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HEMATOLOGIC RESPONSES FOLLOWING CONCURRENT TAEKWONDO AND RESISTANCE TRAINING

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ABSTRACT

The aim was to investigate the effects of two short-term concurrent taekwondo (TKD) and resistance training (RT) programmes of differing intensity on hematological parameters in TKD athletes. Two experimental groups exercised five times weekly, namely a high-intensity concurrent training group (HiCon; n=14) and moderate-intensity concurrent training group (ModCon; n=14). The ModCon performed TKD training at 55-70% (weeks 1-2) and 70-85% (weeks 3-4) maximum heart rate (HR_{max}) and RT training for four sets of 10-15 repetitions for the 13 whole-body RT exercises. The HiCon performed TKD training at 85-100% (weeks 1-2) and 95-100% (weeks 3-4) HR_{max} and RT training for five sets of 10-15 repetitions for the 13 whole-body RT exercises. At post-test, the male HiCon demonstrated significantly ($p<0.05$) higher levels of red blood cells, haemoglobin and haematocrit, while the male ModCon demonstrated significantly lower monocytes and basophil levels. The female HiCon significantly increased their eosinophils, while the female ModCon significantly increased their haemoglobin and mean corpuscular volume, and decreased their red distribution width levels. This suggests that both high-intensity and moderate-intensity concurrent TKD and RT can improve selected hematological parameters, thus oxygen-carrying capacity and immune function, in even already TKD-trained athletes.

***Keywords*:** Combat sport; Immune system; Neutrophils; Red blood cells; Strength training; Weight Training; White blood cells.

INTRODUCTION

Exercise, in general, has been known to increase circulating haematopoietic stem and progenitor cells, both acutely and after a period of exercise training (Wardyn *et al*., 2008). This suggests that exercise may have a role in physiologic repair and/or compensatory mechanisms, such as the promotion of vascular regeneration and/or angiogenesis (Morici *et al*., 2005). The complete blood count (CBC) is one of the most common laboratory evaluations and provides information about the production of all blood cells. This is in addition to the classification of an individual's oxygen-carrying capacity through the evaluation of red blood cell (RBC) indices, haemoglobin, and haematocrit. It also provides information about the immune system through the evaluation of the white blood cell (WBC) count with differential (George-Gay & Parker, 2003).

The physiologic impact of exercise at various durations and intensities, including measurements of haemoglobin levels, platelet and leukocyte counts, has been previously investigated (Gleeson *et al*., 1995). While physical training itself has no substantial effect on selected hematological variables in athletes compared with untrained individuals, the specific, duration and intensity of exercise is important in the blood cell system adaptations (Schumacher *et al*., 2002; Tayebi *et al*., 2010). Normally, endurance exercise has a beneficial effect on the blood cell system, which includes increased blood oxygenation, blood oxygen carrying capacity and supply of oxygenated blood to the working muscles (Wolin *et al*., 2010) and an increase the number of leukocytes, monocytes, neutrophils, eosinophils and lymphocytes (Faraee, 2000). However, the majority of studies have focused primarily on intense endurance exercise in already endurance-trained and sedentary participants (Czarkowska-Paczek *et al*., 2006). As such, it is unknown whether other exercise modalities, specific sports, concurrent modalities and/or the intensities thereof could also affect hematological profiles in athletes (Wardyn *et al*., 2008).

This is problematic in that anaerobic metabolism may cause reticulocyte release (Larderet *et al*., 2006), increased erythropoietin (EPO) synthesis and increased EPO release during exercise-induced hypoxemia (Zaldivar *et al*., 2006) or when exercise is carried out under hypoxic conditions (Ostrowski *et al*., 1999), such as during anaerobic exercise. Furthermore, the sole use or inclusion of other modes of exercise or sporting codes along with endurance exercise may be warranted not for its hematological-altering properties, but also for the additional benefits to be gained from that modality (Shaw & Shaw, 2005; Shaw *et al*., 2015).

