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РОССИИ

National Badminton Federation of Russia

Report on the Outcome of the Research on the Influence of Badminton Exercises on Prevention and Treatment of Myopia

Badminton Playing Impact on Refraction, Accommodation, Aberrations and Hemodynamics of the Myopic Eye

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Elena P. TARUTTA	-	Dr. Med. Sci., Prof., Member of European Association for Vision and Eye Research (EVER), Member of Moscow scientific society of ophthalmologists, Head, Department of refractive pathology, binocular vision and ophthalmoergonomics, Helmholtz National Medical Research Center of Eye Diseases (Moscow)
Maya M. CHICHKOVA	-	Teacher of physical culture, School No. 887 (Moscow)
Stefan GEORGIEV	-	Student, I.M. Sechenov First Moscow State Medical University
Fyodor V. GLUKHOV	-	Senior teacher, School " Pokrovsky Quarter" (Moscow)
Peter R. GUK	-	Head, Council for School Sport at the National Badminton Federation of Russia, Coach of the Moscow Sport Department
Sona G. HARUTYUNYAN	-	Dr. Med. Sci., senior research assistant, Moscow Evdokimov State Medical Stomatological University, Faculty of Postgraduate Education
Narine V. KHODZHABEKYAN	-	Dr Med. Sci., Member of Moscow scientific society of ophthalmologists
Gayane A. MARKOSIAN	-	Dr. Med. Sci., Member of Moscow scientific society of ophthalmologists
Sergey V. MILASH	-	Research fellow, Department of refractive pathology, binocular vision and ophthalmoergonomics, Helmholtz National Medical Research Center of Eye Diseases (Moscow)
Ilya V. NOVOKRESHCHENOV	-	Director, School "Pokrovsky Quarter" (Moscow)

Yulia V. PLOTNIKOVA	-	Director, School No. 887 (Moscow)
Camilla A. RAMAZANOVA	-	Dr. Med. Sci., Head, Division of ultrasound diagnostics, Helmholtz National Medical Research Center of Eye Diseases (Moscow)
Natalia A. TARASOVA	-	Dr. Med. Sci., Member of Moscow scientific society of ophthalmologists
Valery G. TURMANIDZE	-	Candidate of Pedagogy, Professor of RAE, Dean of faculty of Physical Education, Rehabilitation and Sport, Dostoevsky Omsk State University

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Acronyms

AAV	Absolute Accommodation Volume
ACD	Anterior Chamber Depth
AP	Anteroposterior axis
BAR	Binocular Accommodation Response
BWF	Badminton World Federation
CDI	Color Doppler Imaging
CRA	Central Retinal Artery
CT	Choroid Thickness
D	Diopter
FPCV	Far Point of Clear Vision
HAT	Habitual Accommodation Tone
HAT OF	Habitual Accommodation Tone in the Open Field
HEAS	Habitually Excessive Accommodation Strain
MAR	Monocular Accommodation Response
NBFR	National Badminton Federation of Russia
NPCV	Nearest Point of Clear Vision
OA	Ophthalmic Artery
OAR	Objective Accommodation Response
PDI	Power Doppler Imaging
RAR	Relative Accommodation Reserve
RMS	Root-Mean-Square deviation from the ideal wavefront.
SA	Spherical Aberration
WHO	World Health Organization
YPR	Yearly Progression Rate

Executive Summary

Background

Badminton is a unique sport that is available not only to professionals but also to people of all ages and skill levels. Through active and varied movements, players not only maintain themselves in good physical shape but also strengthen the body's defenses. Specialists in sports medicine every year reveal more and more positive effects of badminton, which directly affect the health of people and reduce the likelihood of many serious diseases. In particular, many research already proved that regular badminton classes reduce the risk of cardiovascular disease and osteoporosis, allow effective weight control and diabetes prevention, contribute to the overall improvement of the psycho-emotional state of players [1].

Among the less studied effects significant are the issues related to identifying benefits of badminton for the prevention and treatment of "diseases of the digital age" caused by the sedentary lifestyle of modern humans (e.g., physical inactivity, overweight and obesity[2]), as well as increased load on the organ of vision due to the use of computers and numerous gadgets (true and false myopia, other eye diseases).

Of course, myopia is not among the deadly diseases. But this disease is widely spreading and continually progressing. These defects of vision severely impair the quality of life of people and, above all, the younger generation. Experts compare the rate of spread of myopia with the global epidemic.[3] If today myopia affects almost 1.5 billion people, or a quarter of the global population, by 2050, the disease will affect nearly half of the world's population - 4.8 billion people.[4] The vast majority of them are schoolchildren and students.

The National Badminton Federation of Russia (NBFR) is confident that badminton can make a real contribution to solving this problem – not only in preventing and reducing the progression of myopia but also in restoring the quality of vision impaired by excessive eye strain.

This report focuses on the outputs of research on the benefits of badminton in the prevention and treatment of myopia, organized and conducted by the NBFR with the financial support of the Badminton World Federation (BWF).

[1] *15 Health Benefits of Playing Badminton*, New Vision Badminton - Where The Best Comes Together. January 16, 2018. URL: https://www.newvisionbadminton.com/health-benefits-badminton/

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[3] Dolgin E. The myopia boom: Short-sightedness is reaching epidemic proportions. Some scientists think they have found a reason why // Nature. 2015. 18 March. URL: http://www.nature.com/news/the-myopia-boom-1.17120.

