



Annual Research & Review in Biology

20(2): 1-9, 2017; Article no.ARRB.37718
ISSN: 2347-565X, NLM ID: 101632869

Physiological Reaction of Erythrocytes' Microrheological Properties on Hypodynamia in Persons of the Second Mature Age

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/ARRB/2017/37718

Editor(s):

(1) George Perry, Dean and Professor of Biology, University of Texas at San Antonio, USA.

Reviewers:

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(2) Akapo Olajetemi Abiola, Federal University of Agriculture, Nigeria.

Complete Peer review History: <http://www.sciencedomain.org/review-history/21997>

Original Research Article

Received 26th October 2017
Accepted 17th November 2017
Published 21st November 2017

ABSTRACT

Introduction: Lasting absence of regular physical activity can negatively influence many physiological and morphological indices of a human body. Physiology is deeply interested in peculiarities of erythrocytes' rheological characteristics in conditions of hypodynamia as they mostly determine the processes of microcirculation and metabolism in tissues. Detection of their peculiarities in persons with low physical activity can help to study the mechanisms of development and progression of numerous dysfunctions in able-bodied persons who neglect physical activity.

Aim: The Aim is to estimate erythrocytes' microrheological properties in persons of the second mature age who avoid regular physical activity within lifetime.

Materials and Methods of Investigation: There were taken 45 healthy persons of both sexes of the second mature age (23 men and 22 women, mean age 44.9 ± 2.2 years) into the study. They consciously avoided regular physical activity within lifetime. The 1st control group was composed of 42 persons of both sexes of the same age who attended the section of athletics thrice a week for not less than 10 years. Each training lasted not less than 1.5 hours. The 2nd control group was composed of 46 persons who daily walked not less than 6 km during the last 10 years. We applied biochemical, hematological and statistical methods of investigation.

Results: The examined persons with low physical activity were noted to have strengthening of lipids' peroxidation. The quantity of acylhydroperoxides in their plasma surpassed the values in the

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1st control group by 40.6%, the values in the 2nd control group – by 38.1%. It took place against the background of weakening of plasma antioxidant activity in them by 18.5% in comparison with the 1st control group, in comparison with the second control group – by 16.9%. Blood of the examined persons with hypodynamia was noted to have some increase of thromboxane B₂ level by 28.5% in comparison with the 1st control group, in comparison with the 2nd control group – by 26.3%. At the same time, the level of 6-keto-prostaglandin F_{1α} in their blood was lowered by 14.4% in comparison with the 1st control group, in comparison with the 2nd control group – by 13.6%. In persons who avoided physical activity it was accompanied by content lowering of summary quantity of nitric oxide metabolites in plasma (by 19.2% in comparison with the 1st control group and by 14.7% in comparison with the 2nd control group). Erythrocytes' membranes of persons with hypodynamia were noted to have the rise of cholesterol level by 13.8% in comparison with the 1st control group and by 12.6% in comparison with the 2nd control group. In their erythrocytes it was accompanied by acylhydroperoxides' rise (by 29.6% in comparison with the 1st control group and by 28.3% in comparison with the 2nd control group). The examined persons with low physical activity were noted to have some lowering of erythrocytes-discocytes' percentage in blood by 12.2% (in comparison with the 1st control group) and by 11.2% (in comparison with the 2nd control group). The quantity of observation was increased by more than 39.0% and in 2.3 times, respectively, in comparison with both control groups. At the same time, the examined persons who avoided regular physical activity, were found to have strengthening of erythrocytes' aggregative properties. It was pointed by the index increase of erythrocytes' summary involvement into aggregates by 29.2% and 26.8%, and quantity rise of these aggregates by 36.7% and 32.2%, in comparison with the levels in the 1st and 2nd control groups.

Conclusion: Persons of the second mature age who avoided regular physical activity within lifetime, are characterized by strengthening of lipids' peroxidation processes in plasma and erythrocytes. It is accompanied by worsening of erythrocytes' microrheological properties in them. Given changes can negatively influence the processes of microcirculation and worsen the internals' trophism. That's why, in the course of future search of the variants of physical activity increase for the second mature age persons it seems to be rather important to determine the variants of regular physical activity which can optimize erythrocytes' microrheological properties rather quickly.

