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ORIGINAL PAPER

The effects of acute high intensity interval training on hematological parameters and neutrophils to lymphocytes ratio in elite taekwondo athletes according to gender

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ABSTRACT

Introduction and aim. Intense taekwondo (TKD) training, it is important to know the exercise-induced hematological and inflammatory conditions and to develop conditions suitable for physiological needs. The aim of study is to investigate the effects of TKD-specific training containing a high-intensity interval training (HIIT) component hematological parameters and on systemic inflammatory biomarkers between gender.

Material and methods. The research was carried out with twenty-four elite TKD athletes (12 female, 12 male). 90 minutes of TKD-specific unit training, including 50 minutes of HIIT component was applied to the athletes. Hematological parameters included erythrocytes, platelets, leukocytes and their subgroups and inflammatory biomarkers.

Results. With the effect of TKD-specific HIIT, erythrocytes and hematocrit values decreased regardless of gender (p=0.003, p<0.001, respectively). Platelet values decreased in male and increased in female (p=0.637). White blood cells and neutrophil (p<0.001) and inflammatory biomarkers neutrophils-to-lymphocytes ratio (NLR) and platelet-to-lymphocytes ratio PLR (p<0.001, p=0.022, respectively) increased regardless of gender. Lymphocyte decreased marginally significantly (p=0.059).

Conclusion. This study showed that TKD-specific HIIT increased systemic inflammatory conditions and decreased oxygen-carrying blood parameters. These fundamental findings can contribute to training science in arranging a specific taekwondo training program and sports medicine in protecting the health of athletes.

Keywords. hematological parameter, high intensity interval training, taekwondo

Introduction

Taekwondo (TKD), a traditional martial art, originated in Korea. According to the World Taekwondo Federation (WTF) and International Taekwondo Federation (ITF) reports, there are approximately 80 million individuals worldwide interested in TKD sports. TKD training includes systematic, chronic and progressive activities. Many combat sports including TKD involve extremely high-intensity and interval exercise patterns for short periods, and the possibility of frequent contact, exposure, and injury during competition.[1] TKD training requires high aerobic capacity and anaerobic power, fast

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movement skills, high muscle strength, excellent body composition and practical agility.[2,3] Also, TKD training includes a high-intensity static exercise and a low-intensity dynamic exercise pattern. Therefore, high pressure and low volume load occur in the hearts of TKD athletes.[4] From this point of view, in combat sports like TKD, athletes have to perform training sessions that vary according to the mode, effort, pause, intensity, and rate of exercise.to cope with the physiological demands of these sports and high-intensity intermittent exertion situations.[5,6] High-Intensity Interval Training (HIIT), which has been applied for a long time in many combat sports, including taekwondo, has gained popularity in the last two decades as it has resulted in the special classification of different types of variable combinations to develop particular adaptations.[7,8] Combat-sport-specific combat simulation training like TKD is intermittent in nature.[9]

Recently, many researchers have focused on investigating the effects of martial arts specific standard with complementary HIIT on morphological, physiological and performance adaptations. Therefore, understanding the benefits of HIIT on physiological adaptation and performance can provide valuable insights into the field, in order to improve the training programs and performance of TKD athletes, especially by trainers and sports scientists.TKD athletes are physiologically very tired during competitions and they are at risk of injury. Because, according to Olympic rules and World Taekwondo (WT) regulations, TKD competitions consist of at least 3 rounds with 2 minutes of fighting and 1 minute of rest in between. Athletes may have to fight 4-5 consecutive fights a day for the championship.[10]

Like all professional athletes, TKD athletes and coaches are also concerned for the combat sports training program they apply to achieve the best results in the competition. However, the effects of exercise are of great importance because some hematological disorders seen in athletes can negatively affect training intensity and exercise success.[11] Hematological parameters are affected by both the frequency, intensity, type and duration of the exercise, as well as the age of the person, eating habits and the environment.[12] In many studies, it has been shown that regular training makes changes the hematological patterns of many athletes, including TKD, but in some studies it does not.[13-16]

Due to the close contact between the athletes during the TKD sport, the risk of injury that causes various levels of tissue damage has always been inherent in this sport.[17] In addition, it is well known that inflammation plays an important role in the formation of metabolic and hormonal responses in the body against sequential exercise-induced physiological stress.[15-18] In particular, it has been shown that the duration and intensity of exercise have a positive effect on the regulation of leukocyte response.[19] In addition, neutrophils-to-lymphocytes ratio (NLR) and platelet-to-lymphocytes ratio (PLR) are the most important biomarkers reflecting systemic inflammatory status in athletes including taekwondo.[20]

Most of the studies conducted in TKD athletes to date focused on performance training, field testing methods, physiological responses during competition, and sports injuries.[1-3,21] To our knowledge, these studies did not examine the effects of training on hematological parameters and inflammatory biomarkers such as NLR and PLR in elite TKD athletes. Keeping this in mind, it is critical to develop conditions suitable for the physiological needs specific to TKD sport, in order to achieve high sportive performance, to develop an appropriate periodic training program and to prevent and eliminate possible health problems related to hematological parameters. We hypothesized that the TKD-specific training containing a high-intensity interval training component might affect the hematological profiles of taekwondo athletes and NLR.

