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Original Research

The effects of acute moderate intensity training on hematological parameters in elite para-badminton athletes

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Abstract

Background and objective: The knowledge on the effects of para-badminton sport on physiological parameters is relatively limited in the literature. This study aims to examine the effects of moderate-intensity badminton training on the hematological parameters of elite para-badminton athletes. **Methods**: A total of 12 para-badminton athletes, 6 female and 6 male, with international competitive experience in the Turkish Para-Badminton National Team, participated in the study. A 90-minute badminton training was applied to the athletes for their technical and tactical development. A 4 mL blood sample was taken before and after the training. Hematological parameters were analyzed from these blood samples. White blood cells, red blood cells, platelets count, and their particular subgroups such as hemoglobin, hematocrit, granulocytes, and lymphocytes were examined as the hematological parameters in this study. **Results**: The findings revealed that the female para-badminton athletes exhibited a significant increase in white blood cells, granulocytes percentage, red blood cells, hemoglobin, hematocrit, platelets values after training compared to pre-training. It was determined that there were significant increases in white blood cells, granulocytes, granulocytes percentage, red blood cells, and hematocrit values for male para-badminton athletes after training compared to pre-training, and significant decreases in lymphocytes percentage values. **Conclusion**: In conclusion, the present study showed that a single 90-minute moderate-intensity badminton training session leads to physiological changes on the blood parameters of elite para-badminton athletes. These changes, which differ by gender, can affect the health and performance of the athlete.

Keywords: Physically disabled; Blood cells; Badminton; Unit training

1. Introduction

Para-badminton is a specific sport that has been adapted for the disabled. Para-badminton is the official name for badminton adapted for persons with certain kinds of physical disabilities. Para-badminton athletes can compete in all five traditional badminton disciplines [1,2]. These athletes have varying levels of physical health problems differing in functional levels. Even if the handicaps are similar, their functional features occasionally differ [2]. Players compete in three classes and six categories; i.e., (a) wheelchair (WH1, WH2), (b) standing players (SL3, SL4, SU5), (c) short players (SS6). This classification is performed precisely in order to balance the players' chances on the field and ensure fairness in the competition [3,4]. In particular, SL4, SU5, and SS6 categories, which are relatively fast and exciting, have the same standards as regular badminton in-game rules and court measurements [5]. In addition, wheelchair badminton is characterized by a high level of wheelchair-using skills, fast and sudden forward and backward maneuvering, and high-intensity dynamic activities such as short sprints [6].

The sportsmen, technical team, and various individuals are increasingly interested in badminton globally. The growing interest in the sport is related to the decision by the 2014 International Paralympic Committee (IPC) to include para-badminton among Paralympics sports at the 2020 Tokyo Paralympics (postponed to be held in 2021) [7]. Badminton's rising reputation in the sports community and its inclusion in the Paralympic Games program facilitated para-badminton to attract the attention of the scholarly, and there has been a significant increase in the amount of relevant scholarship. There were several recent attempts on basic information about para-badminton [4], para-badminton curriculum for the motor development of children with physical disabilities [8], reaction times of players [2], physical fitness profiles [5,6] with notational analysis findings [7,9,10]. However, the knowledge on the effects of para-badminton sport on physiological parameters is relatively limited in the literature [11]. In addition to existing studies, the effects of exercise on blood parameters have been an ongoing research topic for several years. The direct correlation between performance determinants and physical and physiological characteristics is the reason behind this interest.

The taxonomy based on the peak static and dynamic components obtained during the races classifies badminton

Table 1. Sports experience and demographic values of Para-badminton athletes (mean ± standard deviation).

Parameters	Male (n = 6)			Female (n = 6)		
	Min	Max	Mean ± SD	Min	Max	Mean ± SD
Age (year)	18.00	39.00	23.33 ± 8.06	19.00	37.00	24.16 ± 6.79
Height (cm)	165.00	187.00	176.00 ± 8.98	158.00	167.00	162.66 ± 3.20
Weight (kg)	50.00	70.00	63.66 ± 7.00	50.00	61.00	56.83 ± 4.35
BMI ($kg \cdot m^{-2}$)	17.93	24.24	20.58 ± 2.30	17.93	22.68	21.50 ± 1.83
Training experience (year)	4.00	13.00	6.66 ± 3.61	4.00	9.00	5.66 ± 1.75