While anaerobic exercise may prove beneficial to the blood cell system, such intense modes of exercise have been found to induce acute exertional rhabdomyolysis (Kargarfard *et al*., 2016). Moreover, intense exercise has a deleterious effect on the immune systems with the functions of Natural Killer cells and B cells being suppressed (Pedersen & Toft, 2000). Consequently, this study was designed to investigate the effects of two intensities of concurrent taekwondo (TKD) and resistance training (RT) on the hematological profile of taekwondo athletes. This is aerobic and anaerobic conditioning along with an ability to produce high muscle forces (Bridge *et al*., 2014; Haddad *et al*., 2014; Shariat *et al*., 2017) and could potentially result in a positive improvement in hematological profiles indicative of an increased oxygen-carrying capacity and enhanced immune response.

PURPOSE OF STUDY

The aim of this study was to investigate the effects of two short-term concurrent TKD and RT programmes of differing intensity on hematological parameters in TKD athletes.

METHODOLOGY

Design and participants

This study is a longitudinal pre-post-test study with two gender-matched and randomised groups. Since physical training itself has no significant effect on selected hematological variables in athletes compared with untrained controls, it is the specific type, duration and intensity of exercise that is critical to the adaptations of the blood cell system (Schumacher *et al.*, 2002), the present study made use of two experimental groups namely, a high-intensity concurrent training group (HiCon) (n = 14) and moderate-intensity concurrent training group (ModCon) (n = 14). A convenient sample of 28 South African male (n = 16) and female (n= 12) TKD athletes aged between 20-26 years volunteered for participation in the present study.

Participants were screened for inclusion and exclusion criteria and all participants were required to be free of any absolute or relative contra-indications to exercise (ACSM, 2010) prior to participation in the study. Eligibility criteria also required that all participants be in good health, with no known diseases, not use medications during the week preceding blood sampling, follow a regular diet, not use dietary supplements, not use steroids or other banned substances. All participants were members of a TKD club and had been training for the past two years or longer.

Ethical considerations

Written informed consent was obtained from the athletes prior to participation and following an explanation of the purpose of the study, measurement procedures and the possible adverse events. This study was approved by the University of Zululand Research Ethics Committee (UZREC171110-030) and South African Taekwondo Federation (SATF), and was conducted in accordance with the principles of the Declaration of Helsinki.

Instruments and procedure

Hematological profile

Red blood cells (RBC), haemoglobin (Hb), haematocrit, mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), mean corpuscular haemoglobin concentration (MCHC), red distribution width (RDW), platelets, leucocytes, neutrophils, lymphocytes, monocytes, eosinophs and basophils were all determined and analysed pre and post-experimentally. Blood samples were obtained by phelbotomists from the antecubital vein, collected into vacutainer tubes, stored at −80 degrees Celsius (˚C) and analysed using commercially available kits (Phoenix Peptides, Karlsruhe, Germany).

Concurrent training programmes

Both groups participated in a five-day weekly four-week training programme that were matched for duration and number of exercises. The *HiCon* participated in a high-intensity concurrent training programme consisting of an one-hour TKD workout that involved both the upper- and lower-body TKD techniques (blocks, punches and kicks) performed in the morning set at an intensity of 85-100% of maximum heart rate (HR_{max}) for weeks 1-2 and 95-100% HR_{max} for weeks 3-4. Target HR ranges were monitored continuously using a HR monitor (Polar Electro, Kempele, Finland) during each session.

The RT exercises were conducted for five sets and 10-15 repetitions each (Hackett *et al*., 2018). The RT portion took place for 30-45min in the afternoon to limit the interference effect (Shaw *et al*., 2015) and consisted of power cleans, push presses, dumbbell raises, power snatches, squats, deadlifts, leg curls, bench press, latissimus dorsi pulldowns, seated row, abdominal crosses, supine 'bicycles' and Spiderman plank crunches (Turner, 2009).

In turn, the *ModCon* participated in a moderate-intensity one-hour TKD workout at a target training intensity of 55-70% HR_{max} for Week 1 and 2 and 70-85% HR_{max} for Weeks 3 and 4. The RT portion of the ModCon utilised the same exercises as that of the experimental group but were conducted for four sets and 10-15 repetitions each (Hackett *et al*., 2018).