Aim

In line with the available information, in this study, it was aimed to investigate the effect of 90-minute TKD-specific unit training, including 50 minutes of HIIT component on systemic inflammatory biomarkers and hematological parameters in elite TKD athletes between gender.

Material and methods

Participants

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 2018/1312. Participants were informed about the study's method and potential risks, and informed consent was obtained.The subjects of this research were selected among the volunteer athletes of the Selcuk University Taekwondo Team.The study was conducted on 24 elite level taekwondo athletes (12 males and 12 females) from the Selçuk University Taekwondo Team, who regularly continued Taekwando training and participated in tournaments. All of the subjects were black belt holders and classified in the national Division I category. Furthermore, in order to form the elite level athlete group, inclusion criteria were formed. According to inclusion criteria, the athletes to be included in the study must have at least a 5-year exercise background (min; 6, max; 14 years), must be participated in national and international level Taekwando competitions, and must have continued taekwando training for 5 days and over in a week. Additionally, based on the inclusion criteria the athletes must be between 17-23 years old and have voluntary to participate in the study. Moreover, they must beno smoking, no use of notorious, alcohol or nutritionalsupplements. All of them had to be physically and mentally healthy. Those with diseases that may impair their hematological terms, such as anemia, thyroid diseases, musculoskeletal injuries, infectious and inflamatuar diseases, were excluded. Moreover, female athletes who are in menstrual period were excluded from the study. Detailed medical examinations of the athletes were made by B.I. who is a medical expert doctor. Hence, all of the athletes who were included this study were healthy in hematological terms. Training experience, demographic values and hematological parameters of the subjects are available in Table 1.

Procedures and hematological analysis

The study was performed in December 2019. Measurements were made during the regular training hours in the afternoon (03:00 PM-05:00 PM) in a gym the athletes were familiar with. The athletes were given a directive not to exhaust alcohol and caffeinated foods/drinks at least 2 days before the measurements. Furthermore, subjects were instructed to refrain from doing any training or vigorous physical activity for at least 2 days before the study to control possible confounding factors influencing blood inflammatory biomarker assessments. An easily digestible diet had been suggested for them, so as not to aggravate their digestive system. Subjects also were restricted from consuming any form of anti-inflammatory drug or antioxidants to minimize the individual variability in detecting inflammatory state before and during the study period.

Baseline anthropometric data were measured in a room at room temperature in the morning the day before the study and were measured after overnight fasting (12 h). All instruments were calibrated before the test. The body mass was measured with light clothes using an electronic scale, and height was measured in an upright position without shoes in the morning. Blood samples were taken from the forearm vein of athletes 10-min before and after the training, per the rules of disinfection by the specialist medical staff. Blood samples were collected in 4 mL of hemogram tubes with K3 EDTA. According to the instructions, haematological 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 subparameters as the white blood cells (WBC $10^3/\mu L$) count, neutrophil (NEU $10^3/\mu L$) count, lymphocytes (LYM $10^3/\mu L$) count and MID cells ($10^3/\mu L$) count, NEU %, LYM % and MID cells %; erythrocyte subparameters as the red blood cells (RBC $10^6/\mu L$) count, hemoglobin (HBG g/dL), 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 subparameters as platelets (PLT $10^3/\mu L$) count, mean platelet volume (MPV fL) count, plateletcrit (PCT %) and platelet distribution width (PDW %) values of the haematological parameters were analyzed from each blood sample. Then, systemic inflammatory biomarkers were calculated such as NLR and PLR from these values.[20] To calculate changes in plasma volume, Dill and Costill formula were used:[22] $\%\Delta PV = [(HBG_1/HBG_2) \cdot (100 - HCT_2/100 - HCT_1) - 1] \cdot 100$.

All blood samples and raw data were subsequently analyzed and statistical analysis applied. The experimental design is summarised in Figure 1.