in sports that require high dynamic and low static exercise, as is the case for long-distance running. Dynamic exercise-oriented sports such as football, tennis, and badminton mainly cause volume loading in the left ventricle of the heart, while static exercise-based sports such as weightlifting, windsurfing, and water skiing cause pressure loading [12]. The effect of exercise on blood parameters in different degrees is of great importance as blood parameters restrict athletes exercise intensity due to various disorders related to hematological status [13]. The frequency, intensity, and duration of regular exercise and the physical-physiological characteristics of the athletes are linked to the hematological changes after exercise [14]. Moreover, exercise-related hematological changes depend on the type, intensity, and exercise duration [15]. The hematological conditions of athletes play an essential role in transporting vital gases, O_2 and CO_2, regulation of acid-base balance, and buffering-facilitating thermoregulation [16].

Surprisingly, there is no comprehensive data in the literature that describe the hematological profile of elite para-badminton athletes during acute exercise (moderate-intensity unit training) Furthermore, there are controversial results regarding both acute and chronic exercise on blood cells in various sports. For example, it was found that exercise is correlated with decreases in the erythrocyte subgroups such as red blood cell count, hemoglobin amount, and hematocrit percentage [16–18]. On the other hand, certain erythrocyte subgroups values were shown to have increased after exercise in several studies [19–21]. In addition, several studies reported that platelets count increased with exercise [19,20,22–25]. It was also determined that exercise in some cases caused a decrease in the platelet count [16,26].

It is therefore essential to determine the potential effects of technical-tactical training on the hematological profiles of elite para-badminton athletes, as the current knowledge does not offer adequate data and insights on this topic. Thus, potential changes in hematological parameters of para-badminton athletes that may occur with training shall be better understood after this study. This study aims to examine the effects of technical and tactical 90-minute moderate intensity level training on some hematological parameters of elite para-badminton athletes.

2. Methods

2.1 Participants

Athletes from the Turkish National Team para-badminton were recruited. A total of 12 elite para-badminton athletes, six male and six female, with international experience (European-World Championships, International Tournaments) were included. Most participants, having varying levels of disabilities, had more than five years of training experience and trained at least five days a week. The sample was recruited by convenience. All of the athletes were in the SL3, SL4, and SU-5 categories of standing badminton players. Those with diseases that may affect their hematological conditions, such as thyroid disease, anemia, and infectious diseases, were excluded. Detailed medical examinations were performed (Dr. B.I. executed examinations of the athletes). All of the participants were healthy in hematological terms, none of them had smoking or alcohol habits, nutritional supplements or drugs. Sports experience and demographic data of the participants are available in Table 1.

2.2 Procedures

The measurements were performed in November 2019. Findings were evaluated during the regular training hours in the afternoon (3:00 PM–5:00 PM) in a gym the participants were familiar with. The athletes were given an instruction not to consume alcohol and caffeinated foods and beverages at least one day before the measurements. Moreover, it was ensured that they avoid intense physical activity at least one day before the tests. Female athletes included in the study were not in their menstrual period.

The body mass was measured without heavy clothes using an electronic scale, and height was measured in an upright position without shoes in the morning. Blood samples were taken from each participant before and after the training, per the rules of asepsis-antisepsis by experienced medical personnel. Blood samples were collected in 4 mL of hemogram tubes with K3 EDTA (4 mL vacutainer tube; BD Vacutainer, Franklin Lakes, NJ, USA) through a catheter placed in the right antecubital vein. The blood samples were preserved at room temperature under suitable preservation conditions without centrifugation and were delivered to the laboratory within 120 minutes. According to the instructions, hematological parameters were examined at the Konya Application Center of Özel Sistem Laboratories through a Cell-Dyn 1800 (Abbott Diagnostics, Abbott Park, IL, USA) hematological analyzer. The leukocyte subgroups as the white blood cells (WBC $10^3/\mu L$) count, Granulocytes (GRAN $10^3/\mu L$) count, Lymphocytes (LYM $10^3/\mu L$) count and MID cells ($10^3/\mu L$) count, GRAN %, LYM % and MID cells %; erythrocyte subgroups as the red blood cells (RBC $10^6/\mu L$) count, hemoglobin (Hb g/dL^{-1}), mean corpuscular volume (MCV fL), mean corpuscular hemoglobin (MCH pg), mean corpuscular hemoglobin content (MCHC g/dL) counts, Red Blood Cells Distribution Width (RDWC %) and hematocrit (Hct %); platelet subgroups as Platelets (PLT $10^3/\mu L$) count, mean platelet volume (MPV fL) count, Plateletcrit (PCT %) and Platelet Distribution Width (PDW %) values of the hematological parameters were analyzed.

