

Effects of Different Exercise Interventions on Selected Hematological, Rheological, and Biochemical Indicators in Older Women

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The aim of this study was to analyze the effects of two different exercise intervention protocols – dance movement therapy exercises (DMT) and general rehabilitation exercises (GRE) – on selected hematological, rheological, and biochemical indicators in older women. The study encompassed two groups of women (mean age: 67 years), who were subjected to a three-month exercise intervention program: DMT (n = 20) or GRE (n = 19). Blood samples from all of the women were examined both prior to the study and directly after the end of the program. DMT and GRE did not cause statistically significant differences in hematological indicators. DMT affected the rheological parameters of blood in women, reducing the half-time of total aggregation. Plasma viscosity decreased after GRE. Neither DMT nor GRE changed the concentration of fibrinogen and glutathione levels in older women. However, in the DMT group, the study revealed a statistically significant increase of G6PD. DMT and GRE modulate selected rheological and biochemical properties in the blood of older women.

Key words: hemorheology, dance movement therapy, general rehabilitation exercises, plasma viscosity, older women.

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Aging affects the rheological parameters of human blood. Blood fluidity disorders occur with age, including increased plasma and blood viscosity, impaired erythrocyte deformability, and increased erythrocyte aggregation (CARALLO *et al.* 2011). An increased concentration of fibrinogen in plasma is a common phenomenon in older people. This increased concentration explains the higher plasma viscosity and higher aggregation of erythrocytes recorded in older adults (SIMMONDS *et al.* 2013). The above mentioned changes constitute an important risk factor of cardiovascular disorders in older individuals (FEHER *et al.* 2006).

With age, the activity of erythrocyte enzymes and the level of glutathione (GSH) decreases (SIVILOTTI 2004). Glutathione, in a special form, is an antioxidant. GSH protects hemoglobin by preventing and reversing oxidation that causes disulphide crosslinks between globin chains and distorts hemoglobin structure. If the level of antioxidants is too low, then hemo-

globin will not bind oxygen (SIVILOTTI 2004). MAURYA *et al.* (2016) examined healthy subjects of both sexes between the ages of 20 and 80 in order to study age-dependent changes in human erythrocyte G6PD (gluco-6-phosphate dehydrogenase) activity. They observed a significant age-dependent decrease in G6PD activity. It was positively correlated with GSH and total antioxidant potential as a function of human age. These findings on erythrocyte G6PD and their correlation with GSH provide evidence of a higher oxidative stress in the older-aged population.

Increased oxidative stress at an elderly age causes changes in blood fluidity through decreased erythrocyte deformability, which is an important factor in deciding blood viscosity (SIMMONDS *et al.* 2013).

CARALLO *et al.* (2011) documented that the age-related increase in blood viscosity results from changes in the erythrocyte membrane. The decrease in the fluidity of erythrocyte membranes, observed in older individuals, is probably associated with high

levels of oxidative stress and impaired mechanisms of antioxidative protection (CARALLO *et al.* 2011).

Aging is connected with a high incidence of chronic illnesses among older persons. The age-related decline in hemorheological health mainly reflects the effect of disease progression rather than the ageing process itself (FEHER *et al.* 2007).

Physical exercise is one of the potential methods that can be used to improve hemorheology in older people. ERNST (1987) reported considerable improvement of the rheological properties of blood (lower viscosity, favorable changes in the elastic properties of erythrocytes) in people with a sedentary lifestyle who started regular physical training. Regular physical activity decreases erythrocyte aggregation (ROMAIN *et al.* 2011), reduces the level of fibrinogen (LETCHER *et al.* 1981) and increases number of platelet and neutrophil (CHAAR *et al.* 2011).

Compared to people with a sedentary lifestyle, trained individuals are characterized by a higher concentration of hemoglobin and lower hematocrit level (ROMAIN *et al.* 2011), along with the above mentioned reduced viscosity of plasma and whole blood (ERNST 1987).

The hematological and rheological changes that result from endurance training can considerably improve the overall health status of older people. Physical exercise programs for older adults can improve vascular perfusion and lower the risk of cardiovascular disorders (MARCHEWKA *et al.* 2015).