Keywords: The second mature age; hypodynamia; erythrocytes; aggregation; membrane's surface properties.

1. INTRODUCTION

Low physical activity is one of very widespread states of people nowadays [1]. Its existence can stimulate the development of many variants of hereditary predisposition to pathology [2] what was tracked in different population categories of industrially developed countries [3,4]. It was also confirmed in experiments [5]. Evident consequences of a man's hypodynamia can manifest themselves in young age. They promote frequency rise of episodes of temporary disability because of weakening of the whole body's functional reserves [6]. Wide prevalence of low physical activity leads to aggravation of many diseases while aging and their chronicity. All this causes the necessity of further determination of mechanisms influencing a body at lasting hypodynamia [7].

It's noted that presence of lasting hypodynamia always leads to aggravation of many blood indices [8]. It is connected with the fact that low

fitness level causes the development of functionally unfavorable changes in it [9]. As previous studies showed – low physical activity is accompanied already in young age by microrheological dysfunctions of some regular blood elements. It promotes the start of hypoxia development in tissues [10]. Developing in these conditions chronic lack of oxygen can aggravate the course of anabolic processes in the whole body weakening its common vitality [11,12]. These very changes form serious basis for pathology development in the internals [13,14] and promote the formation of persistent angiospasm [15,16]. It's tracked that conditions for the rise of arterial pressure leading to gradual development of arterial hypertension [17], can be often formed against the background of hypodynamia. Besides, hypodynamia aggravates the course of already existing cardio-vascular pathology and promotes the formation of resistance to applied pharmacological therapy [18] in these patients. Frequent occurrence of hypodynamia and its deeply negative impact on

metabolism attract persistent researchers' interest to erythrocytes' rheological properties in persons with low physical activity. Clarification of disturbances' peculiarities of these regular blood elements' microrheological properties at hypodynamia can help to study the mechanisms of many pathological processes' development in able-bodied citizens who are engaged in brain work. That's why, we put the following aim in our study: to estimate erythrocytes' microrheological properties in persons of the second mature age who avoided regular physical activity within lifetime.

2. MATERIALS AND METHODS

Conducting of the present research was approved by the local Ethics Committee of South-Western State University in Kursk (Russia) on May, 14th, 2014 (Record №7). All the examined persons gave written informed consent on participation in the conducted research.

The study was conducted on people living in Central Russia (town Kursk and Kursk region). The group of observation was composed of 45 persons of both sexes (23 men and 22 women) of the first mature age (mean age 44.9 ± 2.2 years) who consciously avoided regular physical activity within lifetime. The 1st control group was composed of 42 healthy people of both sexes (22 men and 20 women) of the second mature age (mean age 42.8 ± 2.6 years) who trained regularly in athletics' section thrice a week for not less than 10 years. Each training lasted not less than 1.5 hours. The 2nd control group was composed of 46 persons of mature age (mean age 43.7 ± 2.3 years) who were physically active in their daily life. If it was possible they tried to walk but not drive or take some public transport. Their work was also connected with continuous walking (postmen, bill-stickers, couriers). All of them walked daily not less than 6 km in the course of the last 10 years without any additional physical activity. Existing chronic diseases (chronic bronchitis, chronic tonsillitis, chronic cholecystitis) in some persons from the group of observation and control groups were in the state of lasting persistent remission. All the persons from the group of observation and control groups were examined once. In this study, women were surveyed only in the middle of the menstrual cycle.

In our research we determined the activity of the processes of lipids' peroxidation (LPO) in blood plasma which was registered according to the

content of thiobarbituric acid (TBA)-active products in it with the help of a set produced by the firm "Agat-Med" (Russia) and to the level of acylhydroperoxides (AHP) [19]. We also registered antioxidant activity of blood [20].