2.3 Training procedure

The athletes trained on the test day at moderate intensity with technical-tactical content for 90 minutes. Technical training means training in which techniques specific to badminton are used. These are the exercises in which the shuttlecock is sent from the back and front of the athlete's own court to the back and front of the court on the opponent's court. Tactical training means all of the methods used by the athlete to win the game. The athletes started the training with 20 minutes of warm-up, coordination, and balance exercises followed by 10 minutes of shadow badminton exercises to improve the sensitivity to the court, 25 minutes of technical training with clear, drop, net drop, drive, etc., 20 minutes of drill exercises for defense (10 minutes) and offense (10 minutes) organizations, a free match for 10 minutes, and they concluded the session with 5 minutes of cool-down exercises.

Training intensity was around 50–70% (except for the warm-up and cool-down parts). The heart rates were monitored with an electronic polar clock, and it was kept below 160 beats per minute during the training so that the training level did not exceed the moderate-intensity limits. The heart rate of the athletes was between 60–70 beats per minute before the warm-up period of the training. It was around 100 beats after the warm-up. The heart rates of the athletes were checked every five minutes from the warm-up parts until the cool-down parts. Average heart rates in both female and male athletes ranged from 139 to 154 beats per minute.

2.4 Statistical analysis

The SPSS Software version 24.0 (IBM Corp., Chicago, IL, USA) program was utilized for data analysis as the arithmetic mean, and standard deviation values were measured. The Kolmogorov-Smirnov analysis revealed that the data did not show normal distribution; hence nonparametric tests were applied. The differences between pre-test and post-test were determined by Wilcoxon signed-rank test. A two-way repeated measure analysis of variance (ANOVA) was performed to test for the main effects corresponding to groups (male, female) and time (Pre-Post), as well as the interaction between the two. The confidence interval was determined as $p < 0.05$.

Table 2. Hematological parameter changes before and after the acute moderate-intensity training in male athletes (mean ± standard deviation) (n = 6).

Parameters		Mean ± SD	Mean rank	z	*p*
Leukocyte sub-groups					
WBC ($10^3/\mu L$)	Pre-test	6.38 ± 0.79	0.00	–2.207	0.027*
	Post-test	8.20 ± 0.80	3.50		
GRAN ($10^3/\mu L$)	Pre-test	3.48 ± 1.02	0.00	–2.207	0.027*
	Post-test	4.56 ± 0.91	3.50		
GRAN (%)	Pre-test	47.98 ± 7.92	0 .00	–2.201	0.028*
	Post-test	56.58 ± 8.10	3.50		
LYM ($10^3/\mu L$)	Pre-test	2.51 ± 0.28	2.88	–1.089	0.276
	Post-test	2.36 ± 0.24	3.50		
LYM (%)	Pre-test	38.51 ± 8.48	3.50	–2.201	0.028*
	Post-test	31.01 ± 5.41	0.00		
MID ($10^3/\mu L$)	Pre-test	0.96 ± 0.32	3.00	–1.225	0.221
	Post-test	0.85 ± 0.18	3.00		
MID (%)	Pre-test	14.20 ± 3.42	4.00	–1.997	0.046*
	Post-test	10.91 ± 1.20	1.00		
Erythrocyte sub-groups					
RBC ($10^6/\mu L$)	Pre-test	5.00 ± 0.29	4.00	–1.992	0.046*
	Post-test	5.15 ± 0.26	1.00		
Hb (g/dL^{-1})	Pre-test	14.38 ± 0.80	3.88	–1.051	0.293
	Post-test	14.60 ± 1.02	2.75		
Hct (%)	Pre-test	43.08 ± 2.90	3.50	–2.207	0.027*
	Post-test	44.51 ± 2.75	0.00		
MCV (fL)	Pre-test	85.86 ± 3.56	3.60	–1.577	0.115
	Post-test	85.08 ± 3.33	3.00		
MCH (pg)	Pre-test	28.30 ± 1.00	0.00	–2.023	0.043*
	Post-test	28.76 ± 0.85	3.00		
MCHC (g/dL)	Pre-test	32.80 ± 0.58	0.00	–2.201	0.028*
	Post-test	33.60 ± 0.51	3.50		
RDWC (%)	Pre-test	13.78 ± 0.77	3.90	–1.897	0.050*
	Post-test	13.50 ± 0.85	1.50		
Thrombocyte sub-groups					
PLT ($10^3/\mu L$)	Pre-test	246.83 ± 43.17	2.00	–1.367	0.172
	Post-test	261.50 ± 63.16	4.25		
MPV (fL)	Pre-test	8.81 ± 1.19	4.00	–0.524	0.600
	Post-test	9.26 ± 1.68	3.25		
PCT (%)	Pre-test	0.23 ± 0.02	3.33	–0.677	0.498
	Post-test	0.23 ± 0.01	2.50		
PDW (%)	Pre-test	16.63 ± 0.75	2.83	–0.422	0.673
	Post-test	16.68 ± 0.33	4.17		

