ORIGINAL ARTICLE

Pro-inflammatory effect induced by regular wrestling training in women

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

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Received: 31 July 2021; **Accepted:** 23 August 2021; **Published online:** 31 August 2021

AoBID: 14558

Abstract

Background and Study Aim: Athletes are subjected to intense training to increase their performance and bring them closer to winning the competition. High intensity and time of physical exertion, combined with insufficient time for rest, may contribute to local and systemic inflammations. Thus, the purpose of this study was knowledge about the relationship between 17-week variable intensity and time of training and the concentrations of inflammatory markers.

Material and Methods: The study involved 12 women training wrestling (S) and 14 women not practicing sports (NT). Blood was collected five times during a 17-week training with variable time and intensity. The counts of white blood cells and the concentration of interleukin-1β (IL-1β), interleukin-6 (IL-6), tumor necrosis factor-α (TNF-α), C-reactive protein (CRP) and creatine kinase activity (CK) were carried out.

Results: A significant relationship between the number of monocytes and the date of the study ($p<0.001$). A significantly higher concentrations of IL-1β and IL-6 were found in the S group compared to the NT group at all study dates ($p<0.001$).

Conclusions: In contrary to expectations, apart from the number of monocytes, no correlation was found between the volume and intensity of exercise and the examined markers of inflammation. At the same time, constantly elevated basal levels of IL-1 β and IL-6 suggest a pro-inflammatory effect of exercise. It is recommended to observe the concentration of these cytokines and modify the training plan, extend the time spent on rest to allow to regain their immune balance.

Key words: blood cells • C-reactive protein • inflammation • interleukin-1 beta • interleukin-6 • tumor necrosis factor alpha

Conflict of interest: Authors have declared that no competing interest exists

Ethical approval: The study was approved by the local Ethics Committee

Provenance & peer review: Not commissioned; externally peer-reviewed

Source of support: This study was supported by grant RSA1000451 (PB 75) from the Polish Ministry of Science and Higher Education

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INTRODUCTION

For many years, attempts have been made to identify the role, cause, effects and prevention of inflammation. Inflammation is a defensive reaction in the body that can be triggered by a variety of factors including pathogens, toxins, and tissue damage [1]. It is a coordinated reaction that causes a series of changes taking place in the body, which is an expression of a specific, targeted biochemical, immune and hematological response both at the local and systemic level. It should be remembered that an acute immune system response is beneficial and, at the same time, usually transient, removing harmful changes and initiating healing processes [2]. However, persistent inflammation is associated with tissue dysfunction and pathology [3]. Increased levels of pro-inflammatory cytokines lead to chronic inflammation and are also associated with numerous diseases [1, 4-9] and can lead to muscle wasting [10] which is especially important for athletes.

Athletes are subjected to intense, strenuous and regular training to increase their performance and bring them closer to winning the competition. High intensity and time of physical exertion as well as stress related to participation in competitions, combined with insufficient time for rest, may contribute to muscle damage, local and systemic inflammations [11]. In response to exercise, a number of changes occur in the body. The initial cytokine cascade of TNF-α, IL-1β, IL-6 is reflected in the concentration of CRP [12] and changes in the count of white blood cells. In response to an injury or infection, TNF-α is produced by numerous cells, but its main sources are macrophages, T cells, as well as B cells, neutrophils and endothelial cells [13]. It is an early mediator of inflammation and the main regulator of the production of pro-inflammatory cytokines [14, 13, 15]. It is involved in the expansion of blood vessels and the formation of edema and adhesion of leukocytes to the epithelium [13]. It regulates blood clotting in response to injury [15] and indirectly causes fever by increasing the concentration of IL-1β. Interleukin-1β is mainly produced by hematopoietic cells [16]. It has a wide range of biological functions. It is one of the main regulators of inflammation by controlling innate immune processes [17]. It takes part in vasodilation, attracting monocytes and neutrophils to the sites of damage [18]. It has been linked to pain sensation as well as autoimmune conditions [19]. It is produced in response to various stimuli, including cytokines such as TNF-α and IL-1β itself, further affecting the concentration of IL-6. Interleukin 6 is one of the most studied cytokines. In addition to immune cells, a variety of other cells are also produced by IL-6 [20]. During physical activity, it is largely synthesized and released by contracting muscles [21]. IL-6 is a mediator that exerts a pleiotropic effect on inflammation, haemapoiesis and immune response, and is a warning signal in the event of tissue damage [20]. It can inhibit the action of pro-inflammatory cytokines such as TNF-α [22]. It contributes to the host's defense by stimulating the acute phase response, inter alia, influencing the concentration of CRP [20]. The serum concentration of C-reactive protein increases rapidly in response to inflammation. It is mainly produced in hepatocytes but also by other cells such as smooth muscle, adipocytes, lymphocytes and macrophages. It should be emphasized that it is an important inflammatory regulator and not only an inflammatory marker. It is involved in the activation of complement, apoptosis, phagocytosis and cytokine production [23]. Inflammation is a network of interdependencies between numerous indicator. The changes that are observed after exercise may be maintained and, consequently, contribute to the emergence of disorders of immune homeostasis or be short-term beneficial for human health.