In blood plasma of examined we determined the content of thromboxane A_2 metabolite – thromboxane B_2 and prostacyclin metabolite – 6-keto-prostaglandin $F_{1\alpha}$ by enzymoimmunoassay with the help of sets produced by the firm "Enzo Life science" (USA). We also determined the summary content of nitric oxide metabolites [21] in plasma.

Erythrocytes were washed and resuspended. Then we quantitatively estimated the levels of cholesterol (CS) in them by enzymatic colorimetric method with the help of a set produced by the firm "Vital Diagnostikum" (Russia), and common phospholipids (CPL) – according to the quantity of phosphorus in them [22].

The evidence of the processes of intra-erythrocyte LPO was found in washed and resuspended erythrocytes according to the concentration of malon dialdehyde (MDA) in the reduction reaction of thiobarbituric acid and to the quantity of AHP [19].

We judged the state of erythrocytes' microrheological features by their cytoarchitecture and aggregation. We determined the quantity of erythrocytes' normal and changed forms in blood with the help of light phase-contrast microscopy [23].

The ability of erythrocytes to spontaneous aggregation was determined with the help of light microscopy by calculating the quantity of erythrocytes' aggregates, the number of aggregated and non-aggregated erythrocytes [23] in Goryaev's box.

Received results were processed by Student's t-criterion.

3. RESULTS AND DISCUSSION

Significant differences between men and women during the entire observation have not been found, so all the patients were considered as one group. The persons from the group of observation were noted to have strengthening of LPO processes (Table 1). The quantity of AHP and TBA-products in their plasma surpassed the

values of the 1st control group by 40.6% and 33.0%, the values of the 2nd control group – by 38.1% and 30.9%, respectively. It took place against the background of weakening of their plasma antioxidant activity in comparison with the 1st control group by 18.5%, in comparison with the 2nd control group – by 16.9%.

Blood of the examined persons with hypodynamia was noted to have imbalance of arachidonic acid metabolites: the level of thromboxane B₂ in their plasma turned out to be

higher by 28.5% in comparison with the 1st control group, and by 26.3% - in comparison with the 2nd control group. At the same time, the derivative's level of its functional antagonist – 6-keto-prostaglandin F_{1α} in the group of observation was lower by 14.4% in comparison with the 1st control group, and by 13.6% - in comparison with the 2nd control group (Table 1). It was accompanied by content lowering of summary metabolites' quantity of nitric oxide in their plasma (by 19.2% - in comparison with the 1st control group, and by 14.7% - in comparison with the 2nd control group).

Table 1. Hematologic characteristics of the examined persons second adulthood with inactivity

Indicators	Persons with inactivity, n=45, M±m	Control 1, n=42, M±m	Control 2, n=46, M±m
Acylhydroperoxides of plasma, D ₂₃₃ /l ml	2.32±0.57	1.65±0.20 p<0.01	1.68±0.17 p ₁ <0.01
Thiobarbituric acid-products of plasma, mkmol/l	4.19±0.59	3.15±0.23 p<0.01	3.20±0.26 p ₁ <0.01
Antioxidant activity of plasma, %	26.5±0.48	31.4±0.46 p<0.01	31.0±0.37 p ₁ <0.01
thromboxan A ₂ , pg / ml	208.5±0.72	162.2±0.72 p<0.01	165.1±0.68 p ₁ <0.01
6-keto-prostaglandin F _{1α} , pg / ml	83.0±0.35	95.0±0.45 p<0.05	94.3±0.54 p ₁ <0.05
nitric oxide's metabolites, umol/l	31.2±0.28	37.2±0.32 p<0.05	35.8±0.32 p ₁ <0.05
cholesterol of erythrocytes, mkmol/10 ¹² erythrocytes	1.07±0.012	0.94±0.010 p<0.05	0.95±0.014 p ₁ <0.05
common phospholipids of erythrocytes, mkmol/10 ¹² erythrocytes	0.64±0.010	0.73±0.015 p<0.05	0.71±0.008 p ₁ <0.05
acylhydroperoxides of erythrocytes, D ₂₃₃ /10 ¹² erythrocytes	4.03±0.017	3.11±0.016 p<0.01	3.14±0.011 p ₁ <0.01
malonic dialdehyde of erythrocytes, nmol/10 ¹² erythrocytes	1.89±0.009	1.36±0.014 p<0.01	1.41±0.009 p ₁ <0.01
erythrocytes-discocytes, %	77.8±0.27	87.3±0.18 p<0.01	86.5±0.12 p ₁ <0.01
reversibly modified erythrocytes,%	14.1±0.19	9.5±0.10 p<0.01	10.1±0.07 p ₁ <0.01
irreversibly modified erythrocytes,%	8.1±0.10	3.2±0.15 p<0.01	3.4±0.10 p ₁ <0.01
sum of all the erythrocytes in an aggregate	40.7±0.14	31.5±0.10 p<0.01	32.1±0.07 p ₁ <0.01
quantity of aggregates	8.2±0.09	6.0±0.07 p<0.01	6.2±0.09 p ₁ <0.01
quantity of free erythrocytes	245.0±0.45	296.1±0.35 p<0.01	292.3±0.29 p ₁ <0.01

