Kałużny Krystian, Kałużna Anna, Budzyński Jacek, Hagner Wojciech, Kochański Bartosz, Żukow Walery, Bronisz Agata, Hagner-Derengowska Magdalena. Effect of a ten-week Nordic Walking exercise program on serum electrolyte concentration and plasma acid-base balance in postmenopausal women with overweight or obesity. Journal of Education, Health and Sport. 2016;6(12):353-364. eISSN 2391-8306. DOI http://dx.doi.org/10.5281/zenodo.201929
http://ojs.ukw.edu.pl/index.php/johs/article/view/4065

The journal has had 7 points in Ministry of Science and Higher Education parametric evaluation. Part B item 754 (09.12.2016).
754 Journal of Education, Health and Sport eISSN 2391-8306 7

The authors declare that there is no conflict of interests regarding the publication of this paper.
Received: 01.12.2016. Revised 12.12.2016. Accepted: 14.12.2016.

Effect of a ten-week Nordic Walking exercise program on serum electrolyte concentration and plasma acid-base balance in postmenopausal women with overweight or obesity

Krystian Kałużny[1], Anna Kałużna[1,2], Jacek Budzyński[2], Wojciech Hagner[1], Bartosz Kochański[1], Walery Żukow[3], Agata Bronisz[4], Magdalena Hagner-Derengowska[5]

[1] **Chair and Clinic of Rehabilitation, Faculty of Health Sciences, Nicolaus Copernicus University in Toruń, Ludwik Rydygier Collegium Medicum in Bydgoszcz**

[2] **Chair of Vascular and Internal Diseases, Faculty of Health Sciences, Nicolaus Copernicus University in Toruń, Ludwik Rydygier Collegium Medicum in Bydgoszcz**

[3] **Faculty of Physical Education, Health and Tourism, Kazimierz Wielki University in Bydgoszcz**

[4] **Chair of Endocrinology and Diabetology, Clinic of Metabolic Rehabilitation, Faculty of Medicine, Nicolaus Copernicus University in Toruń, Ludwik Rydygier Collegium Medicum in Bydgoszcz**

[5] **Chair of Clinical Neuropsychology, Faculty of Health Sciences, Nicolaus Copernicus University in Toruń, Ludwik Rydygier Collegium Medicum in Bydgoszcz**

Krystian Kałużny and Anna Kałużna contributed equally to the present work.

Source of financial support: This study was supported by a grant from The Ludwik Rydygier Collegium Medicum in Bydgoszcz, Nicolaus Copernicus University, for the statutory research activity of the Chair and Clinic of Rehabilitation.

Conflict of interest: None declared.

Financial disclosures: None of the authors has any financial disclosures.

Address for correspondence:

Krystian Kałużny, PT, MD

Chair and Clinic of Rehabilitation, Faculty of Health Sciences, Nicolaus Copernicus University in Toruń, The Ludwik Rydygier Collegium Medicum in Bydgoszcz

M. Skłodowskiej-Curie 9 Street, 85-094 Bydgoszcz, Poland

e-mail: krystian.kaluzny@cm.umk.pl

ABSTRACT

Introduction: The effect of exercise program on serum electrolyte concentration and gas partial pressure has not previously been reported.

Aim: The aim of this study was to estimate the effect of a 10-week Nordic Walking exercise program on these parameters.

Patients and methods: The subjects were 32 postmenopausal women with overweight or obesity were studied. Before the start of the exercise program and directly after it had finished, blood samples were taken to determine sodium, potassium, magnesium, calcium, phosphorus, and capillary gasometry parameters.

Results: After the 10-week exercise program, a significant decrease in serum concentrations of sodium, magnesium, calcium, capillary potential of hydrogen (pH), capillary partial pressure of carbon dioxide (pCO_2), bicarbonate (HCO_3), and base excess (BE), as well as an increase in potassium, chloride, capillary partial pressure of oxygen (pO_2), and hemoglobin oxygen saturation (SaO_2) levels was found. The proportional change in sodium serum concentrations correlated significantly with delta BMI, and potassium and calcium proportional alterations after the exercise program had finished correlated with proportional changes in albumin concentration.