Older people get the most benefits when their exercise intervention includes four basic types of exercises: aerobic, balance, strength, and stretching exercises. The exercise interventions used in our study, DMT – dance movement therapy and GRE – general rehabilitation exercises, are based on all the above-mentioned types of exercises (MARCHEWKA 2013).

Additionally, DMT is considered to be a very attractive form of exercise intervention for older patients. According to literature, DMT is one of the most comprehensive forms of therapy since it modulates the biological, psychological, and social needs of trainees (DEMCZYSZAK *et al.* 2007). The versatile character of dance exercise is in part due to the challenge of overcoming dancing-related difficulties and the emotional experience of music-associated movements being a non-verbal form of expressing one's feelings. Having a positive attitude towards dancing, patients engage in this form of exercise intervention more eagerly. Furthermore, dancing-induced emotions are postulated to mobilize the stamina of older adults, enabling them to perform motor tasks characterized with increasing complexity (KUŹMIŃSKA 2002).

To our best knowledge, there are no reports referring to the effects of different exercise interventions on hematological and rheological indicators in older women. Therefore, the aim of this study was to analyse the effects of two various exercise intervention protocols – dance movement therapy exercises

(DMT) and general rehabilitation exercises (GRE) – on the selected hematological, rheological, and biochemical indicators in older women. We hypothesized that both DMT and GRE could similarly influence selected hematological, rheological, and biochemical indicators in older women.

Materials and Methods

Participants

Two groups of women that presented a sedentary lifestyle (lack of any exercise intervention aside from that associated with the activities of daily living) participated in the study. They were subjected to two different, three-month exercise intervention programs: DMT (n = 20) or GRE (n = 19). Qualification was based on a simple randomization (coin toss) performed by the main author (Fig. 1).

The participants subjected to DMT were between 61 and 75 years of age (mean: 67.45 ± 3.8); while the women subjected to GRE were between 61 and 82 years of age (mean: 67.00 ± 3.9). In the DMT group, average body height was 161.5 cm, average body weight was 72.5 kg, and BMI index was 27.6. In the GRE group, average body height was 162 cm, average body weight was 75.4 kg, and BMI index was 28.6. The criteria used for selecting and excluding study participants are presented in Table 2.

The subjects were familiarized with all procedures and gave their informed consent to participate in the study. The protocol of the study was approved by the Local Bioethics Committee at the Regional Medical Chamber, Nr 24/KBL/OIL/2014.

Laboratory procedures

Blood samples were collected from the cephalic vein (5 ml) from all women, both prior to the study and directly after the end of the program, and were examined for the selected hematological, rheological, and biochemical parameters. Blood was collected in the morning (between 8 a.m. and 9 a.m.) after fasting. The samples were collected in vacuum tubes with K2EDTA (1.5 mg/ml), (BD Diagnostics, USA). The parameters were measured directly after sampling in the Blood Physiology Laboratory, Faculty of Motor Rehabilitation of the University of Physical Education in Krakow.

Measurements of the basic hematological parameters

The erythrocyte count, leukocyte count, platelet count and hematocrit level were measured using a blood analyser (ABX Micros 60 Haematology Analyser, Horiba ABX Diagnostics, France).