In the search for natural methods to reduce inflammation, researchers are focusing on physical activity. Movement is widely believed to improve the inflammatory profile [12, 24], reduces the risk of infectious and non-infectious development inflammation, and also promotes neuroprotection. Regular training, at all ages, improves immunosurveillance and immunocompetence [11] and also reduces the risk of death and protects against cancer [25, 26]. However, it should be emphasized that regular physical activity with too much intensity or too long time may have the opposite effect. It is important to control the concentration of immunological markers during long-term observation and to determine whether physical activity does not leave permanent changes in the immune system. Training that does not take into account adequate time to rest contributes to chronic inflammation, and which is especially important for competitive athletes, it causes reduced adaptation to physical exertion [27] or leading to muscle dysfunction [10].

Interleukin 1 beta (IL-1 beta, IL-β) – it is one of the pro-inflammatory cytokines, produced by monocytes, macrophages and dendritic cells. It is one of the major regulators of inflammation [17, 40, 39]. Takes part in vasodilation, attracting monocytes and neutrophils to the sites of damage [18]. It is produced in response to various stimuli, including cytokines such as TNF-α and IL-1β itself, further affecting the concentration of IL-6.

Interleukin 6 (IL-6) – is one of the most studied cytokines. In addition to immune cells, a variety of other cells are also produced by IL-6 [20]. During physical activity, it is largely synthesized and released by contracting muscles [21]. IL-6 is a mediator that exerts a pleiotropic effect on inflammation, haemapoiesis and immune response, and is a warning signal in the event of tissue damage [20]. It can inhibit the action of pro-inflammatory cytokines such as TNF-α [22].

Inflammation – is a defensive reaction in the body that can be triggered by a variety of factors including pathogens, toxins, and tissue damage [1]. It is a coordinated reaction that causes a series of changes taking place in the body, which is an expression of a specific, targeted biochemical, immune and hematological response both at the local and systemic level. Inflammation is a network of interdependencies between numerous biomarkers.

C-reactive protein (CRP) – is an acute-phase protein synthesized by hepatocytes. It is involved in the activation of complement, apoptosis, phagocytosis and cytokine production [23].

Tumor necrosis factor alpha (TNF-alpha, TNF-α) – it is a serum glycoprotein produced by activated macrophages and other mononuclear leukocytes. It is an early mediator of inflammation and the main regulator of the production of pro-inflammatory cytokines [13-15].

White blood cells (WBC) – total number of all types of white blood cells present in the blood sample. It is an important indicator of pathological conditions.

Recently, the area of immunological and inflammation markers has been the subject of numerous discussions. Unfortunately, most of the work focuses on a single, short-term effort such as a test, training unit or competition. Currently, it is necessary to focus on changes that remain during longer observation and determine whether the applied training caused beneficial changes or whether it contributed to the imbalance of the immune system. Additionally, there is conflicting information on the role of inflammation in adaptation to exercise, so regular monitoring of key indicators of inflammation is important.

With this in mind, the aim of this study was knowledge about the relationship between 17-week variable intensity and time of training and the concentrations of inflammatory markers.