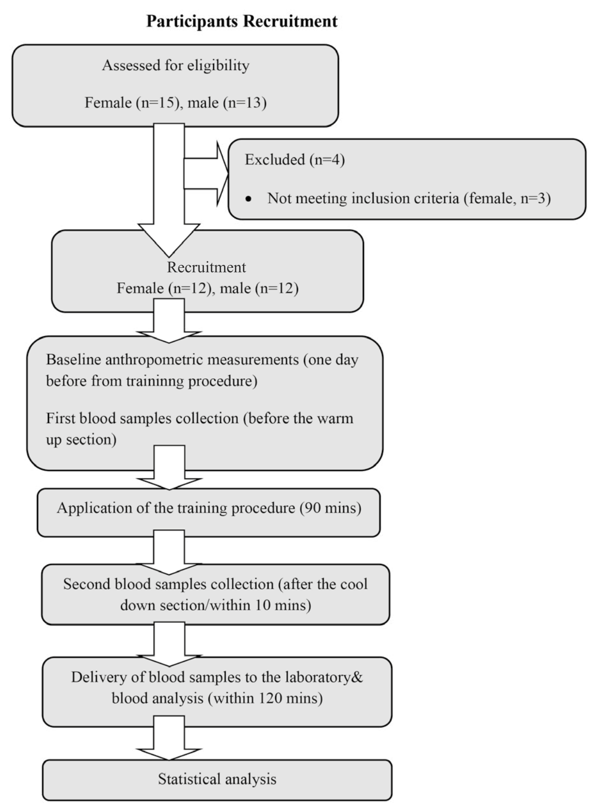

Fig. 1. Schematic of the experimental design

Training procedure

Athletes trained for 90 minutes on the test day according to the content stated below. The high-intensity interval Taekwondo-specific unit training period consisted of three parts:

a. Warm-up part (30 mins); Athletes started training with 10 minutes of light jogging. Afterwards, applied dynamic and static flexibility, joint mobility, coordination and balance exercises to the athletes.
b. Main part (50 mins); During the technical exercises and training competition applied in the main phase of the training, Work, one of the high-inten-

sity interval training (HIIT) protocols reported by Franchini et al.; rest ratios were applied as 1:2 minute.[23] In addition, training intensity ranged from 80–90%, as reported in many previous studies.[24-26] Athletes performed single and combined technical exercises on gloves (with all the techniques used in competitions) for 15 minutes. In addition, single and combined technical studies were carried out on the safeguard for a period of 15 minutes. Work: Rest ratios were applied in the form of 1:2 minutes and 5 repetitions in single and combined technical studies on both gloves and safeguards. Finally, a training competition called Sparring was held for 20 min (the athletes participated in the competition with the "pull system" method). In the meantime, tactical indications were given by the coach regarding the offensive and defensive stance, technical demonstration and protection, by intervening when necessary.

c. Cool-down part (10 mins): Light jogging and static flexibility exercises were applied to the athletes for 5 minutes each.

During the training, the heart rates of the athletes were recorded with an electronic polar watch. The average heart rate of both male and female athletes was between 57-70 beats/min before the warm-up period and around 100 beats/min after the warm-up period. In the main circuit, the heart rates of male athletes were between 158-172 beats/min and between 160-174 beats/min for female athletes. During the collection of second blood samples within 10 minutes after the cooling section, the mean heart rates of female and male athletes were 79 and 73 beats/min, respectively. The heart rates of the athletes were checked every three minutes from the warm-up to the cool-down.

Statistical analysis

These analyses were performed using open-source jamovi statistical platform [The jamovi project 2021, Sydney, Australia, *Jamovi* (Version 1.2.1.1)] [Computer software]. Retrieved from https://www.jamovi.org.

The data were presented as mean ± standard error of mean (mean ± SEM.) Normal distribution was analysed by Kolmogorov-Smirnov test and age, training experience, BMI by independent t-test.The direction and strength of the relationship between training experience, hematological parameters and some these ratio such as NLR, PLR were evaluated with the Pearson correlation. 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 (groups and time: the effect of gender on the pre-post change). Results were considered statistically significant at the level of $p < 0.05$.

Table 1. Training experiences, demographic values, plasma volume changes, hematological parameters and inflammatory biomarkers of Taekwondo athletes (mean ± SEM)[a]

	Female athletes (n= 12)	Male athletes (n= 12)	p
Age (years)	20.33 ± 0.57	20.67 ± 0.43	0.645
BMI (kg/m^2)	20.91 ± 0.66	21.33 ± 0.34	0.579
Training experience (years)	8.83 ± 0.56	9.67 ± 0.7	0.363
Plasma Volume Change (%)	1.48 ± 0.52	2.55 ± 0.51	0.155