*$p < 0.05$.

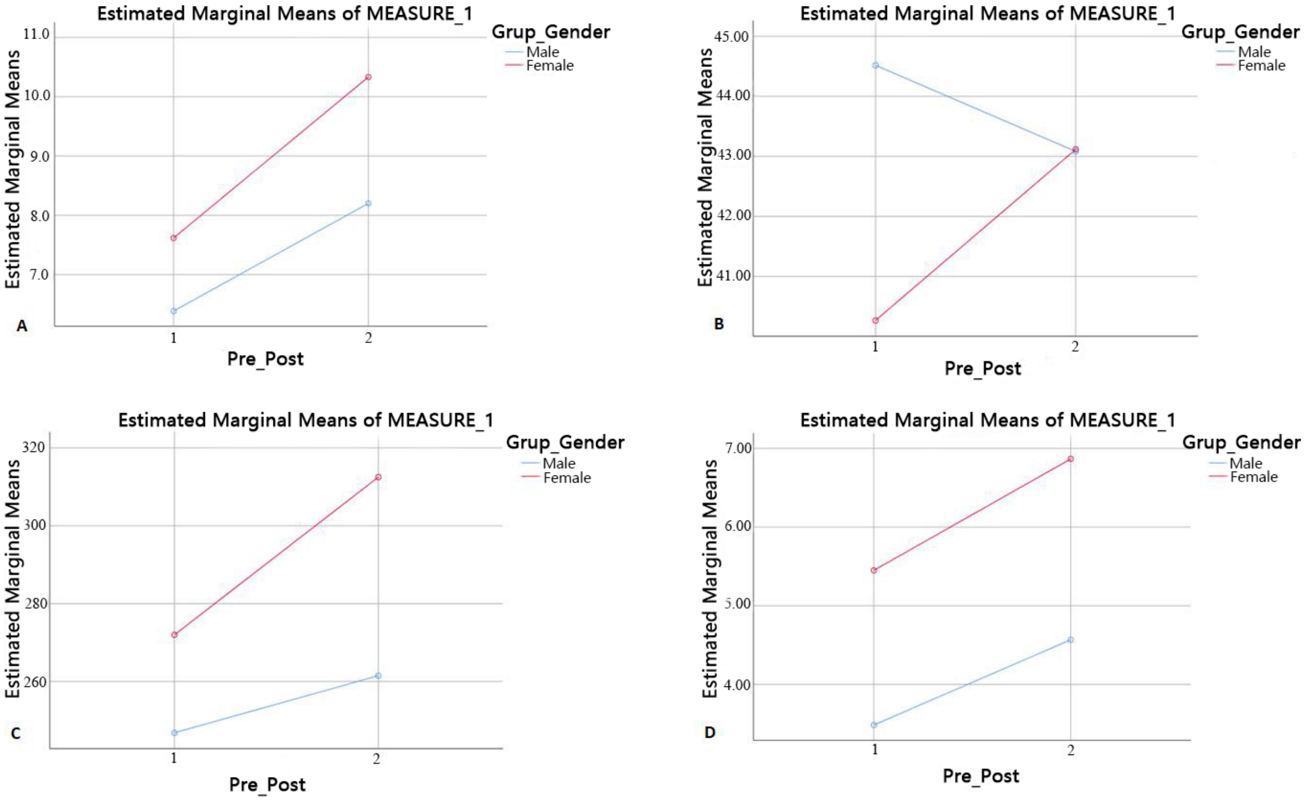

Fig. 1. The interaction effect of gender on hematological parameter changes. (A) WBC ($10^3/\mu$L). (B) Hct (%). (C) PLT ($10^3/\mu$L). (D) GRAN ($10^3/\mu$L), *$p < 0.05$.