MATERIAL AND METHODS

Participants

The study involved 12 women practicing wrestling (S) who belonged to the academic sports association and represented the national team. The reference group consisted of 14 non-competitive women (NT) of the similar age to the group of athletes. The athletes participated 5 times in the measurements carried out in different periods of the training cycle. The study dates were analogous to the reference group. All participants were healthy and nonsmokers.

The participants of the study had their height and weight measured with an accuracy of 0.1 cm and 0.1 kg, and then the body mass index (BMI) was calculated. The percentage of body fat was estimated by measuring the thickness of the skinfold in four places – biceps, triceps, subscapular and suprailiac, according to Durnin and Womersley [28]. The thickness of the skinfolds was measured to an accuracy of 0.2 mm using a Harpenden Skinfold Caliper. Measurements were taken in standing position on the left side of the body, three times and the mean results were used for further analysis. The method of anthropometric calculation was according to previous studies [29]. The physical characteristics of the participants are shown in Table 1.

All participants gave their written and voluntary consent to participate in the research. They were informed about the purpose and course as well as about the exclusion procedure. People who did not report to the study at whatever any time were excluded from further stages of the work, and the previously collected biological material was also not taken into account. The study was approved by the local Ethics Committee according to the Declaration of Helsinki (SKE 21/2011).

Training protocol

The study took place in the winter/spring season. Blood was taken at five time points from both group in the similar time. The athletes trained five times per week. Blood was collected for the first time from participants in the study at the beginning of the preparatory period (1). During this period, training mainly involved aerobic exercise to develop overall endurance and improve tactical and technical skills. This part of the training cycle was dominated by high time exercise at moderate intensity. Then blood was collected after 6 weeks – after the end of the preparatory period. This time point was also the beginning of the starting period (2). During this period, special emphasis was placed on the individualization of technical and tactical training, as well as general training. The trainings were characterized by high intensity and shorter duration. Increasing the intensity was also achieved by participating in tournaments. After 6 weeks of the start-up period biological material for research was collected again (3). After the end of the competition period, the competitors had a week of active rest during which the athletes undertook physical activities not related to their discipline. Two consecutive blood collections were performed at the beginning (4) and after the end of the 4-week transition period (5). At that time, the athletes had general development training of relatively low intensity.

Blood acquisition and cytokine, CRP and CK measurement

The biological material for the research was collected at five dates of the training cycle, in the morning (between 7.00 am and 8.30 am) from the elbow vein. All participants of the study did not participate in sports activities 12 hours before blood sampling and they were overnight fasting.

Hematological indicators were calculated in whole blood collected in EDTA-containing tubes. ABX PENTRA 60 5DIFF hematology analyzer (Horiba, France) was used to determine the number of white blood cells, neutrophils, lymphocytes, monocytes, eosinophils and basophils. All hematology determinations were performed on the same day the biological material was collected.

Serum was used to determine the measurements of cytokine concentration, hsCRP and creatine kinase activity. To obtain the serum, blood was collected in tubes containing no anticoagulant. Until a clot formed, blood samples were incubated at room temperature. The blood samples were then centrifuged for 15 minutes at 3000 rpm. The obtained supernatant was transferred to plastic Eppendorf tubes, and then the serum was frozen until the tests were carried out at −70°C.

Serum TNF-α, IL-1β, IL-6 and hsCRP concentrations were measured using standard DIASource ELISA kits (Belgium, for TNF-α - KAP1751, IL-1β - KAP1211, IL-6 - KAP1261, hsCRP - KAPDB 4360) according to the manufacturer's instructions. All tests were run twice, and mean results were used for further analysis. The sensitivity of the ELISA kit was 0.7pg ml, 0.35pg/ml, 2.0pg/ml, 10.0ng/ml for TNF-α, IL-1β, IL-6 and hsCRP, respectively. CK activity was examined using a standard kinetic method. Determinations were made in accordance with the enclosed instruction of the manufacturer Alpha Diagnostics (Poland, C6412-060) and the sensitivity of the test was 1.0U/l.