The sessions of both programmes began with a five-minute warm-up that entailed jogging, shuttle runs, cone drills and five minutes of dynamic whole-body stretching and concluded with a five-minute cool-down entailing jogging and soft kicks and five-minutes of whole-body static stretching exercises (Murphy *et al*., 2010).

Data analysis

Data are presented as mean±standard deviation (SD) and percentages. To control for the effect of gender (gender-based hormones), the groups were further delineated in males and females. The normality of the distribution of the data for each group and variable studied (including pre- and post-test [prepost] differences) was evaluated by the Shapiro-Wilk test and equal variance was determined by Levene's test. Differences in prepost evolution for each group and variable were examined using Student's t-test for paired samples. The error probability of p<0.05 and was considered significant. Statistical analyses were performed using the SPSS for Windows software (version 20.0, SPSS Inc., Chicago, IL, USA).

RESULTS

The data of the hematological parameters, such as RBC, Hb, haematocrit, MCV, MCH, MCHC, RDW, platelets, leucocyte, neutrophil, lymphocyte, monocyte, eosinophil and basophil, measured before and after the experimental period are shown in Table 1 and 2. The values of these hematological parameters were normal and within the acceptable clinical ranges for the conditions under which they were collected.

In order to control for the effect of gender, the groups were further delineated in males and females. In this regard, at baseline, data were normally distributed with no significant (p>0.05) differences observed in RBC (p=0.156), haemoglobin (p=0.167), haematocrit (p=0.719), MCH (p=0.232), RCW (p=0.221), leucocytes (p=0.100), lymphocytes (p=0.074), neutrophils (p=0.116), and basophils (p=0.107), between the male HiCon and ModCon participants. However, the ModCon exhibited a lower monocyte (p=0.189) and higher platelet level (p=0.218) at pre-test. After the training period, the HiCon demonstrated significantly higher levels of RBC (p=0.047), haemoglobin (p=0.041) and haematocrit (p=0.036). Conversely, the ModCon demonstrated significantly lower monocytes (p=0.025) and basophil (p=0.014) levels following their respective training period.

***Table 1*. HEMATOLOGICAL PARAMETER RESPONSES TO CONCURRENT TAEKWONDO AND RESISTANCE TRAINING IN MALE TAEKWONDO ATHLETES**

	High-intensity concurrent training group (HiCon) (n=8)		**Moderate-intensity concurrent training group (ModCon)** (n=8)	
Parameters	**Pre-test**	**Post-test**	**Pre-test**	**Post-test**
RBC (L/L)	4.0±0.3	5.0±0.4[a]	5.1±0.1	4.9±0.2
Haemoglobin (g/dL)	14.4±0.7	15.5±0.5[a]	14.0±0.7	14.8±0.9
Haematocrit (L/L)	0.4±0.0	0.5±0.0[a]	0.4±0.0	0.4±0.0
MCV (fl)	76.2±5.2	81.9±4.3	80.3±6.6	81.8±6.6
MCH (pg)	26.8±2.4	26.7±2.8	28.5±2.7[b]	28.4±2.8[b]
MCHC (g/dL)	34.2±1.0	34.2±1.0	34.5±0.9	34.7±0.8
RDW (%)	14.1±1.9	13.5±1.4	12.5±0.5	12.2±0.6
Platelets (G/L)	352±37.8	331.4±37.8	215.4±37.3[b]	214.1±46.9[b]
Leucocytes (G/L)	6.5±2.1	6.0±1.8	5.5±1.8	5.1±1.5
Neutrophils (%)	2.9±1.6	2.5±1.5	2.5±1.1	2.9±1.3
Lymphocytes (%)	1.8±0.9	1.8±0.6	2.0±0.2	2.4±0.4
Monocytes (%)	0.5±0.2	0.5±0.7	1.5±2.7[b]	0.4±0.1[a]
Eosinophils (%)	0.6±0.7	0.6±0.7	0.3±0.3	0.3±0.3
Basophils (%)	0.03±0.01	0.02±0.01	0.02±0.00	0.01±0.00[a,b]

Data are presented as mean±SD. RBC=Red Blood Cells; L/L=Litre per Litres; g/dL=grams per decilitre; MC=Mean Cellular volume; fl=femtolitre; MCH=Mean Cellular Haemoglobin; pg=picograms; MCHC=Mean Cellular Haemoglobin Concentrate; RDW: Red Distribution Width; G/L=Grams per Litre; [a]($p<0.05$)=Statistically significant change between pre- & post-training; [b]($p<0.05$)=Statistically significant difference between HiCon and ModCon.