3. Results

The differences between male athletes' pre-test and post-test average values are presented in Table 2.

The differences between female athletes' pre-test and post-test average values are presented in Table 3.

The interaction effect of gender on hematological parameter changes are presented in Fig. 1.

As shown in Fig. 1, it was observed that A (WBC), C (PLT), D (GRAN) values changed with the effect of training ($p < 0.001$, $p = 0.004$, $p = 0.009$, respectively). No difference was observed in the interaction effect of gender on these changes ($p = 0.137$, $p = 0.111$, $p = 0.675$, respectively). While it was observed that there was no change in the B (Hct) value with the effect of training ($p = 0.210$), when the averages of the interaction effect of gender on this change were considered, an incremental difference was observed in female athletes ($p = 0.002$).

4. Discussion

This study on the adaptation response of hematological parameters in para-badminton athletes to training with technical-tactical content at moderate intensity level for 90 minutes revealed that some values differ by gender. It was determined that some major components of hematological parameters, such as WBC and RBC values, increased for both genders after training, while PLT values increased only in females. Furthermore, the study examined the differences in WBC and RBC sub-group parameters for male athletes compared to females in general. Normally, the exercise performance boost is affected by several factors, including the nervous system, hormones, and a variety of proteins, that significantly control the muscle tissue, resulting in effective oxygen and energy usage and hematological factors, such as improved oxygen-transporting capacity in the blood circulation [27]. From this point of view, it is considered that the existing hematological conditions of paralympic athletes or the hematological changes that occur as a result of exercise may affect their performance and even lead to particular health problems. The literature disclosing hematological conditions of disabled athletes is extremely limited. Therefore, it is considered that the periodic evaluation of hematological parameters of para-badminton athletes, which are lacking in the literature to the extent of our review, both during training periods and at rest, may be beneficial in terms of supporting and improving the training programs, increasing performance, or preventing possible adverse events in the future. It can be argued that the changes in the hematological parameters of para-badminton athletes after acute exercise offer essential insights for the literature. Therefore, it is asserted that the data obtained from this study shall contribute to the development of para-badminton sports and lead the literature.

Table 3. Hematological parameter changes before and after the acute moderate-intensity training in female athletes (mean ± standard deviation) (n = 6).

Parameters		Mean ± SD	Mean rank	z	*p*
Leukocyte sub-groups					
WBC ($10^3/\mu L$)	Pre-test	7.61 ± 2.84	0.00	–2.207	0.027*
	Post-test	10.33 ± 2.81	3.50		
GRAN ($10^3/\mu L$)	Pre-test	5.45 ± 1.91	2 .00	–1.782	0.075
	Post-test	6.86 ± 2.25	3.80		
GRAN (%)	Pre-test	56.31 ± 9.51	0.00	–2.023	0.043*
	Post-test	65.00 ± 6.14	3.00		
LYM ($10^3/\mu L$)	Pre-test	2.41 ± 0.53	4.00	–0.316	0.752
	Post-test	2.35 ± 0.48	3.00		
LYM (%)	Pre-test	23.78 ± 6.31	3.75	–0.943	0.345
	Post-test	21.63 ± 2.86	3.00		
MID ($10^3/\mu L$)	Pre-test	0.80 ± 0.27	0 .00	–2.207	0.027*
	Post-test	1.11 ± 0.24	3.50		
MID (%)	Pre-test	12.11 ± 1.62	3.80	–1.782	0.075
	Post-test	11.10 ± 1.09	2.00		
Erythrocyte sub-groups					
RBC ($10^6/\mu L$)	Pre-test	4.82 ± 0.29	0.00	–2.023	0.043*
	Post-test	5.16 ± 0.40	3.00		
Hb (g/dL^{-1})	Pre-test	13.41 ± 1.45	1.00	–1.997	0.046*
	Post-test	14.25 ± 1.58	4.00		
Hct (%)	Pre-test	40.26 ± 4.42	1.00	–1.992	0.046*
	Post-test	43.11 ± 4.40	4.00		
MCV (fL)	Pre-test	84.20 ± 4.76	3.38	–1.625	0.104
	Post-test	83.63 ± 4.10	1.50		
MCH (pg)	Pre-test	28.08 ± 1.40	3.00	–2.032	0.042*
	Post-test	27.78 ± 1.43	0.00		
MCHC (g/dL)	Pre-test	33.35 ± 0.68	3.25	–0.530	0.596
	Post-test	33.21 ± 0.54	4.00		
RDWC (%)	Pre-test	14.81 ± 1.52	3.80	–1.787	0.074
	Post-test	14.38 ± 1.59	2.00		
Thrombocyte sub-groups					
PLT ($10^3/\mu L$)	Pre-test	272.00 ± 39.06	0.00	–2.207	0.027*
	Post-test	312.50 ± 51. 61	3.50		
MPV (fL)	Pre-test	8.90 ± 0.80	3.50	–0.137	0.891
	Post-test	8.75 ± 0.75	2.67		
PCT (%)	Pre-test	0.24 ± 0.02	2.67	–1.134	0.257
	Post-test	0.23 ± 0.04	2.00		
PDW (%)	Pre-test	16.73 ± 0.85	2.67	–1.134	0.257
	Post-test	16.41 ± 0.80	2.00		