Statistics analysis

Differences in several subgroups were checked by ANOVA, Welsch ANOVA, or Kruskal-Wallis test. The choice of the test depended on the results of the Shapiro-Francia normality test and Levene's test for equality of variance. If there was a significant difference in the subgroups, revised appropriate post-hoc tests: Tuckey HSD or paired Wilcoxon tests with Benjamini-Hochberg were used. However, the differences in the two subgroups were checked with the Student's t-test (with/or without Welch's correction) or the Wilcoxon test. The choice of the test depended on the results of the Shapiro-Francia normality test and the F test for equality of variance. All calculations were performed in R version 3.6.3. The cut-off level for all tests was set at $p<0.05$.

RESULTS

There were no significant differences in the age of the subjects, body height and weight, as well as BMI and the percentage of body fat between the analyzed groups. There was no difference in the analyzed variables across time periods (Table 1).

Table 1. General characteristic group female wrestlers (S) and non-training group (NT). The values presented in the table are mean and SD.

Variable	Time point	S (n = 12)	NT (n = 14)
Age [years]		20.67 ±2.06	20.07 ±1.00
Height [cm]		165.67 ±7.19	170.64 ±5.21
Body weight [kg]	1	58.67 ±8.75	60.21 ±3.60
	2	57.71 ±9.00	60.20 ±3.38
	3	57.43 ±8.82	60.49 ±3.83
	4	58.57 ±8.38	60.37 ±3.90
	5	57.27 ±8.57	60.43 ±3.47
BMI	1	21.32 ±2.24	20.72 ±1.55
	2	20.96 ±2.28	20.71 ±1.48
	3	20.86 ±2.18	20.81 ±1.65
	4	21.29 ±2.21	20.77 ±1.65
	5	20.81 ±2.22	20.79 ±1.49
Percent of body fat [%]	1	22.00 ±3.40	23.44 ±2.47
	2	19.26 ±2.19	24.13 ±3.00
	3	21.08 ±4.19	24.58 ±3.08
	4	22.10 ±3.40	23.36 ±2.60
	5	19.28 ±2.14	24.13 ±3.00
Training hours [h/week]		18	8
Training experience [year]		9.48 ±2.44	-

The study showed no differences in the number of WBC, neutrophils, eosinophils and basophils between the analyzed groups and study dates. There was a significantly higher number of lymphocytes in the S group compared to the NT group at time 3 (W = 45, p = 0.047). At the same time, significantly higher values of lymphocytes at time 5 were shown in the S group compared to the NT group (t = −2.09, df = 24, p = 0.047). The study showed a higher number of monocytes in the S group at time 3 (W = 42, p = 0.03), 4 (W = 40, p = 0.021) and 5 (W = 14, p<0.001) compared to the NT group. After the Kruskal-Wallis test was performed, a significant relationship was shown between the number of monocytes and the date of the tests ($\chi 2$ = 26.6,

Table 2. Amount of white blood cells (WBC), lymphocytes (LYM), monocytes (MON), neutrophils (NEU), eosinophils (EOS), basophils (BAS) in the group of wrestlers (S) and non-training group (NT). The values presented in the table are mean and SD.

Indicator	Time point	S (n = 12)	NT (n = 14)
WBC [thous/µl]	1	5.923 ±0.44	6.056 ±1.07
	2	5.998 ±0.55	5.836 ±1.07
	3	6.517 ±1.11	6.123 ±1.17
	4	6.328 ±0.86	5.907 ±1.08
	5	6.261 ±0.86	5.999 ±1.07
LYM [thous/µl]	1	2.151 ±0.47	2.241 ±0.54
	2	2.187 ±0.44	2.257 ±0.54
	3	2.830 ±0.73*	2.279 ±0.53
	4	2.603 ±0.65	2.200 ±0.45
	5	2.648 ±0.38*	2.250 ±0.55
MONO [thous/µl]	1	0.396 ±0.10	0.412 ±0.13
	2	0.385 ±0.13	0.415 ±0.15
	3	0.533 ±0.10*†	0.431 ±0.11
	4	0.583 ±0.25*†	0.428 ±0.18
	5	0.638 ±0.08*†‡	0.422 ±0.11
NEU [thous/µl]	1	2.684 ±0.68	3.099 ±0.78
	2	2.832 ±0.67	2.924 ±1.02
	3	2.710 ±0.82	3.348 ±1.13
	4	2.893 ±0.32	3.031 ±1.05
	5	2.693 ±0.49	3.404 ±1.17
EOS [thous/µl]	1	0.243 ±0.24	0.213 ±0.20
	2	0.288 ±0.34	0.209 ±0.11
	3	0.315 ±0.23	0.219 ±0.16
	4	0.348 ±0.34	0.216 ±0.10
	5	0.328 ±0.16	0.218 ±0.14
BASO [thous/µl]	1	0.0358 ±0.012	0.0336 ±0.017
	2	0.0367 ±0.013	0.0343 ±0.009
	3	0.0433 ±0.018	0.0329 ±0.014
	4	0.0450 ±0.018	0.0350 ±0.008
	5	0.0425 ±0.015	0.0336 ±0.013