Conclusions: A 10-week Nordic Walking exercise program resulted in statistically significant changes in almost all serum electrolyte concentration, but only to a small extent and probably without clinical importance. The improvement in oxygen partial pressure in capillary blood after the exercise program shows a potentially complex, favorable effect of a prolonged exercise program and requires further study.

Keywords: Nordic Walking, exercise physiology, physical activity, obesity, aging.

1. Introduction

Blood electrolyte concentrations and acid-base balance are important for homeostasis in the human body. Isotonia, isoionia, isohydria and isoosmia are the aims of the complicated regulatory mechanisms which maintain body hydration, macro- and microelement concentrations, as well as appropriate body fluid pH. Such balance is crucial for the function and/or structure of the heart, brain, vessels, smooth and striated muscles, bones, digestive tract, and kidneys. The potential clinical manifestations of both acute and chronic imbalance in blood electrolyte concentration are: cardiac arrhythmia, shock, sudden cardiac death, pulmonary and cerebral edema, coma, confusion and other conscious disorders (e.g., hyponatremic encephalopathy), seizures, headache, paresthesia, tetany, muscle paralysis, ileus, bowel spasm, nausea, vomiting, and polyuria [1]. The clinical consequences of these disorders may be greater in individuals with serious damage to the respective organs or systems. In this way, acute dyselectrolytemia in one patient may lead to mild cardiac arrhythmia, but, in another, to sudden cardiac death.

Both acute, strenuous exercise and chronic exercise programs can affect either body hydration, macro- and micronutrient blood concentration, and blood pH. These disturbances result mainly from sweating, excessive fluid consumption, and complex central and peripheral neural and endocrine responses to exercise [1-5]. They stabilize body homeostasis to a new set point. Autonomic nervous system adjustment consists of decreased parasympathetic and increased sympathetic nerve activities [2,6]. The last is an important factor affecting the renin-angiotensin-aldosterone system (RAAS), which influences urinary ion excretion [4-7]. Moreover, the following mediators are involved in human body responses to exercise: cortisol [7], testosterone [8], growth hormone [8], ovarian hormones [9], adiponectin [10], and cytokines [7]. They also take part in blood electrolyte and gas-base balance regulation. The aforementioned regulative processes are at their strongest during and after strenuous effort but, with time, their effects become more and more blunted. Therefore, although adaptive processes in response to a chronic exercise program may only lead to slight changes, they are favorable in the clinical sense. They may improve effort tolerance, decrease cardiovascular risk, and improve vascular tone, autonomic nervous system balance, bone mineralization, etc.

The effect of autonomic nervous and endocrine systems on cardiovascular and other human body systems changes, not only in response to exercise, but also after menopause.[9] However, the influence of a Nordic Walking exercise program on blood electrolyte and acid-base balance in postmenopausal women has not previously been reported. A few of the available papers concern changes in blood electrolyte concentration in response to acute or chronic exercise in athletes [1,4,5,7]. Moreover, the favorable effect of pre-exercise metabolic alkalosis induced by oral ingestion of sodium bicarbonate ($NaHCO_3$) on oxygen uptake at the end of supramaximal exercise test was also recently reported by Thomas et al. [11]. Regular exercise and increased physical activity are generally recommended for women after menopause, so recognition of this subject among this patient group would seem to be important. For this reason, we performed this study, the aim of which was to analyze the effect of a 10-week Nordic Walking exercise program on serum electrolyte concentration and capillary blood gas values.

2. Material and Methods

The study was designed as an experimental, non-randomized prospective controlled trial. Thirty-two postmenopausal women with overweight or obesity (average BMI 30.5 ± 4.1kg/m^2; range 26.1-39.9kg/m^2) aged 59.6 ± 5.9 years (range: 50-68 y) were included into the investigation. The inclusion criteria for the study were: female gender, age 50-75 y, natural cessation of menstruation, and overweight or obesity. The exclusion criteria were: diabetes mellitus, mental illness, cancer, age under 50 y, body mass index (BMI) below 25 kg/m^2, and irregular participation in the exercise program.