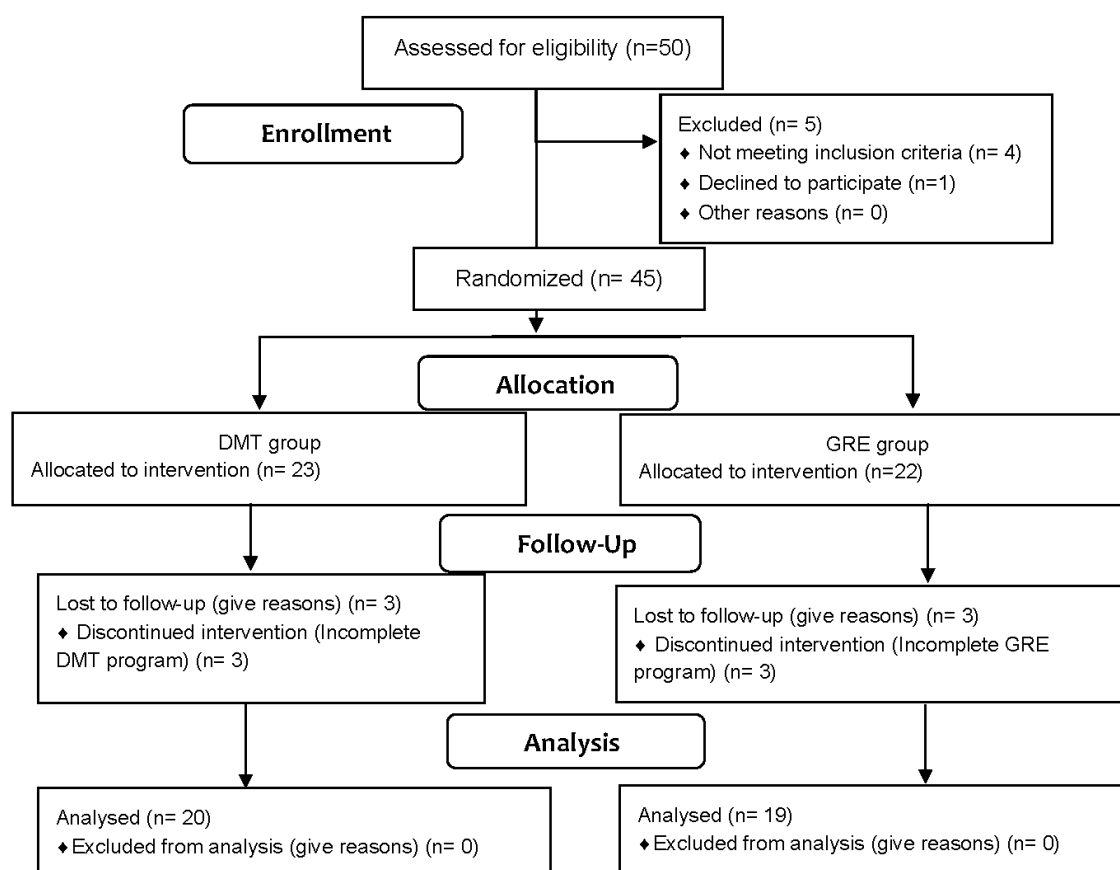


Fig. 1. Flow diagram of the study participants.

Table 1
Criteria for selecting and excluding the study participants.

Criteria for selecting	Criteria for excluding
female age over 60 years sedentary lifestyle	paralysis and paresis hindering independent mobility severe vertigo dementia diabetes cardiovascular disorders using drugs that can modulate vascular perfusion absence from more than one class no smoking not drinking alcohol drastic change in eating habits

Rheological analysis

The erythrocyte aggregation of red blood cells was determined using a Laser-assisted Optical Rotational Cell Analyzer (LORCA, RR Mechatronics, Holland), according to the Hardeman method (HARDEMAN *et al.* 2001). The following aggregation parameters were estimated: 1) aggregation index (AI, in %), 2) the am-

plitude and total extent of aggregation (AMP, in arbitrary units), and 3) the half time ($T_{1/2}$, in s) which describes the kinetics of the aggregation process and is proportional to the time of re-aggregation of disintegrated red cell complexes. Measurements of aggregation parameters were carried out at native hematocrit.

The temperature in the LORRCA was adjusted to 37°C. All other preparations and measurements were carried out at room temperature (22±1°C).

Aggregation measurements obtained from the LORRCA aggregometer were based on the detection of laser backscattering from the sheared (disaggregated) and unsheared (aggregated) blood using a computer assisted system. Each 2 ml sample of blood was transferred into a glass vessel and oxygenated through incubation and being mixed with carbo-gen for 10 to 15 minutes prior to obtaining measurements. A 1 ml sample of blood was injected into the gap between the outer cylinder “cup” and inner cylinder “bob” of the LORRCA. During the measurement, the cup was driven by a computer-controlled stepper motor. The blood sample was sheared at 400 s⁻¹, when shear rate decreases rapidly to zero. The backscattering data was evaluated by the computer and the AI was calculated from the syllectogram (light scatter vs. time curve during a 120 s period). This method relies on the fact that there is less light backscattered from aggregating red cells.

Measurements of the plasma viscosity

The viscosity of the blood plasma was determined with a viscosimeter (type D-52159 Roetgen, Myrenne, Germany) with the results displayed in mPas.