	Female athletes (n= 12)		**Male athletes (n= 12)**	
	Pre	**Post**	**Pre**	**Post**
RBC*,† (10^6/µL)	4.53 ± 0.08	4.38 ± 0,07	5.27 ± 0.12	5.19 ± 0.1
HBG*,¶,†(g/dL)	13.1 ± 0.2	12.64 ± 0.24	15.24 ± 0.31	15.17 ± 0.42
HCT*,†(%)	39.71 ± 0,61	38.88 ± 0.64	46.45 ± 0.88	45.11 ± 0.94
MCV¶(fL)	87.9 ± 1.68	88.85 ± 1.48	88.49 ± 2.3	87.04 ± 1.9
MCH¶(pg)	28.99 ± 0.54	28.91 ± 0.53	29.01 ± 0.8	29.27 ± 0.82
MCHC¶,†(g/dL)	33 ± 0.18	32.5 ± 0.15	33.12 ± 0.21	33.94 ± 0.29
PLT¶(10^3/µL)	244.42 ± 15.7	264 ± 16.87	253.5 ± 10.8	241.83 ± 9.83
MPV*,¶,†(fL)	11.29 ± 0.3	10.86 ± 0.36	10.26 ± 0,25	10.2 ± 0.24
MPV/PLT ratio¶	0.05 ± 0	0.04 ± 0	0.04 ± 0	0.04 ± 0
WBC*,†(10^3/µL)	7.07 ± 0.55	8.81 ± 0.7	6.19 ± 0.34	7.06 ± 0.44
NEU*,†(10^3/µL)	4.65 ± 0.53	6.38 ± 0.74	3.42 ± 0.28	4.52 ± 0.37
NEU*,† %	63.78 ± 3.34	70.64 ± 3.78	54.93 ± 1.5	64.86 ± 1.99
LYM*(10^3/µL)	1.82 ± 0.1	1.74 ± 0.19	2.12 ± 0.08	1.78 ± 0.12
LYM*,† %	26.73 ± 2.79	21.67 ± 3.23	34.77 ± 1.59	25.91 ± 1.89
MID(10^3/µL)	0.67 ± 0.06	0.71 ± 0.06	0.66 ± 0.03	0.66 ± 0.05
MID*,† %	9.48 ± 0.75	8.13 ± 0.64	10.74 ± 0.27	9.55 ± 0.34
NLR*,†	2.68 ± 0.39	4.29 ± 0.71	1.62 ± 0.11	2.7 ± 0.28
PLR*	138.46 ± 10.8	171.69 ± 21.46	121.7 ± 7.11	143.09 ± 11.31

[a](*: within subject <0.05, ¶: interaction <0.05 †: between subject <0.05)

Results

This study was conducted on 24 elite level taekwondo athletes (12 males and 12 females), who regularly continued TKD training and participated in tournaments. The TKD-specific training containing a high-intensity interval training component was applied to athletes. Blood samples were taken from the athletes 10-min before and after the training (Figure 1). Subjects' characteristics are display in Table 1.Statistical results of hematological parameters are presented in the text and Figure 2 and 3.

The main effect for time training-induced RBC count was significant [$F(1, 22)=11.615$, $p=0.003$, $\eta^2=0.346$]. Its trend was downward. However, time and group interaction was not significant [$F(1, 22)=0.868$, $p=0.362$, $\eta^2=0.038$]. The mean of RBC count was significantly different between groups, with males being higher [$F(1, 22)=37.669$, $p<0.001$, $\eta^2=0.631$], (Figure 2).

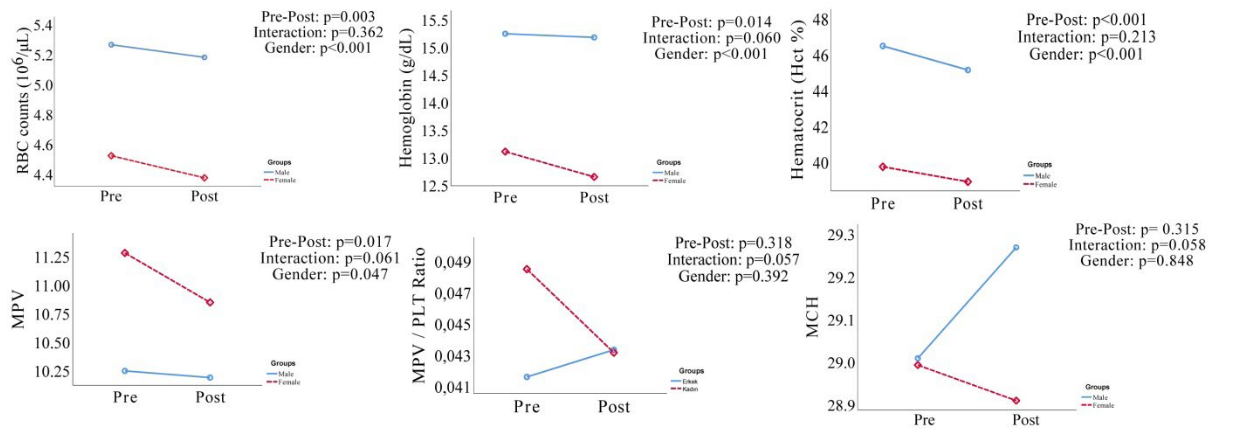

Fig. 2. Changes in hematological parameters and MPV/PLT ratio in response to TKD-specific training containing a high-intensity interval training component. The changes of RBC count, HBG, HTC, MPV, MPV/PLT ratio and MCH were measured pre and post TKD-specific training. There were statistically differences in pre and post (RBC, HBG, HTC, MPV), interaction (marginal significant HBG, MPV, MPV/PLT, MCH) and gender (RBC, HBG, HTC, MPV), ($p<0.05$)

The main effect for timetraining-induced HBGvalue was significant [F(1, 22)=7.084, p=0.014, η^2=0.244]. Also, time and group interaction was marginally significant [F(1, 22)=3.943, p=0.060, η^2=0.0152]. The change in HBG was more in female gender. The mean HBG was significantly different between the groups, with males being higher [F(1, 22)=31.267, p<0.001, η^2=0.587], (Fig. 2).