Patients were recruited by open access through notices placed in outpatient clinics and published in newspapers, as well as during health promotion classes at Bydgoszcz University entitled ‘An active senior citizen’. None of the patients suffered from serious somatic (including diabetes mellitus) or mental diseases. In addition, patients who participated in the study did not take any medication other than metabolically neutral hypotensive drugs, diet supplements containing electrolytes or affecting the gas-base balance, and did not change their medication during the study period.

The primary intervention of the experiment was a rehabilitation program: Nordic Walking (NW). Rehabilitation was carried out under a trainer’s supervision (three times a week) and at home without the trainer’s guidance. Meetings took place three times a week for 10 weeks (in total: 30 sessions, 60 minutes each, and for the same amount of time at home). Prior to commencing the program, training in the NW technique was carried out and participants were tested on their mastery. All the participants mastered the exercise rules. A warm-up was organized before every exercise session. Initially, the average daily distance amounted to 3.6 km. As progress in rehabilitation was made and exercise tolerance improved, the average daily distance increased to 4.8 km. The average estimated energy expenditure in each session amounted to 428 kcal. All the patients completed the full rehabilitation program.

During the entire period of the study, each woman was on the same diet (meals consumed in catering establishments). The participants' daily diet consisted of five meals with a total caloric value of 1.700 kcal. Energy sources were allocated as follows: complex carbohydrates = 60%, fat = 20%, and protein = 20%. They did not eat snacks between meals. During rehabilitation, the participants did not change their medication, as this could otherwise have influenced the studied parameters. The patients did not take any dietary supplements.

All the participants underwent a medical examination at the beginning and at the end of the study. During these examinations, among other things, BMI value was calculated. Serum concentrations of sodium, potassium, chloride, magnesium, calcium and phosphorus, as well as capillary gasometry with the following parameters: potential of hydrogen (pH), oxygen partial pressure (pO_2), carbon dioxide partial pressure (pCO_2), oxygen hemoglobin saturation (SaO_2), and bicarbonate (HCO_3) concentration were examined at the beginning and at the end of the rehabilitation program. Blood sampling for biochemical determinations was performed in the morning, before exercise, from the fingertip of the right hand and left cubital fossa vein, with minimum tourniquet pressure, 14 hours after the last meal and after 15 minutes of rest. All biochemical investigations were carried out at the same laboratory.

The effects of the rehabilitation program were measured through changes in the above-described values of biochemical parameters. The absolute (delta) and relative (percentile, proportional) changes in each parameter's value were calculated.

The study protocol was carried out after the Bioethical Commission of the Nicolaus Copernicus University in Toruń, Ludwik Rydygier Collegium Medicum in Bydgoszcz, granted its consent (No. KB/602/2011) in September 2011. Each patient expressed her consent regarding participation in the study in writing. The study was carried out in conformity with the Declaration of Helsinki.

The results were presented as a mean value and 95% confidence interval (95% CI). Analysis of the statistical significance of the difference between the values of the studied parameters at the beginning and the end of the rehabilitation program was carried out using the Wilcoxon test. Non-parametric correlations between the studied parameters were estimated using Spearman's rank coefficient. A licensed version of STATISTICA 10.0 for Windows was used.

3. Results

After the 10-week Nordic Walking exercise program, a significant decrease in serum concentrations of sodium, magnesium, calcium, as well as pH, pCO_2, HCO_3, and base excess (BE) (Tab. 1, 2) was seen in the 32 postmenopausal women who took part, whereas potassium, chloride, pO_2, and SaO_2 increased during the study. The absolute and proportional amplitudes of the changes were individual and parameter specific and not greater than a few percent. Only changes in magnesium levels altered by more than 10% (Tab. 1). The greatest changes in acid-base balance parameters concerned pO_2 and BE (Tab. 2).

