increase might continue for several hours after the activity. In general, it seems there is a direct relationship between leukocytosis and intensity and duration of activity while there is an inverse relationship between a person's readiness and leukocytosis level [9]. Second, there is strong evidence that hormones play a vital role as regulators of changes caused by sport in leukocytosis and its subgroups. It has been shown that some hormones such as cortisol and epinephrine affect leucocytes distribution. Studies indicate that epinephrine will increase the leukocyte counts during intense and short-terms sports, because the increase in cortisol is slow when reacting to activity, and increases in leukocyte counts is related to increased cortisol levels after the exercise [32–34]. In addition, release of catecholamine and cortisol during long-term activities leads to a decrease in leukocyte counts [31]. The differences between results of the present study and previous studies might be attributed to exercise schedule, type and duration of activity [15], respondents' situation, gender and age differences, and damage rate.

Physical exercise has many beneficial and protective effects on the functions of many systems [35]. Consequently, the results can be regarded as standards for the effects of compound circular exercises on blood parameters and immune system components in non-athlete students. Furthermore, this report combined blood parameters and immune system in one study. Although not all aspects of blood and immune components were examined, the results might form a reference guide for future studies on the effects of exercise on blood hemodynamics. The results showed that one session of compound resistance−endurance programs reduced the risk of immune system disease and improved hematological blood parameters. Compound circular exercise in young people can play an important role in reducing inflammatory markers.

There were some limitations in this study, including the absence of a control group, the gender of the subjects (only females) and just the non-athlete students, studied in this research. These limited our ability to generalize the results. A future investigation could include randomization with control group in both genders by comparing these variables in athletes and non-athlete students to resolve these limitations.

Conclusion

In summary, circular compound exercise training improved hematological parameters and promoted significant changes in immunologic variables. These findings suggest the potential effects of circular compound exercise on immune system and blood indices in non-athlete students, indicating that, regardless of inactive status of students, the intervention affected both blood parameters and immune system, suggesting that future studies should consider the mechanism and the relationship between internal glands and CNS in these changes. It is recommended that compound circular training should be used to prevent adverse effects of increased incidence of infections and many diseases for people with a sedentary lifestyle.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in this study.

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