Biochemical analyses – measurements of the fibrinogen

The concentration of fibrinogen in the plasma was determined with a Chrom-7 coagulometer (Slamed Ing GmbH, Germany). The measurement was based on a determination of the changes in optic density (without simultaneous mechanical mixing) occurring during the clotting reaction, and a kinetic analysis of the reaction. The results were expressed as g/l.

Biochemical analyses – measurements of the gluco-6-phosphate dehydrogenase and glutathione

G6PD and GSH were marked using a spectrophotometer Helios β (Thermo Spectronic, Germany). The activity of gluco-6-phosphate dehydrogenase (G6PD) was determined in washed erythrocytes according to the BEUTLER spectrophotometric method (BEUTLER 1986). The level of reduced glutathione (GSH) in washed erythrocytes was determined spectrophotometrically following BEUTLER *et al.* (1963).

Exercise intervention protocols

Both the GRE and DMT programs lasted for 3 months (three sessions per week). Exercises were lead and su-

pervised by qualified physiotherapists at the University of Physical Education in Krakow. In line with exercise intervention guidelines for geriatric patients, each session lasted for no longer than 45-50 minutes and the intensity of exercising corresponded to no more than 40-60% of the heart rate reserve (MARCHEWKA 2013). Therefore, the heart rates of participating women were monitored with the aid of a cardiac monitor (Polar Sport Tester, Polar Electro Oy, Finland) during exercise intervention sessions.

The GRE program consisted of a 5-10-minute warm-up, a 30-minute program including aerobic, balance, and strength exercises, and a 5-10-minute cool-down. Strength training included low-level progressive resistance exercises with light free weights, exercise ladders, and exercise benches. Strength training included exercises of the following muscles: the adductor muscles in the brachial joint, the flexor and extensor muscles in the elbow joint, abdominal muscles, back muscles, the flexor muscles in the knee joint, thigh muscles, and buttock muscles (MARCHEWKA 2013). Each of the above exercises was performed in sets of 2, each set consisted of 10-15 repetitions. The break between sets lasted about 30 seconds. The upper and lower limb exercises were performed with one kilo weights.

Balance training included exercises resembling the motor activities of daily living: standing up from a chair, reaching, stepping forward and sideways, heel and toe stands, stepping on and over an obstacle, staircase walking, tandem foot standing and single-limb standing (MARCHEWKA 2013).

Each DMT session followed the same protocol. They would start with a low-intensity warm-up lasting for 5-10 minutes, preparing the participants for more strenuous exercise. The warm-up included light exercises performed in a sitting position, such as movements of the head and distal limb segments. Due to a gradual involvement of the major joints and trunk, the patients were then asked to resume a standing position and continue exercising, marching, clapping and stamping to music. The main phase of each training session included selected steps and moves from folk dance, ballroom dance, and integration dance, as well as predefined and modified choreographies, dancing-gymnastic exercises, and dancing improvisation. The main phase of the DMT program lasted 30 minutes. The aim of the training was to improve muscle strength, endurance, and the general exercise capacity of the participants. Moreover, practising simple choreographies improved the visual and auditory motor coordination of the patients, as well as their general physical fitness, balance, and agility. The final phase of each training session lasted for 5-10 minutes and included a cool-down with breathing and relaxation exercises, as well as stretching exercises aimed at the optimisation of the training effects.

Statistics

The measurements taken prior to and after the exercise intervention programs were subjected to a statistical analysis. The normality of distribution was verified with the Shapiro-Wilk test.

For the variables for which the data was distributed normally (WBC, PLT, AMP in both groups and only RBC in the GRE group and Ht, AMP, G6PD in the DMT group) an attempt was taken to apply an analysis of variance with repeated measures, but it turned out that the homogeneity of variance assumptions were not met. In this situation, for all variables, a non-parametric test, the Wilcoxon signed-rank test, was used in order to compare changes in time within the groups and the Mann-Whitney test was used to examine the differences between the DMT and GRE groups in each time point. All calculations were carried out with the Statistica 7 package (StatSoft, USA), with the threshold of statistical significance set at $p \leq 0.05$.

Results

In both groups (DMT and GRE) there were no statistically significant changes in time in the red blood cell count (RBC), hematocrit value (Ht), leukocyte count (WBC), or platelet count (PLT). Statistically significant differences were observed between the DMT and GRE groups in the level of red blood cell count (RBC) at both time points and in hematocrit value (Ht) only after the exercise intervention (significantly greater for GRE group) (Table 2).