*$p < 0.05$.

It is a well-known fact that exercise, which still requires further research, is a stressor that causes an inflammatory response in the hormonal and metabolic components of the body [25]. Changes in the number and functions of WBC, a major hematological component, are closely related to the direct effect of different factors on the endothelial tissue [28]. Any stress, including exercise, causes secretion from the adrenal gland in the body and increases stress hormones such as catecholamine and cortisol in the blood. The amount of neutrophil (granulocyte) predominantly increases WBC in the blood, especially in the early period of exercise, with demargination and a series of immunological changes due to stress hormones and hemodynamic shear stress after exercise [29,30]. Moreover, exercise, a fundamental cause of stress in the body, causes an increase in neuronal transmitters and peptide-structured or chemical transmitters in the blood besides stress hormones such as adrenaline, neural adrenaline, and cortisol and lead to demargination, resulting in neutrophil increases in the vascular compartment during the early period of exercise. This means an increase in the amount of WBC in the blood. The idea that this increase is caused by the stress hormones released into the blood increased volume in the circulation, and demargination that allows the leukocyte in the endothelial wall to be presented to the circulation after exercise is widely accepted [31].

It was observed in the study that there was neutrophil (granulocyte) increase immediately after exercise in male and female athletes as the amount of WBC increased. Similarly, several studies involving both sedentary individuals and nondisabled athletes reported that the amount of WBC, including neutrophil increase during the early period of exercise [20,21,25]. On the other hand, in a study investigating the pre- and post-competition hematological parameters of a male Brazilian Jiu-Jitsu Paradesport athlete, who was an elite paralympic athlete, it was shown that WBC and monocytes increased significantly in the early period after the competition, while lymphocytes decreased. It was argued that this case might be closely related to the catabolic mechanisms triggered by the effect of increasing cortisol during the competition, and there was no difference between nondisabled athletes and disabled athletes in terms of acute hematological immune response to exercise [32]. It was determined that there were decreases in the lymphocyte values and in the WBC sub-group parameters, MID % value including eosinophils, basophils and monocytes and small group leukocytes besides granulocyte values increased for both gender groups, which is consistent with the common findings of previous studies with regard to the shared feature of the participants being athletes. It can be argued that this is caused by the inflammatory processes triggered by stress hormones, primarily cortisol and others, which increase through a body's adaptation to exercise [20,30]. Furthermore, previous studies have also shown an increase in neutrophil and lymphocyte values [21,31], and a decrease in MID values [31] in the early period of exercise. It is considered that the findings regarding increased lymphocyte values in some studies contrary to the decrease in lymphocyte values after training in this study may have stemmed from the increased lymphatic flow resulting in increased lymphocyte increase in addition to the increase in cortisol hormone, catecholamines and the subsequent immune response with the stress caused by exercise.