Regarding the findings of the female participants, the female HiCon and ModCon participants were found to be homogenous for all their hematological parameters at pre- and post-test. Following their high-intensity training period, the HiCon were found to have significantly increased their eosinophils (p=0.034). In turn, the ModCon were found to have significantly increased their hemoglobin (p=0.043) and MCV (p=0.021), and decreased their RDW levels (p=0.036) following their moderate-intensity training period.

***Table 2*. HEMATOLOGICAL PARAMETER RESPONSES TO CONCURRENT TAEKWONDO AND RESISTANCE TRAINING IN FEMALE TAEKWONDO ATHLETES**

Parameters	High-intensity concurrent training group (HiCon) (n=6)		Moderate-intensity concurrent training group (ModCon) (n=6)	
	Pre-test	**Post-test**	**Pre-test**	**Post-test**
RBC (L/L)	4.1±0.1	4.9±0.3	4.3±0.2	4.3±0.8
Haemoglobin (g/dL)	11.8±0.5	12.0±0.9	11.45±1.7	12.2±1.3[a]
Haematocrit (L/L)	0.3±0.0	0.4±0.0	0.3±0.0	0.4±0.0
MCV (fl)	85.9±3.8	86.9±3.6	79.3±5.2	83.3±4.1[a]
MCH (pg)	28.9±1.5	29.2±1.6	26.8±2.7	28.4±1.7
MCHC (g/dL)	28.6±0.3	33.5±0.7	33.8±1.3	34.2±1.0
RDW (%)	12.9±0.7	13.7±0.7	14.1±1.9	13.4±1.4[a]
Platelets (G/L)	277.3±56.5	282.5±60.2	353.0±46.6	331.4±37.9
Leucocytes (G/L)	4.5±1.3	5.6±1.6	6.5±2.1	6.0±1.8
Neutrophils (%)	2.1±0.6	2.6±1.4	2.9±1.6	2.5±1.3
Lymphocytes (%)	2.5±0.2	2.4±0.4	2.1±0.8	1.9±0.6
Monocytes (%)	0.4±0.2	0.5±0.2	0.4±0.1	0.4±0.1
Eosinophils (%)	0.2±0.2	0.3±0.0[a]	0.6±0.7	0.6±0.6
Basophils (%)	0.02±0.0	0.02±0.0	0.03±0.0	0.02±0.03

Data are presented as mean±SD. RBC=Red Blood Cells; L/L=Litre per Litres; g/dL=grams per decilitre; MC=Mean Cellular volume; fl=femtolitres; MCH=Mean Cellular Haemoglobin; pg=picograms; MCHC=Mean Cellular Haemoglobin Concentrate; RDW: Red Distribution Width; G/L=Grams per Litre; [a](p<0.05)=Statistically significant change between pre- & post-training; [b](p<0.05)=Statistically significant difference between HiCon and ModCon.

DISCUSSION

During training and competition, athletes are periodically monitored by using biochemical and hematological indices for evaluating possible pathologies and performance status (Dolci *et al*., 2007; Lombardi *et al*., 2013a). However, such information is scarce (Lombardi *et al*., 2013a), especially with regard to specific sports. When such information is forthcoming, the influence of physical activity on the levels of many routinely measured hematological variables seem to be ambiguous (Nikolaidis *et al*., 2003). This statement by Nikolaidis *et al*. (2003) is echoed by the present study.