Table 1. Changes in blood electrolytes after a 10-week Nordic Walking exercise program in postmenopausal women with overweight and obesity

Parameter	Baseline (n = 32)	Post intervention (n = 32)
BMI (kg/m^2)	30.5; 28.9 – 31,9	28.8; 27.2 – 30.4 *
Delta BMI	-1.7; -2.1 - -1.2	
Proportional BMI change (%)	-5.7; -7.3 - -4.1	
Na (mmol/l)	140.39; 139.62 - 141.16	139.03; 138.3 - 139.76 *
Delta Na (mmol/l)	-1.36; -2.0 - -0.71	
Proportional Na change (%)	-0.96; -1.42 - -0.49	
K (mmol/l)	4.42; 4.29 - 4.55	4.54; 4.41 - 4.67
Delta K (mmol/l)	0.12; -0.02 - 0.26	
Proportional K change (%)	3.06; 0.12 - 6.0	
Cl (mmol/l)	105.21; 104.42 - 105.98	108.44; 107.6 - 109.27 *
Delta Cl (mmol/l)	3.24; 2.33 - 4.15	
Proportional Cl change (%)	3.11; 2.23 - 3.99	
Mg (mmol/l)	0.95; 0.92 - 0.97	0.85; 0.82 - 0.86 *
Delta Mg (mmol/l)	-0.10; -0.12 - -0.08	
Proportional Mg change (%)	-11.03; -13.3 - -8.76	
Ca (mmol/l)	2.43; 2.39 - 2.45	2.36; 2.32 - 2.39 *
Delta Ca (mmol/l)	-0.07; -0.1 - -0.03	
Proportional Ca change (%)	-2.73; -4.0 - -1.38	
PO_4 (mmol/l)	1.13; 1.07 - 1.18	1.13; 1.05 - 1.19
Delta PO_4 (mmol/l)	-0.003; -0.05 - 0.05	
Proportional PO_4 change (%)	-0.10; -4.3 - 4.2	

Annotation: data were presented as a mean value; 95% confidence interval (95% CI);
Na = sodium; K = potassium; Cl = chloride; Mg = magnesium; Ca = calcium; PO_4 = phosphorus.
Statistical significance of difference between groups: * - $p < 0.001$.

Table 2. Changes in blood gas-base balance after a 10-week Nordic Walking exercise program in postmenopausal women with overweight and obesity

Parameter	Baseline (n = 32)	Post intervention (n = 32)
pH	7.44; 7.43 - 7.45	7.42; 7.41 - 7.43 *
Delta pH	-0.02; -0.030 - -0.01	
Proportional pH change (%)	-0.28; -0.41 - -0.16	
pO_2 (mmHg)	65.83; 63.58 - 68.08	71.84; 68.67 - 75.02 *
Delta pO_2 (mmHg)	6.0; 4.3 - 7.7	
Proportional pO_2 change (%)	9.0; 6.6 - 11.5	
pCO_2 (mmHg)	35.95; 34.92 - 36.98	34.02; 32.95 - 35.09 *
Delta pCO_2 (mmHg)	-1.93; -2.5 - -1.35	
Proportional pCO_2 change (%)	-5.32; -6.9 - -3.7	
BE (mmol/l)	-0.54; -1.14 - 0.06	-1.68; -2.20 - -1.14 *
Delta BE (mmol/l)	-1.13; -1.45 - -0.82	
Proportional BE change (%)	-16.34; -181.4 - 148.71	
HCO_3 (mmol/l)	23.18; 22.45 - 23.91	22.11; 21.49 - 22.74 *
Delta HCO_3 (mmol/l)	-1.07; -1.51 - -0.62	
Proportional HCO_3 change (%)	-4.39; -6.24 - -2.53	
SaO_2 (%)	93.93; 93.54 - 94.31	95.49; 95.05 - 95.93 *
Delta SaO_2 (%)	1.57; 1.21 - 1.92	
Proportional SaO_2 change (%)	1.67; 1.29 - 2.06	

Annotation: data were presented as a mean value; 95% confidence interval (95% CI);
pO_2 = oxygen partial pressure; pCO_2 = carbon dioxide partial pressure; BE = base excess; HCO_3 = bicarbonate; SaO_2 = oxygen saturation.
Statistical significance of difference between groups: * $p < 0.001$.