The main effect for time training-induced HCT % was significant [F(1, 22)=30.395, p<0.001, η^2=0.580]. However, the time and group interaction was not significant [F(1, 22)=1.648, p=0.213, η^2=0.070]. The change in HCT % was similar in both genders. The mean HCT % was significantly different between the groups, with it being higher in males [F(1, 22)=35.735, p<0.001, η^2=0.619], (Figure 2).

The main effect for time training-induced MCV value was not significant. [F(1, 22)=0.383, p=0.542, η^2=0.017]. However, time and group interaction was significant [F(1, 22)=8.962, p=0.007, η^2=0.289. A change in different ways was observed in the MCV in the form of an increase in females and a decrease in males. Mean MCV was similar in groups [F(1, 22)=0.555, p=0.816, η^2=0.003].

The main effect for time training-induced MCH value was not significant [F(1, 22)=1.055, p=0.315, η^2=0.046]. However, time and group interaction was marginally significant [F(1, 22)=3.986, p=0.058, η^2=0.153]. A decrease in MCH in females and an increase in males were observed in different ways.MCH mean was similar in groups [F(1, 22)=0.038, p=0.848, η^2=0.002], (Figure. 2).

The main effect for time training-induced MCHC value was not significant [F(1, 22)=0.677, p=0.419, η^2=0.030]. However, time and group interaction was significant [F(1, 22)=11.436, p=0.003, η^2=0.342]. A decrease in the MCHC in females and an increase in males were observed in different ways.The mean of MCHC was significantly different between groups [F(1, 22)=11.349, p=0.003, η^2=0.340].

The main effect for timetraining-induced PLT count was not significant [F(1, 22)=0.229, p=0.637, η^2=0.010]. However, time and group interaction was marginally significant [F(1, 22)=3.573, p=0.072, η^2=0.140]. The PLT count trend was downward in males and upward in females. The mean of PLT count was similar between groups [F(1, 22)=0.141, p=0.711, η^2=0.006], (Figure.3).

The main effect for time training-induced MPV value was significant [F(1, 22)=6.709, p=0.017, η^2=0.234]. Time and group interaction was marginally significant [F(1,22)=3.903, p=0.061, η^2=0.151]. The MPV downward trend was more in females. The mean MPV value was significantly different between the groups, with it being higher in females [F(1, 22)=4.431, p=0.047, η^2=0.168], (Figure 2).

The main effect for time training-induced MPV/PLT was not significant [F(1,22)=1.044, p=0.318, η^2=0.045]. However, time and group interaction was marginally significant [F(1,22)=4.028, p=0.057, η^2=0.155]. The MPV/PLT trendwas downward in females and upward in males. The rate of change in the mean MPV/PLT with the effect of training was 11.1 % in females and 4.1 % in males. MPV/PLT mean was not significantly different between groups [F(1,22)=0.761, p=0.392, η^2=0.033], (Figure 2).

The main effect for time training-induced WBC count was significant [F(1, 22)=17.352, p<0.001, η^2=0.441]. Its trend was upward. However, time and group interaction was not significant [F(1, 22)=1.953, p=0.176, η^2=0.082]. Although the increase in WBC count was slightly higher in females, there was marginally significant difference between the groups [F(1, 22)=3.798, p=0.064, η^2=0.147), (Figure 3).