In the DMT group, the exercise intervention resulted in a marked decrease of $T_{1/2}$, while no significant training-related changes were observed in AI and AMP values. No statistically significant changes in aggregation parameters were observed in the GRE group. After comparing the results of the two groups, a statistically significant difference in $T_{1/2}$ between the groups was found, but only at one time point – prior to exercise intervention. (Table 3).

In the DMT group, no statistically significant changes in the level of plasma viscosity were ob-

Table 2

Hematological parameters in the researched groups prior to and after the exercise intervention programmes

Within groups at two time points (Wilcoxon signed-rank test)

DMT (n = 20)									
	Prior to DMT				After DMT				
Parameter	Mean	SD	Median	CV (%)	Mean	SD	Median	CV (%)	p
RBC($10^6/\text{mm}^3$)	3.921	0.511	3.930	13.04	3.856	0.352	3.815	9.14	0.0967
Ht (%)	36.32	4.401	36.55	12.12	35.33	2.420	35.25	6.85	0.2149
WBC($10^3/\text{mm}^3$)	5.465	1.171	5.500	21.43	5.170	0.977	5.100	18.89	0.1387
PLT ($10^3/\text{mm}^3$)	202.4	38.0	202.5	18.77	210.6	36.4	196.0	17.30	0.3803
GRE (n = 19)									
	Prior to GRE				After GRE				
Parameter	Mean	SD	Median	CV (%)	Mean	SD	Median	CV (%)	p
RBC($10^6/\text{mm}^3$)	4.783	0.904	4.610	18.90	4.702	1.218	4.730	25.90	0.5098
Ht (%)	39.44	5.456	39.70	13.83	40.02	10.43	39.90	26.05	0.3610
WBC($10^3/\text{mm}^3$)	5.600	1.953	5.100	34.87	5.579	2.599	5.900	46.59	0.5713
PLT ($10^3/\text{mm}^3$)	235.3	94.6	250.0	40.22	227.9	118.4	215.0	51.94	0.2860

Between groups at the same time point (Mann-Whitney test)

Parameter	DMT vs GRE	
	Prior to exercise intervention	After exercise intervention
	p	p
RBC($10^6/\text{mm}^3$)	0.0024*	0.0004*
Ht (%)	0.0977	0.0217*
WBC($10^3/\text{mm}^3$)	0.8549	0.8837
PLT ($10^3/\text{mm}^3$)	0.0389*	0.5489

*significantly different ($p < 0.05$)

Table 3

Aggregation index (AI), half-time of the total aggregation ($T_{1/2}$) and aggregation amplitude (AMP) in the researched groups prior to and after the exercise intervention programmes

Within groups at two time points (Wilcoxon signed-rank test)

DMT (n = 20)									
	Prior to DMT				After DMT				
Parameter	Mean	SD	Median	CV (%)	Mean	SD	Median	CV (%)	p
AI (%)	67.45	5.935	66.92	8.80	69.33	5.891	69.13	8.50	0.0590
$T_{1/2}$ (s)	1.807	0.462	1.800	25.60	1.600	0.468	1.585	29.22	0.0352*
AMP(au)	17.06	3.639	16.52	21.33	15.69	2.350	15.56	14.98	0.2668
GRE (n = 19)									
	Prior to GRE				After GRE				
Parameter	Mean	SD	Median	CV (%)	Mean	SD	Median	CV (%)	p
AI (%)	69.88	5.893	69.22	8.43	67.67	6.315	65.10	9.33	0.1474
$T_{1/2}$ (s)	1.530	0.407	1.530	26.58	1.742	0.432	1.820	24.79	0.0702
AMP(au)	15.90	4.379	15.28	27.54	17.51	3.275	17.92	18.71	0.0910

Between groups at the same time point (Mann-Whitney test)

Parameter	DMT vs GRE	
	Prior to exercise intervention	After exercise intervention
	p	p
AI (%)	0.1559	0.1715
$T_{1/2}$ (s)	0.0264*	0.1599
AMP(au)	0.5992	0.0151*

*significantly different ($p < 0.05$)

served after the applied exercise intervention; whereas in the GRE group, the study revealed a statistically significant decrease of plasma viscosity after the exercise intervention program.