*significantly higher compared to NT group (p<0.05); † significantly higher compared to terms 1 and 2 in the S group (p<0.05); ‡ significantly higher compared to terms 3 and 4 in the S group (p<0.05)

df = 4, p<0.001). Statistically significant higher values in the S group compared to the first term were found at dates 3 (p = 0.011), 4 (p = 0.049) and 5 (p<0.001). Compared to the second term, the number of monocytes at term 3 (p = 0.025), 4 (p = 0.042) and 5 (p = 0.001) were significantly higher in group S. At the same time, it was found that the number of monocytes in group S at term 5 was higher on values within 3 (p = 0.025) and 4 (p = 0.04). There were no differences between the dates of the tests and the number of monocytes in the NT group (Table 2).

Statistically significantly higher values of IL-1β were found in the group subjected to regular training compared to the group not involved in competitive sports in the following period: 1 (W = 0, p<0.001), 2 (t = −11, df = 24, p<0.001), 3 (t = −9.24, df = 24, p<0.001), 4 (t = −8.49, df = 24, p<0.001) and 5 (t = −9.67, df = 24, p<0.001). At the same time, no differences in the concentration of IL-1β were found between the analyzed test dates in both groups. The study showed a higher concentration of IL-6 in the S group compared to the NT group in: 1 (t = −12.9, df = 19.72, p<0.001), 2 (t = 16.6, df = 24, p<0.001) , 3 (t = −12.7, df = 24, p<0.001), 4 (W = 0, p<0.001) and 5 (t = −17, df = 24, p<0.001). There were no differences in the concentration of IL-6 between the individual time points in both groups. After statistical analysis, significantly lower TNF-α values were found in the S group compared to the NT group at time 1 (t = 2.26, df = 18.31, p = 0.036), 2 (t = 2.24, df = 24, p = 0.034) and 4 (t = 2.71, df = 24, p = 0.012). There were no differences in the concentration of this indicator between the examined dates in both groups. After analyzing the results of CRP concentration, no significant differences were found in the concentration of C-reactive protein between the studied groups and study dates. The study showed significantly higher CK values in the group training wrestling compared to the reference group at time 1 (W = 35.5, p = 0.013), 3 (t = −3.82, df = 16, p = 0.001), 4 (t = −2.6, df = 15.52, p = 0.02) and 5 (t = −5.4, df = 24, p<0.001). There were no differences in creatine kinase activity depending on the date of the study (Table 3).

DISCUSSION

The impact of physical activity on human health is known. It induces positive changes in the musculoskeletal, circulatory systems [30, 11] and leads to adaptive changes in aerobic and respiratory indicator [31]. It affects sleep, pain relief, cognition and even intelligence [30, 11]. Physical activity has health benefits and is recognized as one of the most accessible tools to prevent many diseases or neutralize their negative effects [25, 32, 11, 33]. Recently, researchers have focused on observing and neutralizing inflammations that can cause many diseases. The role of physical activity is often emphasized as an element that contributes to the reduction of the concentrations of inflammation mediators, having an anti-inflammatory effect on the human body [12]. However, in order for physical effort to fulfill a protective role, it should be carried out in a proper way, taking into account the time to rest and selecting the correct loads.