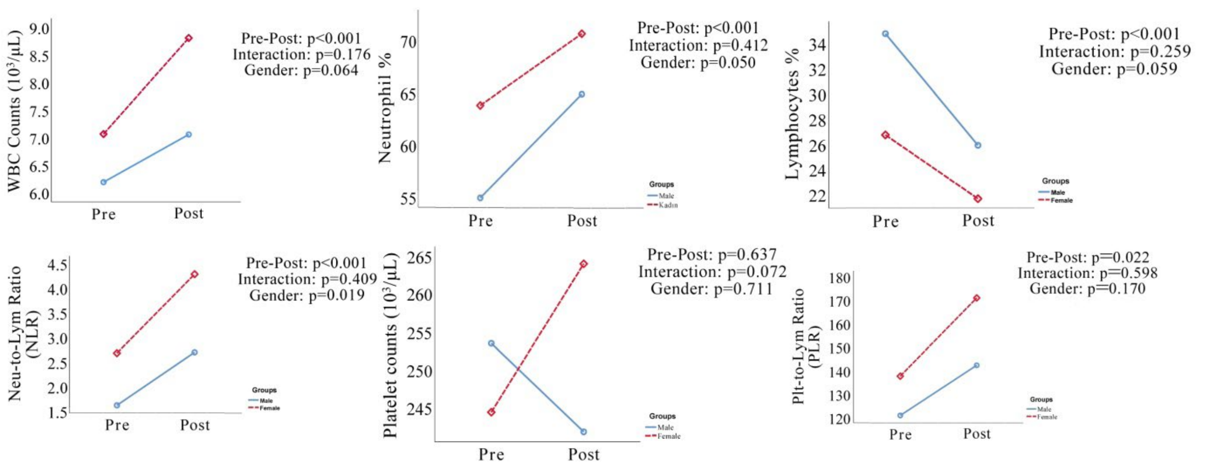

Fig. 3. Changes in WBC subparameters, PLT and systemic inflammation biomarkers in response to TKD-specific training containing a high-intensity interval training component. The changes in total WBC and PLT counts and leukocytes subparameters % (NEU, LYM) and systemic inflammation markers NEU-to-LYM Ratio and PLT-to-LYM Ratio were measured pre and post TKD-specific training, ($p<0.05$)

The main effect for time training-induced NEU count and NEU % were significant [F(1, 22)=19.709, p<0.001, η^2=0.473, F(1, 22)=20.987, p<0.001, η^2=0.488, respectively]. Both trendswere upward. However, the time and group interaction for both parameters were not significant [F(1, 22)=0. 985, p=0.332, η^2=0.043, F(1, 22)=0.701, p=0.412, η^2=0.03, respectively]. While the mean of NEU count was significant [F(1, 22)=5.712, p=0.026, η^2=0.206), the NEU % value was marginally significant, between the groups(F(1, 22)=4.293, p=0.050, η^2=0.163]. While the average increase in NEU count in females was significantly higher than that of males, the increase in NEU % in the proportional distribution of leukocyte subgroups such as NEU and LYM within the total leukocyte count was more pronounced in males, (Figure 3).

While, the main effect for time training-induced LYM countwas marginally significant, the main effect of Lym % was significant [F(1, 22)=3.957, p=0.059, η^2=0.152, F(1, 22)=18.137, p<0.001, η^2=0.452, respectively]. Both trends were downward. However, time and group interaction in Lym count and LYM % value was not significant [F(1, 22)=1.621, p=0.216, η^2=0.069, F(1, 22)=1.345, p=0.259, η^2=0.058, respectively]. While the mean of LYM count was not significant between groups, the mean of LYM % was marginally significant [F(1, 22)=1.271, p=0.272, η^2=0.055, F(1, 22)=3.977, p=0.059, η^2=0.153, respectively]. In other words, in the proportional distribution of leukocytes within themselves, the LYM % decreased more significantly in males. In males, this supported the marginally significantly higher distribution of NEU % in leukocytes, (Figure 3).

While the main effect for time training-induced MID count was not significant, the main effect of MID % change was significant [F(1, 22)=0.353, p=0.558, η^2=0.016, F(1, 22)=16.693, p<0.001, η^2=0.431, respectively]. While the MID count trend was upward in females, it was linear in males. MID % trend was downward in both groups. However, time and group interaction in MID count and MID % value was not significant [F(1, 22)=0.353, p=0.558, η^2=0.016, F(1, 22)=0.071, p=0.792, η^2=0.003, respectively]. Also, the MID count mean was similar between groups, while the MID % mean was marginally significant [F(1, 22)=0.183, p=0.673, η^2=0.008, F(1, 22)=3.733, p=0.066, η^2=0.145, respectively]. In other words, although the decrease in the mean % of the MID value, which includes the sum of the small group leukocytes, eosinophils, basophils and monocytes, with the effect of training, was more pronounced in females than in males, the mean MID % was found higher in males.

The main effect for time training-induced NLR was significant [F(1,22)=18.332, p<0.001, η^2=0.455]. Its trend was upward. However, time and group interaction in NLR value was not significant [F(1,22)=0.707, p=0.409, η^2=0.031]. Athletes' training-related NLR change was not affected by gender. The NLR change rate with the effect of training was 60.1% in females and 66.3% in males. The mean NLR was significantly different between the groups, with the females being higher [F(1, 22)=6.353, p=0.019, η^2=0.224], (Figure 3).

The main effect for time training-induced PLR was significant [F(1,22)=6.096, p=0.022, η^2=0.217]. Its trend was upward. However, time and group interaction in the PLR value was not significant [F(1,22)=0.287, p=0.598, η^2=0.013]. Athletes' training-related PLR change was not affected by gender. The rate of change in the mean PLR with the effect of training was 24% in females and 17.57% in males. Although the mean PLR was higher in females, there was no significant difference between the groups [F(1,22)=2.013, p=0.170, η^2=0.084], (Figure 3F).