In the DMT group, the study revealed a statistically significant increase of G6PD. While in the GRE group no statistically significant changes in the level of G6PD were observed.

No statistically significant post-exercise intervention changes were observed in the levels of fibrinogen and GSH in either of the researched groups.

The study observed statistically significant differences at both time points in the levels of fibrinogen and G6PD between the women from both groups. A statistically significant difference was observed in the level of plasma velocity prior to the exercise intervention between the groups, however, after the exercise intervention, there was no difference in that parameter. Additionally, a statistically significant difference in the level of GSH was observed between groups, but only after the exercise intervention (Table 4).

Discussion

Because of the age-related deterioration of hemorheological parameters, older people should be motivated to perform physical exercise. The implementation of exercise intervention regimens can lead to the improvement of hemorheological parameters in older people (FILAR-MIERZWA *et al.* 2017).

The blood of older people shows changes such as a decrease in the number of erythrocytes, as well as decreased hematocrit and hemoglobin concentration, which can lead to anemia (ANIA *et al.* 1997). Subjecting older people to physical exercise can result in a higher erythrocyte count and a resulting increase in the oxygen capacity of blood. Regardless of age, the positive effect of endurance training, as manifested by a higher erythrocyte count, is a well-documented phenomenon (SZYGULA 1990). Studies by AHMADIZAD and EL-SAYED (2005) and by HU *et al.* (2008) confirm that the erythrocyte count in young adults increases after resistance training.

Table 4

Plasma viscosity (BPV), fibrinogen concentration, gluco-6-phosphate dehydrogenase (G6PD) and level of reduced glutathione (GSH) in the researched groups prior to and after the exercise intervention programme

Within groups at two time points (Wilcoxon signed-rank test)

DMT (n = 20)									
Parameter	Prior to DMT				After DMT				p
	Mean	SD	Median	CV (%)	Mean	SD	Median	CV (%)	
BPV(mPas)	1.311	0.094	1.300	7.21	1.415	0.420	1.290	29.66	0.7937
Fibrinogen(g/l)	5.569	1.419	5.099	25.49	5.337	1.188	5.425	22.26	0.4900
G6PD (IU/g)	1.642	0.286	1.705	17.43	1.797	0.285	1.855	15.83	0.0358*
GSH(mmol/lg)	8.660	1.751	8.660	21.71	8.927	1.722	9.230	19.30	0.1354
GRE (n = 19)									
Parameter	Prior to GRE				After GRE				p
	Mean	SD	Median	CV (%)	Mean	SD	Median	CV (%)	
BPV(mPas)	1.434	0.171	1.375	11.93	1.325	0.111	1.310	8.39	0.0041*
Fibrinogen(g/l)	3.446	2.497	4.100	72.45	3.670	2.446	4.350	66.65	0.7022
G6PD (IU/g)	1.180	0.372	1.130	31.50	1.190	0.210	1.130	17.64	0.9723
GSH(mmol/lg)	6.219	3.911	5.240	62.89	6.719	3.493	6.780	51.99	0.4979

Between groups at the same time point (Mann-Whitney test)

Parameter	DMT vs GRE	
	Prior to exercise intervention	After exercise intervention
	p	p
BPV(mPas)	0.0024*	0.2402
Fibrinogen(g/l)	0.0255*	0.0389*
G6PD (IU/g)	0.0001*	0.0001*
GSH(mmol/lg)	0.3153	0.0064*

*significantly different (p<0.05)

In our study, neither the dance movement therapy nor the general rehabilitation exercises caused statistically significant changes in the number of erythrocytes, thrombocytes, leukocytes, or in the hematocrit values of older women.

In the literature available, reports on the changes of hematological parameters after the application of physical exercise are ambiguous. BOBEUF *et al.* (2009) analyzed the hematological parameters of older women and men (61 to 73 years of age) who were subjected to a 6-month regimen of endurance training, and did not observe any significant changes in erythrocyte, thrombocyte, or leukocyte counts, hemoglobin concentration, hematocrit levels, or in MCV, MCH, or MCHC. Aging may weaken the blood's response to resistance training, which may be related to body homeostasis, which in turn is responsible for maintaining the physiological proportions in blood (MURRAY-KOLB *et al.* 2001).

In contrast, in the study by MARCHEWKA *et al.* (2015), there was a significant increase in erythrocyte count and in hematocrit levels in older women who were subjected to exercise intervention in the form of DMT.