The present finding that high-intensity training, but not moderate-intensity, yielded improvements in the oxygen-carrying capacity of the male participants as demonstrated by improvements in RBC, haemoglobin and haematocrit, which are to be expected as the effects of long-term endurance training on RBC indices are well documented (Szygula, 1990). What is novel is the finding that the high-intensity training failed to elicit those same changes in the female participants following their high-intensity training. While the present study and its chronic hematological profile adaptation findings could be considered unique, previous research has demonstrated that a single session of concurrent anaerobic (running based anaerobic test: RAST) and aerobic exercise (running one mile) did not alter RBC, haemoglobin, and haematocrit in the same sample (Azarbayjani *et al*., 2014).

However, the female participants participating in the moderate-intensity training were found to have significantly increased their hemoglobin and MCV, and decreased their RDW levels following their training period. The six-month study of Bobeuf *et al*. (2009) demonstrated that an RT programme using three sets of eight repetitions at 80% one-repetition maximum (1-RM) also had no effect on hematological blood parameters (RBC, haemoglobin, haematocrit, mean corpuscular volume, mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration or RDW) in older individuals. In the light of these findings, it appears that RT alone does not improve the ‘oxygen-carrying capacity’ hematological blood parameters.

While the male participants performing the high-intensity training found no changes in their immune system function, the moderate-intensity training resulted in deleterious decreases in monocyte and basophil levels. An important finding is the increase in basophils in the female participants participating in the high-intensity training. The current findings are of particular interest in that it is generally thought that while moderate-intensity exercise exerts a protective effect, strenuous exercise results in immune dysfunction. The lack of findings in the immune system blood cells in this population of TKD trained athletes may be explained by previous research demonstrating an already increased number of lymphocytes and monocytes, but not granulocytes and leukocytes, in comparison to non–athletes (Dolci *et al*., 2007).

Similarly, Bobeuf *et al*. (2009) demonstrated that a six-month RT programme at 80% 1-RM had no effect on haematological blood parameters (platelets, leukocytes, neutrophils, lymphocytes or monocytes) in older individuals. The findings are consistent with those found in literature that exercise has a variable effect on the immune system due to a multitude of underlying reasons (neuroendocrine, metabolic and environmental factors, and nutritional status of the athlete (Brolinson & Elliott, 2007)).

While the sample size may be considered relatively low, this is due the fact that only a small number of participants met the inclusion criteria. However, the data was normally distributed. The measurement and understanding of the physiological changes in the hematological profile related to physical training, allows for the discernment of variations induced by different training practices and even from those not associated with exercise but rather illicit and/or banned substances (Lombardi *et al*., 2013b). Regarding clinical significance, the treatments in the present study effectively resulted in the participants’ values being stimulated to within normal range for those variables that were found to be significantly improved.

The findings of the present study are novel in their contribution to add new information about the physiological response arising from concurrent TKD and RT. This knowledge could be utilised to contribute to the current knowledge of sports physiology and doping biomarkers in the Athlete Biological Passport (ABP) programme. The ABP is an algorithm which tracks the longitudinal record of hematological parameters as a means to define an individual’s hematological profile and thereby identify potential deviations (Sottas *et al*., 2011).

In addition, understanding the relationship between exercise programme design and hematological parameters has important potential implications not only for clinicians caring for athletes and athletic teams, but also for public health. This is so since given the possible benefits of regular exercise, and specifically TKD and RT, on hematological parameters as found in the present study, which may provide alternative exercise programme design options that allow practitioners to prescribe such modes of regular exercise to not only otherwise healthy older adults, but possibly those diseases and/or conditions that require the offset of diminished adaptive responses and chronic inflammation.

CONCLUSION

In conclusion, the present study indicates that both moderate- and high-intensity concurrent TKD and RT have beneficial effects on selected hematological factors related to oxygen-carrying capacity. However, what is ambiguous is the effect that concurrent TKD and RT has on the immune system, with both moderate- and high-intensity TKD and RT providing mixed results. Further research is needed on the role of intermittent sports/activities, such as TKD and combat sports in general, on hematological parameters given their recent rise in popularity (Shariat *et al*., 2017). This would allow for the optimal exercise programme design for athletes and patient care.

Disclosure statement

No potential conflict of interest was reported by the authors.

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