This study revealed that the increases in the hemoglobin, hematocrit, MCH, and RBC, that carry oxygen to the tissues, values and are related to plasma losses after exercise, were observed to be largely coherent with the discipline [19,21,25]. On the other hand, in a study conducted in 2020 in which the effects of a short-term training program applied under hypoxic conditions on the hematological parameters of Korean disabled cycling national team athletes was investigated, it was revealed that there were no significant differences in oxygen-transporting capacity parameters. This situation was stated to have possibly been caused by increased RBC production and increased plasma volume due to the increased erythropoietin with the effect of training applied under hypoxic conditions, which could last for days [33]. Çelik *et al*.'s [34] study on male football players, athletes engaged in a sports branch requiring high dynamic and low static exercise as in badminton, found an increase in RBC and sub-group parameter values such as hemoglobin and hematocrit, which are formed after acute exercise, and our results regarding the increase in RBC and sub-group parameter values such as hemoglobin and hematocrit are similar. This supports the argument that the genre of sports and type of exercise engaged in can lead to results with similar effects on hematological parameters. Similar results in RBC and sub-group parameter values such as hemoglobin and hematocrit for different genres of sports where similar exercise types are performed may be rooted in the increase in the RBC count introduced into the circulation with higher blood flow and metabolic rate due to the metabolic and neuroendocrine mechanisms to meet the increased oxygen demand of the muscles [34]. Likewise, the exercise type, duration, intensity, individual factors such as training status, gender, and age are also important factors in the hematological changes that occur in the body with exercise [15]. Furthermore, Erdağı *et al*. [20] revealed that acute exercise decreases RBC and sub-group parameter values such as hemoglobin and hematocrit through their study on female weightlifting athletes training with high static and low dynamic exercises in contrast to badminton. It can be asserted that the type, duration, intensity, and sports branch, besides the hemolysis due to intravascular stress and trauma due to exercise, may have caused this decrease.

It was shown in previous studies involving female athletes that acute exercise causes an increase in the PLT count like other main blood cells and these findings coincide with the results [23,35,36]. Furthermore, the PLT level of a disabled Jiu-Jitsu Paradesport athlete was shown to have significantly increased immediately after the competition relative to before [32]. It was argued that this increase in the PLT count is due to the hemoconcentration that occurs after exercise, the platelets released from the spleen and other stores to meet the demand [36]. MPV, which increases with the effect of exercise and indicates platelet hyperactivity [37], was observed to increase after exercise in male athletes in our study, as in multiple previous studies [23,36,38]. The findings revealed that the PDW value increased for male athletes after exercise in insignificant levels and decreased female athletes. Moreover, a study conducted with 12 handball players found that this value was increased. However, previous studies conducted in different branches at different intervals determined decreased values [39]. The general scientific opinion for PDW, a reflection of how uniform the platelet sizes are, is that the effect of exercise on PDW is insignificant [39].

This study had certain limitations, as well. First, it comprises a small sample of elite para-badminton athletes. The research findings may not apply to other badminton populations, such as nondisabled and amateur players in this regard. Second, the number of blood parameters examined might be considered to be small. Thus, eliminating these limitations in future studies and refining these findings may contribute significantly to the literature.

5. Conclusions

In the present study, which was conducted on elite para-badminton athletes, a total of 18 parameters including WBC, RBC, PLT, and their sub-parameters were examined. Significant differences were found for 9 parameters of the male para-badminton athletes, and 8 parameters of the female para-badminton athletes. Although some variations were observed in other parameters as well, they were considered to be insignificant.

As a result, it can be concluded that the technical-tactical content at moderate intensity level exercises conducted for 90 minutes caused increases or decreases in the hematological parameters of both male and female para-badminton athletes. This limited effect, which does not lead to a surprising change, can be attributed to the fact that the athletes in the research group were elite-level competitors, and to their ability to develop physiological adaptation to exercise stress thanks to their training background. From this point of view, the hematological conditions of para-badminton players should be evaluated periodically at different times. This may be beneficial for trainers to improve the training program, for athletes to increase performance, and for sports medicine to prevent and rehabilitate possible health problems in the future.

Author contributions

ME, MFY and BI designed the research study. MFY and EB performed the research. TS provided advice on the training procedure. KE analyzed the data. ME, MFY and BI wrote the manuscript.

Ethics approval and consent to participate

The information and consent interviews were conducted with the participants, their trainers, and club managers. The study was conducted in accordance with the Declaration of Helsinki and under the approved protocol by Meram Medical Faculty, Ethics Committee of non-Pharmaceuticals and non-Medical Device Researches of Necmettin Erbakan University with the number 2018/1236. Participants were informed about the study's method and potential risks, and informed consent was obtained.

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Conflict of interest

The authors declare no conflict of interest.

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