According to MANETTA *et al.* (2006), regular cycling training maintains a low hematocrit level in cyclists aged 51.6 years, but it does not prevent an increased rigidity of erythrocytes or their aggregation. The erythrocytes from older males, compared to the erythrocytes from young males, showed a higher aggregability and a lower potential to de-aggregate; these differences occurred irrespectively of the exercise intervention levels (MANETTA *et al.* 2006).

The increase of red blood cell aggregation connected with age is caused by an increase in the fibrinogen concentration of plasma. A decrease in the fibrinogen concentration after physical training causes a decrease in the aggregation of red blood cells (SIMMONDS *et al.* 2013).

SIMMONDS *et al.* (2012) researched the rheological properties of blood in older women aged between 56 and 74 years of age who suffered from Type 2 diabetes, following a 12-week training program that involved walking on a treadmill. The research revealed a decrease in erythrocyte aggregation in the studied women.

In our study, DMT caused a reduction of the half-time of total aggregation. However, as far as the other erythrocyte aggregation parameters are concerned, neither DMT nor GRE caused statistically significant changes.

The reduction of the half-time of total aggregation results in faster RBC aggregation. This can markedly impair blood flow and affect the delivery of oxygen to the tissues during exercise.

In the study by *CAKIR et al.* (2009), after 6 weeks of resistance exercise training, the aggregation half time was decreased in the studied young men. Therefore, erythrocyte aggregation was significantly increased.

HARDEMAN et al. (1995) reported increased RBC aggregation after physical stress. Exercise induces significant alterations in blood rheology that depend on the type, duration, and intensity of the exercise (*EL-SAYED et al.* 2005). It has also been shown that RBC aggregability increases and disaggregability decreases during submaximal aerobic exercise (*VARLET-MARIE et al.* 2003; *BRUN et al.* 1996).

DMT was more of an aerobic training than GRE. Perhaps, more oxidative stress caused a reduction in the half-time of the total RBC aggregation in the DMT group.

Regular physical training is one of the most effective methods of preventing hemorheological disorders (*SIMMONDS et al.* 2013). On the other hand, a single training session usually leads to increased plasma blood viscosity, and decreased erythrocyte deformability (*YALCIN et al.* 2003) due to hemoconcentration (*BOBEUF et al.* 2009).

It was believed that increased blood viscosity had a negative influence on the cardiovascular system and the aerobic capacity (*SALAZAR et al.* 2011). Most recent studies suggest that dynamic changes in blood viscosity may have a positive effect on the functioning of blood vessels during exercise, through the production of nitric oxide (*SIMMONDS et al.* 2013).

The effect of excessive viscosity reverses twenty-four hours after the physical effort. The volume of plasma increases, which indicates a considerable dilution of the blood (*BRUN et al.* 2010). This process is referred to as 'auto-hemodilution', which is a positive adaptive change – it increases endurance and resistance to tiredness during long-term exercise by increasing the stroke volume, improving the effectiveness of thermoregulation mechanisms, improving the rheological properties of blood, etc. Consequently, blood viscosity decreases and blood fluidity improves, which increases blood flow to the muscles and improves oxygen supply to working tissues (*CONCERTINO* 1992).

Increased blood viscosity can be explained by an increase of plasma viscosity (*CARALLO et al.* 2011), especially in women (*SIMMONDS et al.* 2013). Plasma viscosity and blood viscosity decrease after regular

exercise, as a consequence of a decrease of the fibrinogen concentration in the plasma (*SIMMONDS et al.* 2013).

In our study, plasma viscosity decreased after GRE, but not after DMT, although fibrinogen was not altered after both exercise treatments.

Increased plasma viscosity in older adults can cause blood flow disorders and affect the occurrence of atherosclerosis (*LOWE et al.* 2002), myocardial infarction (*CECCHI et al.* 2009), cerebrovascular diseases, and the deterioration of cognitive functions (*RAFNSSON et al.* 2010).

Plasma viscosity depends on fibrinogen concentration. This latter parameter was reported to increase with age. Fibrinogen concentration can reach the upper limit of its reference value in older adults, whereas the levels of other plasma proteins do not change considerably (*HAGER et al.* 1994).