Conventions: p – the significance of differences in the parameters of those surveyed who have inactivity and control 1 groups;

p₁ – the significance of differences in the parameters of those surveyed who have inactivity and control 2 groups; the significance of differences between indicators 1 and 2 are not detected

Erythrocytes' membranes of persons with hypodynamia were noted to have rise of CS level by 13.8% in comparison with the 1st control group and by 12.6% in comparison with the second control group. It was accompanied by CPL lowering in them by 14.1% and 10.9%, respectively. At the same time, erythrocytes of untrained persons were found to have AHP rise (by 29.6% in comparison with the 1st control group and by 28.3% in comparison with the 2nd control group) and MDA rise by 38.9% in comparison with the 1st control group and by 34.0% in comparison with the 2nd control group.

The examined persons with low physical activity were noted to have lowering of erythrocytes-discocytes' percentage in blood in comparison with the 1st control group (by 12.2%) and in comparison with the 2nd control group (by 11.2%) (Table 1). The quantity of reversibly and irreversibly modified erythrocytes' forms in blood of persons from the group of observation was increased in comparison with both control groups by more than 39.0% and in 2.3 times, respectively. At the same time, the examined persons with hypodynamia were found to have strengthening of erythrocytes' aggregative properties. It was pointed by their increase of summary indices of erythrocytes' involvement into aggregates by 29.2% and 26.8% in comparison with the 1st and 2nd control groups, and quantity rise of these aggregates by 36.7% and 32.2% at decrease of freely lying erythrocytes by 20.8% and 19.3%.

Achievement of lasting maintenance of a human body's physiological optimum and its effective rehabilitation are possible only in the case of basing on the results of deep investigation of human physiology's different aspects [24,25]. It becomes clear that serious attention should be devoted in such case to the impact of motor activity's different levels and, especially, - in the second mature age.

It was noted long ago that hypodynamia itself could cause pre-pathological states and strengthen the existing pathology, sometimes sharply aggravating life quality [26]. Last decades notwithstanding the successes of medicine and propaganda of medical knowledge hypodynamia remains to be very spread worldwide among people of mature age. At the same time, its consequences go on to damage economics because of high frequency of lowering of working capacity's level against its

background [1]. It's noted that formation of hypodynamia is accompanied by not only state worsening of musculoskeletal system but also lowering of metabolism intensity and blood circulation processes. Given situation negatively influences the functioning of the whole human body [27]. It points at the necessity of continuation of thorough studying of hypodynamia consequences' progression mechanisms.