The proportional change in sodium serum concentrations correlated significantly with the BMI delta ($R = -0.38$; $p < 0.05$). Proportional changes in total calcium blood concentration correlated significantly with absolute and proportional changes in potassium ($R = 0.59$) and chloride ($R = 0.42$) and proportional changes in albumin ($R = 0.75$) concentrations. The age of the patients correlated with proportional changes in chloride (R = -0.47) and calcium (R = 0.46) concentrations.

4. Discussion

In this non-randomized study performed on 32 postmenopausal women with overweight and obesity, significant alterations in basic serum electrolytes concentrations (Tab. 1) and acid-base balance parameters (Tab. 2) were found at the end of the 10-week Nordic Walking exercise program. Only a small number of papers are available concerning alterations in electrolyte concentrations in response to exercise. The majority of the papers concern the effect of strenuous effort (e.g., ultra-distance running, triathlon, mountain bike, 24-hour, marathon, and ultra-marathon races) on hydration and plasma sodium levels [1,5]. In these studies, exercise-associated hyponatremia concerned 5.7-22% of the athletes involved after strenuous effort. Potential pathomechanisms of this disorder with an increase in body mass are recognized as fluid overintake, non-osmotic secretion of vasopressin (syndrome of inappropriate antidiuretic hormone secretion [SIADH]), RAAS activation, or impaired renal blood flow or glomerular filtration. However, when hyponatremia coexisted or was correlated with body mass decrease after exercise, this suggested the simultaneous loss of water and sodium due to sweating, inability to mobilize exchangeable internal sodium stores, an inappropriate inactivation of osmotically-active sodium, and metabolic water production [1]. Risk factors for exercise-associated hyponatremia were considered to be as follows: low race pace, prolonged exercise with duration of more than four hours, female gender, a low body mass, pre-exercise hyperhydration, the use of non-steroidal anti-inflammatory drugs (NSAIDs), non-elite status, and an extremely hot or cold environment [1]. In our study (Tab. 2), the patients did not perform an acute, but a chronic exercise program lasting 10 weeks and they did not achieve hyponatremia criteria (Na<135mmol/l), but a regressive association between a proportional reduction in serum sodium concentration and body mass was found. In a study by Döker et al. [12], the effect of swimming frequency during three weeks in three subject groups (elite, amateur swimmers and sedentary individuals) on serum concentrations of certain trace elements (chromium, iron, copper, zinc and selenium) and electrolytes (sodium, magnesium, potassium and calcium) was investigated. In the elite swimmers, pre-test calcium and potassium levels were higher compared to those of the amateurs and controls. After the 3-week exercise program, for the elite and amateur swimmers, in contrast with our study, an increase in blood concentrations of magnesium, calcium, copper, zinc, and selenium immediately following the end of their exertions was found. However, copper, zinc, and selenium levels dropped one hour after the test in the elite swimmers. The authors explained their observations as an effect of adaptive mechanisms that emerged with frequent exercise. In a study by Karakukcu et al. [13] on 32 healthy adolescent male amateur boxers after acute exercise, serum calcium, zinc and copper levels decreased, phosphorus increased, and iron and magnesium levels did not change. However, after four weeks of regular boxing exercise, there was a decrease in zinc and an increase in calcium concentrations, in contrast to our study results (Tab. 1). In a study by Wang et al. [14] on 10 well-trained elite basketball athletes, macroelement (chloride, sodium, and calcium) levels in the blood increased significantly, but not for potassium, after one week of high-intensity basketball exercise. Similarly, contrary to our investigation, changes in serum electrolyte concentration in athletes after strenuous acute effort during an Ironman competition (an increase in sodium, calcium and plasma osmolarity, and a decrease in chloride) were observed by Menicucci et al. [7]. In their study, only potassium blood concentration increased after exercise, similarly to the results of our study (Tab. 1).