An age-related increase in fibrinogen concentration was reported by *KOVACS et al.* (2006) among others. In their study, the average plasma fibrinogen concentration of individuals between 60 and 74 years of age amounted to 3.3 g/l, compared to 3.5 g/l, in 75 to 90-year-old subjects, and 4.0 g/l in participants older than 90 years of age. Both this study and several others confirmed that increased fibrinogen concentration constitutes the principal determinant of higher plasma viscosity (*KOVACS et al.* 2006).

Training reduces the level of fibrinogen (*BRUN et al.* 1999), and the difference in plasma viscosity between training and non-training persons is mainly attributed to a lower concentration of fibrinogen in the training people (*LETCHER et al.* 1981).

In persons between 65 and 78 years of age, regular physical activity, even of a moderate intensity, correlates with a lower level of fibrinogen regardless of the person's sex, which then reduces the risk of cardiovascular complications or even death (*PARA et al.* 2005).

The study by *STRATTON et al.* (1991) revealed that six months of regular physical training improved aerobic capacity and considerably reduced the level of fibrinogen in the plasma of older men.

In the study by *MARCHEWKA et al.* (2015) however, dance movement therapy did not result in significant changes in fibrinogen levels in a research group of older women after 5 months.

In our study, DMT and GRE did not cause statistically significant changes in the levels of fibrinogen in the research group of older women.

Glutathione (GSH) and enzymes, such as glutathione peroxidases, are essential components in all cells, for the detoxification of reactive oxygen species (ROS), as well as for the reduction and repair of oxidatively damaged cellular components. The level of glutathione decreases with age (*VAN ZWIETEN et al.* 2014).

In our study, DMT and GRE did not change the levels of glutathione of older women.

Glucose 6-phosphate dehydrogenase (G6PD) affects the level of glutathione. Glucose-6-phosphate dehydrogenase (G6PD) is the rate-limiting enzyme in the generation of NADPH (nicotinamide adenine dinucleotide phosphate) which is needed to maintain cellular glutathione in its reduced form (SALVEMINI *et al.* 1999). The deficiency of G6PD reduces NADPH regeneration in the pentose phosphate pathway and subnormal levels of reduced glutathione result in an insufficient antioxidant defense, increased susceptibility of red blood cells (RBCs) to oxidative stress, and acute hemolysis following exposure to pro-oxidant drugs and infections (REISZ *et al.* 2017).

Our study revealed an increase of G6PD in the research group after DMT, which may affect the maintenance of an appropriate level of glutathione in older women.

G6PD is critical for GSH, an increase of G6PD should also lead to increased GSH. In our study, despite the increase of G6PD, there was no increase of GSH after DMT.

Oxidative stress upregulates the expression of G6PD (URSINI *et al.* 1997). DMT was a more intense aerobic training than GRE. Oxidative stress could have caused an increase in the expression of G6PD in the DMT group.

It needs to be stated that this study is not free from potential limitation. A larger sample and the addition of a control group would be beneficial in future studies. Furthermore, all participants of this study lived in a large city, meaning that women from small cities or villages were not included. This is important due to the fact that a rural lifestyle is slightly different to an urban lifestyle, and that a larger-scale study could bring a broader insight into the subject matter. As exercise interventions are multifaceted, the psychological and social effects of this modality should be further evaluated.

Conclusions

DMT and GRE modulate selected rheological properties in the blood of older women. DMT affects the rheological parameters and biochemical properties of the blood of older women reducing the half-time of total aggregation and increasing G6PD level. Plasma viscosity decreases after GRE. Some indicators such as the number of erythrocytes, leukocytes, and platelets, the hematocrit value, fibrinogen level, and the glutathione level are not affected by DMT and GRE in older women. The results of this study suggest that exercise intervention programs for older women, to a small degree, have an effect on selected hematological, rheological, and biochemical indicators, suggesting the maintenance of homeostasis. This observation

is particularly favorable in the context of the natural age-related tendency to change in those parameters.

Author Contributions

Research concept and design: K.F.-M., A.M.; Collection and/or assembly of data: K.F.-M., A.B.; Data analysis and interpretation: K.F.-M., A.M., A.B.; Writing the article: K.F.-M, A.B.; Critical revision of the article: A.M., A.B.; Final approval of article: A.M.

Conflict of Interest

The authors declare no conflict of interest.

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