Although there was a weak negative correlation (r = -0.303, p=0.150) between training experience and NLR in taekwondo athletes, no relationship could be found between training experience and PLR (r=-0.17, p=0.938). Surprisingly, a negative correlation (r = -0.259, p=0.221) was shown between the mean of MPV and PLT values, while a positive correlation (r=0.145, p=0.498) was shown between the mean of MPV/PLT and the training experience. However, statistical significance was not found in these relationships.

Discussion

In this study, adaptation responses of hematological parameters and systemic inflammatory biomarkers including NLR and PLR to 90-minute TKD-specific training containing HIIT component were investigated in elite TKD athletes. In the current study, the main effect of training-induced change in RBC and its subparameters HBG and HCT was shown to be significant. It was observed that the changes in RBC and HCT values in the direction of decrease were not affected by the gender factor, but the change in HBG was marginally significantly affected. It was determined that the mean of the aforementioned values was significantly higher in men. In any study, investigating the effects of chronic exercise on hematological parameters in TKD athletes, it was interpreted that significant changes in oxygen-carrying blood parameters were caused by intravascular hemolysis due to exercise-induced trauma.[27] But, in another study, increases in hematological parameters have been associated with exercise-induced plasma losses.[28] Plasma change was not remarkable in our study; therefore, we think that other factors rather than plasma change are effective in the decrease of hematological parameters.Erdağı et al. showed that RBC, HBG and HCT decreased with the effect of acute exercise, similar to the findings of our study, in a study they conducted in elite female weightlifters in 2018.[29] It is known that TKD and weightlifting sports trainings include high-intensity static and low-intensity dynamic exercise patterns.[4] Surprisingly, a decrease in RBC, HBG and HCT values was detected in TKD athletes in our study, as well as in weightlifters, due to acute exercise. It has been shown that the type, duration and intensity of exercise, as well as individual factors such as gender and age, have important effects on the hematological changes that occur in the body with the effect of exercise.[30] For this reason, it can be said that intravascular hemolysis in the vessel wall as a result of high blood pressure, stress and trauma due to training with acute HIIT component are effective in the decrease in RBC, HGB and HCT values as well as the type, duration, intensity of exercise and sports branch. On the other hand, Özen et al. showed that there was a significant increase in RBC subparameters MCH and MCHC values in professional male football players with the effect of 6-week preparation training.[12] Similarly, in the findings of our study, the increase in MCH and MCHC values with the effect of TKD-specific training in males can be considered as a adaptation response to the increased metabolic and oxygen demand during exercise.

In this study, PLT counts decreased in males and increased in females with the effect of training. The change in MPV values, on the other hand, decreased more in female than in males. The change in both coagulative parameters was marginally significant. The present findings are in full agreement with the findings of Boyalı et al.'s study on TKDathletes.[27] Similar studies have shown increasesin PLT and its sub-parameters, and decreases in some others,with the effect of acute and chronic exercise.[28,31,32] Consistent with the literature, in our study, PLT increase in female taekwondo athletes; It may be due to activation of the sympathetic nervous system, which occurs to meet the increased metabolic needs in the tissues with the effect of acute exercise, release of platelets into the circulation from blood cell stores such as the spleen and bone marrow, and hemoconcentration due to plasma loss. The decrease in PLT in males may be due to intravascular trauma, cellular damage in the body under stress and pressure due to acute exercise and platelet fragmentation. Decrease in MPV value, which is an indicator of platelet hyperactivity in both genders, on the other hand, may indicate that the platelet hyperactivity caused by the effect of exercise in athletes can be adequately compensated. However, more extensive research is needed to elucidate its cellular mechanisms.