In our study, only some significant correlations between amplitudes of change in respective ion concentrations were found. Therefore, our own observations only partially corroborate the report by Liu et al. [15], who, in 290 postmenopausal women aged from 45 to 65, found a significant correlation between serum calcium and phosphonium, potassium, sodium and magnesium, and trace elements, such as zinc, iron, copper, and selenium.

An increase in pO_2 and SaO_2 levels and a decrease in pCO_2 in capillary gasometry observed in our study after the 10-week Nordic Walking exercise program (Tab. 2) were not previously reported in any subject group. Such alterations in blood gas partial pressures should be considered as favorable. They might be attributed to many pathomechanisms, such as: improvement in chest movement and better blood oxygenation, increase in the possibilities of gas transport in the blood, better oxygen use in peripheral tissues and muscle (metabolism enhancement) [11], or reduced oxygen release (secondary to a decrease in pH, and, probably, 2,3-diphosphoglycerate, which affect the oxyhemoglobin dissociation curve).

The practical meaning of the present findings is that metabolic adaptation to the chronic exercise program in postmenopausal women with overweight may lead to mild changes in serum electrolytes concentrations and highly individually differential influence on base excess level. These disturbances may reach a clinical importance, especially in patients with comorbidities sensitive to such abnormalities, e.g. cardiac arrhythmia, muscle cramps or osteoporosis [16-25]. This imply needs to plan the future research evaluating safety of exercise programs and the role of electrolytes supplementation within exercise programs.

Our study seems to have some limitations, related mainly to the size of the group studied, lack of a control group, wide range of age of research participants (proportional changes in chloride and calcium correlated with subjects age), and there were no measures during exercise to assess the respective patients work-load during the exercise intervention. On the other hand, the other investigations mentioned, reporting the effect of acute effort or prolonged exercise programs on blood electrolyte levels, were also performed with similar numbers of subjects, and were also not randomized.

5. Conclusions

1. The 10-week Nordic Walking exercise program resulted in statistically significant changes in the serum concentration of almost all electrolytes, but only to a small extent and without clinically overt complications.
2. The effect of 10-week NW program on values of acid-base balance parameters shows on highly individually diversified adaptation to dynamic exercise in postmenopausal women and improvement in oxygen partial pressure in capillary blood post intervention suggests a complex and favorable effect of a prolonged exercise program and requires further study.

References

1. Chlíbková D, Knechtle B, Rosemann T, et al. The prevalence of exercise-associated hyponatremia in 24-hour ultra-mountain bikers, 24-hour ultra-runners and multi-stage ultra-mountain bikers in the Czech Republic. J Int Soc Sports Nutr 2014; 11(1):3.
2. Nobrega AC, O'Leary D, Silva BM, et al. Neural Regulation of Cardiovascular Response to Exercise: Role of Central Command and Peripheral Afferents. Biomed Res Int 2014; 2014:478965.
3. Galy O, Chamari K, Peyreigne C, et al. Sequential exercise in triathletes: variations in GH and water loss. PLoS One 2014; 9(4):e96145.
4. Land MA, Webster J, Christoforou A, et al. The association of knowledge, attitudes and behaviours related to salt with 24-hour urinary sodium excretion. Int J Behav Nutr Phys Act 2014; 11(1):47.
5. Knechtle B, Knechtle P, Rosemann T. No exercise-associated hyponatremia found in an observational field study of male ultra-marathoners participating in a 24-hour ultra-run. Phys Sportsmed 2010; 38(4):94-100.