It is believed that the immune system's response to exercise is dependent on the time (repetitions, rhythm, smooth movement etc.) and intensity of training, but also on the type of exercise performed. An increase in the concentration of cytokines and the number of WBC is observed mainly in response to intense exercise [34]. Additionally, it was found that the maximum concentration of CRP is usually noticed 24 hours after the end of training [35, 34]. Contrary to popular opinions, this study found that athletes subjected to regular training of varying time and intensity have consistently elevated resting levels of IL-1 β and IL-6, regardless of exercise load. Only the number of monocytes depended on the time and intensity of exercise and increased in response to vigorous exercise of less shorter time (fewer repetitions etc.). These values increased even in the periods of reduced load. Possibly, this condition persisted in response to skeletal muscle injury during the starting period as reflected in CK activity. Damaged skeletal muscles are known to recruit monocytes exhibiting inflammatory profiles. Then these cells are transformed into anti-inflammatory macrophages. Consequently, this process stimulates myogenesis and has a positive effect on the growth of muscle fibers [36]. However, it seems that monocyte values should fall again during active rest. Probably the time devoted to regeneration was too short, which made it impossible to fully return to the initial state.

In athletes, a very important aspect is the adaptation of muscles to physical exertion. Inflammatory responses are now believed to be integral to muscle growth, repair and regeneration [37]. Nevertheless Chen et al [27] after examining elite taekwondo athletes, they showed that a slightly higher initial systemic inflammation may interfere with adaptation to exercise training. The role

Table 3. Differences in interleukin 1β (IL-1β), interleukin 6 (IL-6), tumor necrosis factor-α (TNF-α), high sensitivity C-reactive protein (CRP) concentration and creatine kinase activity (CK) between wrestlers (S) and non-training group (NT).

Indicator	Time point	S (n = 12)	NT (n = 14)
IL-1β [pg/ml]	1	11.34 ±2.05*	4.92 ±1.71
	2	11.77 ±1.56*	4.67 ±1.69
	3	12.33 ±2.54*	4.79 ±1.57
	4	11.35 ±2.32*	4.88 ±1.54
	5	12.11 ±1.91*	5.05 ±1.81
IL-6 [pg/ml]	1	16.30 ±1.25*	6.50 ±2.49
	2	16.77 ±1.23*	6.78 ±1.74
	3	16.38 ±1.56*	6.94 ±2.12
	4	16.58 ±1.56*	6.96 ±1.67
	5	16.05 ±1.22*	6.79 ±1.51
TNF-α [pg/ml]	1	4.42 ±0.76†	5.58 ±1.74
	2	4.41 ±1.09†	5.42 ±1.20
	3	4.00 ±0.98	5.39 ±1.83
	4	4.35 ±1.10†	5.84 ±1.60
	5	4.60 ±1.17	5.88 ±1.64
CRP [mg/l]	1	0.89 ±0.51	0.95 ±0.45
	2	0.94 ±0.56	1.01 ±0.69
	3	1.01 ±0.55	1.01 ±0.55
	4	1.12 ±0.68	0.81 ±0.34
	5	0.95 ±0.76	0.85 ±0.19
CK [U/l]	1	85.00 ±34.32‡	54.50 ±38.87
	2	80.75 ±32.36	57.93 ±29.21
	3	93.92 ±28.65‡	58.79 ±14.95
	4	84.67 ±35.99‡	55.00 ±17.80
	5	83.58 ±14.53‡	57.57 ±9.93

*significantly higher compared to NT group ($p<0.001$); † significantly lower compared to N group ($p<0.001$); ‡ significantly higher compared to N group ($p<0.02$)