There is some basis to suspect that great role in the formation of inactivity belongs to disturbances of regular blood elements' microrheological properties [28] and, first of all, of their most numerous population – erythrocytes [29]. At the same time, weakening of a body's antioxidant protection has special significance for their development as it leads to the growth of LPO intensity in plasma and cells. Surplus of lipids' peroxidation products in plasma and erythrocytes causes membranes' changes in these cells from the outside and inside what worsens their functions. It is aggravated by development of lipid imbalance in erythrocytes' membranes at inactivity which additionally promotes worsening of these regular blood elements' functioning [30]. Forming changes of quantity and ratio of phospholipids and cholesterol in their membranes are, evidently, functionally unfavorable. They disturb membrane's selective permeability and viscosity and negatively influence membrane-bound proteins in the result of their secondary structure's modification. Given situation rather negatively influences the membrane state of erythrocytes. As the conducted research showed, persons with inactivity are characterized by increased content of erythrocytes' reversibly and irreversibly modified forms in blood against the background of lowering of their discoid forms' quantity.

Found strengthening of erythrocytes' aggregation at inactivity can be estimated as the result of joint effect of low physical activity which negatively influence microrheological processes. Reliable increase of erythrocytes' reversibly and irreversibly modified forms inevitably leads to the growth of erythrocyte aggregates' quantity in blood of these people and the degree increase of more and more new erythrocytes' involvement into them. Found evidence rise of erythrocytes' aggregation in conditions of inactivity can be mostly explained by the increasing catecholamines' impact on them. Their level in blood reliably increases at any dysfunction [31].

The increase of catecholamines' quantity in blood of persons from the group of observation should be mostly estimated as the mechanism of metabolism intensification in tissues [32]. Given process is inevitably accompanied by activity growth of α_2 -receptors on their cells, including erythrocytes. It leads to inhibition of adenylate cyclase and, consequently, to level lowering of cyclic adenosine monophosphate [33]. Besides, the rise of erythrocytes' aggregation in the group of persons with inactivity can be also connected with gradual increase of Ca^{2+} content in them.

In these conditions vascular wall of persons with inactivity is characterized by synthesis lowering of biologically active substances which can limit erythrocytes' aggregation. At the same time, proaggregates' level rises in their blood. So, noted in the group of observation intensification of thromboxane formation and production weakening of its functional antagonist – prostacyclin – creates imbalance of arachidonic acid metabolites. Given disturbances are aggravated in them by developing weakening of NO production in vascular wall. May be, it takes place in the result of endothelial NO-synthase's suppression by increased LPO in plasma [34]. Forming in these conditions erythrocytes' microrheological dysfunctions can worsen microcirculation processes themselves and weaken trophism, including vascular walls and disaggregants' production in them.

Found disturbances of erythrocytes' characteristics in persons with inactivity allow us to look at the given state under some new visual angle [35].

In these conditions worsening of erythrocytes' microrheological properties and manifestations of angiopathy at hypodynamia aggravate each other and inevitably damage microcirculation in tissues. It becomes clear that it's possible to make the body healthier in such situation and to weaken manifestations of hypodynamia only with the help of planned physical activity. In order to reach such results we should conduct wide propaganda of healthy way of life among representatives of brain work's professions [36,37]. There is some ground to consider that application of adequate physical activity can optimize morpho-functional characteristics of regular blood elements [38,39] rather quickly in the given group of persons. At the same time, it is still necessary to clarify the most efficient variants of physical activity from physiological

point of view for leaving the field of hypodynamia [40], and they should be widely propagandized in society.

4. CONCLUSION

Hypodynamia is rather often accompanied by worsening of regular blood elements' rheological properties. It has special significance for erythrocytes as their most numerous population. It was detected in the conducted research that persons of the second mature age who avoided regular physical activity within lifetime, were characterized by strengthening of lipids' peroxidation processes in plasma and erythrocytes. It was accompanied by quantity rise of erythrocytes' modified forms in their blood and increase of their aggregative ability. Found disturbances inevitably worsen the processes of blood rheology in capillaries. It promotes negative changes of trophism in all the internals, development and progression of different pathology. Taking the evidence of microrheological disturbances at hypodynamia into consideration, it seems to be very important to conduct further search of physical activity's variants for fast correction of the given state with account of their capacities to influence aggregation and abnormalities of most erythrocytes' form. Its results must help to work out efficient variants of hypodynamia manifestations' physiological overcoming for the wide range of persons willing to rehabilitate their bodies in mature age.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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