6. Hackney AC. Stress and the neuroendocrine system: the role of exercise as a stressor and modifier of stress. Expert Rev Endocrinol Metab 2006; 1(6):783-792.
7. Menicucci D, Piarulli A, Mastorci F, et al. Interactions between immune, stress-related hormonal and cardiovascular systems following strenuous physical exercise. Arch Ital Biol 2013; 151(3):126-36.
8. Hackney AC, Viru M, VanBruggen M, et al. Comparison of the hormonal responses to exhaustive incremental exercise in adolescent and young adult males. Arq Bras Endocrinol Metabol 2011; 55(3):213-8.
9. Souza HC, Tezini GC. Autonomic Cardiovascular Damage during Post-menopause: the Role of Physical Training. Aging Dis 2013; 4(6):320-8.
10. Kim HJ, Oh JK, Kim C, et al. Effects of six-week cardiac rehabilitation and exercise on adiponectin in patients with acute coronary syndrome. Kardiol Pol 2013; 71(9):924-30.
11. Thomas C, Delfour-Peyrethon R, Bishop DJ, et al. Effects of pre-exercise alkalosis on the decrease in VO2 at the end of all-out exercise. Eur J Appl Physiol 2016; 116(1):85-95.
12. Döker S, Hazar M, Uslu M, et al. Influence of training frequency on serum concentrations of some essential trace elements and electrolytes in male swimmers. Biol Trace Elem Res 2014; 158(1):15-21.
13. Karakukcu C, Polat Y, Torun YA, et al. The effects of acute and regular exercise on calcium, phosphorus and trace elements in young amateur boxers. Clin Lab 2013; 59(5-6):557-62.
14. Wang L, Zhang J, Wang J, et al. Effects of high-intensity training and resumed training on macroelement and microelement of elite basketball athletes. Biol Trace Elem Res 2012; 149(2):148-54.
15. Liu SZ, Yan H, Xu P, et al. Correlation analysis between bone mineral density and serum element contents of postmenopausal women in Xi'an urban area. Biol Trace Elem Res 2009; 131(3):205-14.
16. Murray D, Miller KC, Edwards JE. Does a Reduction in Serum Sodium Concentration or Serum Potassium Concentration Increase the Prevalence of Exercise-Associated Muscle Cramps? J Sport Rehabil 2015; [Epub ahead of print] PubMed PMID: 25945453.
17. Joo SH, Kim MT, Cho JH, Lee HK, Ahn JO. Blood levels related to the Z-score of bone mineral density in young males and females. J Phys Ther Sci 2015; 27(4):1117-20.
18. Cho JH, Kim MT, Lee HK, Hong IS, Jang HC. Factor analysis of biochemical markers associated with bone mineral density in adults. J Phys Ther Sci 2014; 26(8):1225-9.

19. Stankiewicz, Błażej, Arkadiusz Majchrowski, and Walery Zukow. Nordic walking as an alternative form of physical recreation. Nordic Walking jako alternatywna forma rekreacji ruchowej." Journal of Health Sciences 3.7 (2013): 109-126.
20. Gozhenko, E. A., et al. "Эффективность применения лечебной дозированной «Нордической ходьбы» у пациентов с ишемической болезнью сердца ассоциированной с артериальной гипертензией. The effectiveness of therapeutic use" Nordic walking" in patients with coronary heart disease." Journal Of Health Sciences 2.5 (2012): 52-74.
21. Stankiewicz, Błażej, Arkadiusz Majchrowski, and Walery Zukow. "Nordic walking as an alternative form of physical recreation. Nordic Walking jako alternatywna forma rekreacji ruchowej." Journal of Health Sciences 3.7 (2013): 109-126.
22. Wiech, Monika, et al. "Changes in the ranges of motion in the joints of the upper and lower extremities in elderly people under the influence of the nordic walking training. Zmiany zakresów ruchów w stawach kończyn górnych i dolnych u osób starszych pod wpływem treningu Nordic." Journal of health Sciences 3.5 (2013): 267-276.
23. Gotowski, Rafał, et al. "Leader, przewodnik, instruktor, trener i sędzia Nordic Walking–system przygotowania kadry w dwóch największych organizacjach zajmujących się propagowaniem Nordic Walking w Polsce= Leader, guide, instructor, trainer and judge of the Nordic system of pre." Journal of Health Sciences 3.11 (2013).
24. Gotowski, Rafał, and Marta Żurawik. "Nordic walking instructor training in Great Britain and Poland-case studies." (2013).
25. Гоженко, А. И. "Очерки теории болезни." Гоженко АИ. Одесса (2010). Gozhenko, A.I. "Essays of the theory of disease." Gozhenko AI. Odessa (2010).