The duration and intensity of exercise have an important effect on the regulation of leukocyte response.[19] Belviranlı et al. showed that WBC, NEU, and LYM, which are associated with all aspects of the immune system, increase immediately after acute HIIT exercise.[33] In some studies, LYM was shown to be decreased in the early period after exercise and recovered over time.[15,34] In the current study, which has similar findings with the literature, it was shown that the main effect of the change in WBC and NEU due to training was significant, but the gender group interaction was not significant. The change was in the direction of increase. While NEU mean was found to be significantly higher in females than in males, it was observed that the increase in NEU % within the leukocyte subparameters was marginally significantly more pronounced in males than in females. Exercise is a factor that causes systemic inflammatory response and cell damage by causing the secretion of stress hormones such as cortisol and catecholamines from the adrenal gland under the influence of stress in both the normal population and martial arts athletes including taekwondo players.[34] Hemodynamic shear stress, which is caused by stress hormones and exercise, cause an increase in WBC and NEU in the early phase of exercise with a series of immunological reactions and demargination.[35] In the current study, while the main effect of training-related LYMcount and LYM % change was significant, gender-group interaction was not. LYM change lines are trending in the decreasing direction. Similar to our findings, Chuang et al. showed a significant decrease in the number of circulating LYM after TKD competition in 2019. The authors speculated that LYM reduction may be related to cytotoxic agents released from injured muscles and altered immune cell balance profiles during recovery after combat exercise.[36] In our study, it was also observed that, in the proportional distribution of leukocyte subparameters, it was observed that the % of LYM decreased significantly more in males. This was a finding supporting the proportional distribution of NEU % within the leukocytes subparameters in males than in females. The mean % of the MID value, which is the sum of the subparameters of leukocytes, eosinophils, basophils and monocytes decreased more significantly in females than in males under the training effect. In the current study, it was shown that the mean % of MID was higher in males, as demonstrated by Erdoğdu et al.[15] This may be due to the inflammatory process triggered by stress hormones such as cortisol and catecholamines that increase in order to tolerate the increased meatbolic needs during exercise.[29,35] Inflammation is considered as a basic physiological process inducing exercise adaptation mechanisms, as well as facilitating the repair process by collecting the internal resources of the organism to the damaged area.[18] NLR and PLR are accepted as indicators of systemic inflammatory status in athletes, including TKD.[20,37] It was thought that NLR could be a safe and appropriate biomarker to determine the systemic inflammatory state during acute HIIT in TKD athletes.But there was no study on this field in the literature review. Therefore, in this study, these biomarkers were selected to determine the systemic inflammatory state caused by acute HIIT in TKD athletes. In a study by Chen et al. in TKD athletes in 2017, they showed that chronic exercise increases NLR. They associated the increased systemic inflammatory state with weakening the adaptive response to training, resulting in decreased aerobic capacity, low anabolic hormone (testosterone, DHEA-S), and increased catabolic hormone (cortisol) levels. Furthermore, they argued that increased systemic inflammation after training may impair the development of aerobic capacity and local muscle repair mechanisms.[20] Interestingly, a negative correlation between training experience and NLR was detected in our study. Therefore, we think that intense TKD-specific training for a long time can reduce inflammation due to training. Also in this study, although the main effect of the change in NLR and PLR, which occurred in the direction of increase with the training effect, was found to be significant, it was observed that this change was not affected by gender. In this study, while the mean NLR was found to be significant in females and the PLR was non-significantly high, the rates of change were observed to be 60.1%, 24% in females, 66.3% and 17.57% in males, respectively. Similar to our findings, in their study, Chuang et al. showed that NLR and PLR increased with the effect of real TKD competition including acute TKD training, and the increase after the competition was more than the increase after simulated combat training. The authors declared that this increased systemic immune response is associated with many endocrine, metabolic and immune processes that occur with the effect of exercise.[36] On the other hand, in a study conducted in 2016 among elite Taekwondo athletes, it has been claimed that the increase of approximately 48% in the NLR value measured after 10 weeks of competition preparation training after an 8-week period of no training may be related to the anti-inflammatory effect of regular exercise.[37]

Our study had particularly limitations, as well. First, it comprises a small sample of elite TKD athletes. The research findings may not apply to other TKD populations, such as disabled and amateur athletes in this field. Second, the markers of muscle damage, such as myoglobin, creatine kinase, caused by exercise, and the blood parameters of the recovery period after exercise could not be measured in the current study. Thus, eliminating these limitations in future studies and refining these findings may contribute significantly to the literature.

Conclusion

Finally, it can be concluded that the TKD specific training containing a HIIT component caused some changes in hematological parameters and systemic inflamatuar status of both male and female TKD athletes. It can increase systemic inflammatory biomarkers such as NLR and PLR or decrease oxygen transporter hematological parameters such as RBC and HGB in both males and females. 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 and inflammatory conditions of TKD athletes should be evaluated periodically at different times. The basic data provided by the present study may help coaches, athletes, and sport scientists to develop a more realistic TKD-specific training program and for sports medicine to prevent or rehabilitate possible health problems in the future. However, the precise physiological mechanisms underlying the inflammatory response to the consecutive full-contact TKD combat warrant further investigations.

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Declarations

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Author contributions

Conceptualization, B.I. and M.F.Y.; Methodology, M.F.Y., E.B, B.I.; Software, B.I, K.E.; Validation, B.I., M.A.K. and S.K..; Formal Analysis, S.K..; Investigation, M.F.Y., B.I., E.B.; Resources, B.I.; Data Curation, B.I., M.F.Y.; Writing – Original Draft Preparation, B.I., M.F.Y., S.K..; Writing – Review & Editing, B.I., M.F.Y., S.K., M.A.K.; Visualization, B.I., S.K., M.F.Y.; Supervision, K.E., E.B.; Project Administration, B.I., M.F.Y.; Funding Acquisition, B.I., M.F.Y., K.E.

Conflicts of interest

No conflict of interest was declared by the authors.

Data availability

The data that support the findings of this study are available from corresponding author, but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. However, data are available from the authors upon reasonable request.

Ethics approval

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 2018/1312. Participants were informed about the study's method and potential risks, and informed consent was obtained.

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