of IL-1β and IL-6 should also be looked at here, as sustained high values of these cytokines were noted throughout the study period. Interleukin-1β is a pleiotropic cytokine and a powerful inflammatory regulator and plays a key role in inflammatory and autoimmune diseases [19, 38]. It causes a number of various reactions in the body e.g. activates the immune system and fever [39]. It is essential in the body's response to an infection. At the same time, it increases damage during chronic diseases and acute tissue damage [40]. It takes part in causing pain at the peripheral and central level, but also in its maintenance [19]. Its role is widely discussed as one of the elements involved in muscle regeneration [37]. However, at the same time it has been shown that overproduction of IL-1β contributes to muscle wasting in chronic diseases [41]. A higher concentration of IL-1β can be maintained by the synergistic effect of IL-6 produced in response to physical activity [40]. IL-6 is produced by contracting muscles and plays an important role in energy homeostasis. In response to physical exercise, it takes part in the mobilization of glycogen and fat oxidation, and also regulates the level of glucose [12, 21]. Contrary to the initial assumptions, the concentration of IL-6 does not depend on the degree of muscle damage [22] observed in the activity of CK considered as an indirect marker for the damage price [42]. It is known that IL-6 contributes to the adaptation of muscle tissue to exercise, its regeneration and promotes the activation of satellite cells [43].

However, it has been proven that high levels of IL-6 cause muscle wasting [44, 43. 10], and they can contribute to inhibition of regeneration [45]. Consequently, it reduces muscle strength, function and increases pain [46]. For athletes, muscle regeneration and adaptation to multiplied efforts is key, and dysregulation of inflammation can disrupt ordinary muscle regeneration [47], may result in the forced interruption of training and, as a consequence, deterioration of the obtained results.

It is worth paying attention to the fact that in the study increased levels of IL-6 and IL-1β were observed, but at the same time low levels of TNF-α. TNF-α is a pro-inflammatory factor, the concentration of which increases significantly immediately after injury [48]. Additionally, its role as a physiological regulator of muscle regeneration is also emphasized. It causes the activation of satellite cells, which results in entering the cell cycle, and also accelerates the transition from the G1 to S phase [49]. High concentrations of TNF-α may negatively affect myogenic progression [45]. It is worth emphasizing that the concentration of TNF-α in terms characterized by a relatively low training intensity was lower in the sports group compared to the reference group, suggesting an anti-inflammatory effect of training. There is evidence that IL-6 is involved in the reciprocal maintenance of TNF-α by its anti-inflammatory action [50, 12] which could have contributed to the situation.

Contrary to the publications reporting on the anti-inflammatory effect of exercise, a slightly different effect is presented here. Although the levels of CRP and TNF-α did not increase, consistently higher concentrations of IL-1β and IL-6 were recorded. It is not known what effects will increase the concentration of these indicators in the athletes. We do not know whether they will contribute to muscle damage in the long run, cause disturbances in the immune balance or they will return to basic values in the next training cycles.

It is possible that the reported elevated resting concentrations of IL-1β and IL-6 are the result of a much more strenuous training than in previous publications, but the more attention should be paid to athletes subjected to very intense and long training. Thus, trainers are suggested to modify the athletes' training plan, extend the regeneration phase to avoid too much load leading to non-functional fatigue, overtraining, possible muscle damage caused by a disturbance in the inflammatory profile and chronic inflammation.

CONCLUSIONS

Although there is often information about the anti-inflammatory effect of regular training, it should be remembered that the effort of athletes is often very large and long, which may leave negative effects in the body and have a pro-inflammatory effect. It is not fully understood how the cytokine network is regulated during exercise and how long it takes for full recovery. In contrary to the original assumptions, persistently elevated resting values of IL-1β, IL-6 were found in athletes group suggesting the pro-inflammatory effects of exercise. In addition, it was shown that, apart from the number of monocytes, other biomarkers were not dependent on the volume and duration of training.

Due to contradictory information on the role of inflammation in adaptation to physical effort, further analysis and determination of appropriate levels of effort and time spent on rest are recommended. Thanks to this, it will be possible to adjust the training in such a way that it does not leave negative consequences and brings the athlete closer to the desired sports level.

ACKNOWLEDGEMENTS

Author thanks the late Elżbieta Hübner-Woźniak for her valuable advice and support and Elżbieta Bączkowska-Pośnik for her expert technical assistance. Thanks are also due to Grzegorz Golonka for performing a thorough statistical analysis moreover coaches and athletes who participated in this study.

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Cite this article as: Walczyk T. Pro-inflammatory effect induced by regular wrestling training in women. Arch Budo 2021; 17: 263-271