[4] Heiting G. Myopia Control - A Cure for Nearsightedness? // All About Vision.com. 2016. 21 March. URL: http://www.allaboutvision.com/parents/myopia.htm

The document presents the evidence-based results of a systematic long-term (during a year) research aimed at studying the impact of regular badminton playing on the prevention and treatment of children not only myopia but also other visual pathologies associated with modern lifestyles.

The subject of the analysis is the impact of features of the badminton exercises (the need to track a moving shuttlecock in combination with deep breathing and various active movements of the head, neck and body) on the change in the physiological characteristics of the visual organ and, accordingly, various ophthalmic diseases associated with reduced visual acuity.

The group of diseases, selected for analysis, is characterized in general by a violation of the focus of the image on the retina. We are talking about the so-called *refractive errors* of different origins.

The refraction errors can be due to both the progression of *myopia* ("true myopia"), which occurs due to the anatomical and optical features of the eyes, and various functional disorders, for example, the effects of *cycloplegia* (a pathological condition associated with paralysis of the ciliary muscle), *spasm of accommodation* (so-called *pseudomyopia*, or" false myopia", which occurs as a result of violations of the ocular (ciliary) muscle).

Attention to the problems of pseudomyopia is especially crucial because false myopia occurs mostly in children older than six years, adolescents and young people. The leading cause of spasm of accommodation is an excessive strain of the organs of vision, for a long time focused on a close object (monitor screen, various gadgets).

Due to the lack of attention to the problem, false myopia almost inevitably turns into true myopia, since overstrain and fatigue of the eyes can lead to irreversible anatomical and physiological changes in the organ of vision.

Methodology

The group for studying has consisted of 40 children (80 eyes) aged 7 to 11 years with various eye refractive errors of a typical nature.

The primary research attention concerned to changes in refraction, accommodation, and blood flow in the vessels of the eye of children systematically engaged in badminton exercises by the method of Valery Turmanidze, Elena Tarutta, Sergei Shakhray (see Annexes 1 and 2). A large number of different indicators were measured before, six months after and one year after badminton classes began.

The autorefractometry, color Doppler and energy Doppler mapping, as well as spectral optical coherence tomography, were used to obtain evidence-based data. Comparative analysis of the aberration level used Wavefront aberrometry methods.

The instrumental base of the research consisted of the following devices:

- Grand Seiko Binocular Open Field Autorefkeratometer WR-5100K (Japan);
- ultrasound scanner VOLUSON-730 Pro (GE Healthcare, USA) and a linear sensor with a frequency of 10-16 MHz;
- Optical Coherence Tomography RS–3000 Advance (Nidek, Japan);
- Wavefront Analyzer OPD-Scan III (Nidek, Japan).

Key Findings

- Outcomes of research have confirmed the positive impact of badminton on the functional state, blood supply to the visual organ and refractive dynamics, which means that this type of physical activity can be used to effective treatment various functional disorders of vision.
- For the first time, the researchers reliably proved the high efficiency of regular badminton playing as a method of treatment of spasm of accommodation (pseudomyopia). The evidence shows that false myopia can entirely disappear after regular badminton exercises, in particular, due to the normalization of the tone of the ciliary muscle and strengthened the ligamentous apparatus of the lens of the eye.
- The data show that regular badminton is one of the effective practices for the prevention of myopia and fight against its progression, in particular, due to the positive effect on the increase in the length of the child's eye (adjusted for natural growth) and a significant improvement in the blood supply of its vascular membrane.

Key Recommendations

- We can reliably recommend the regular badminton exercises as the therapeutic strategies for the treatment of pseudomyopia (along with medication, laser therapy, and conservative treatment), as well as the method to prevent the transition of this disease into true myopia due the subsequent development of irreversible anatomical and physiological changes in the organ of vision.
- The regular badminton exercises have proven value for the treatment of spasm of accommodation and other functional disorders of the organs of vision in children, prevention of myopia, and its progression. Therefore, we believe that they should become part of everyday practice in the education system at all levels – from pre-school educational institutions to universities.
- The methodology of badminton exercises ("Badminton against Myopia"), designed with the support of the NBFR and proven to be useful for the treatment and prevention of eye disease, should be available to all stakeholders (primarily coaches, school and university sport teachers, sports doctors, etc.), for which it is necessary to expand the number of educational activities and various kinds of training. One of the further steps may be the holding of the next international forum "Badminton and Vision" (well-established in Russia) in one of the European countries.
- It is necessary to widely popularize information about the benefits of badminton to combat myopia (in all its forms) - "disease of the digital age", as it will contribute to the solution of several important tasks: the development of badminton as a mass sport, the promotion of healthy lifestyles, improving the overall health of people around the world.

Publications and Conferences

With the support of the NBFR and the BWF, the key outcomes of the research were published in leading peer-reviewed scientific journals in Russian and English (see Annexes 3 and 4). Thus, new evidence and recommendations were promptly presented to the attention of international professional communities, in particular, ophthalmologists, sports scientists, and practitioners.

As part of the project, the NBFR organized and held the First international training and practical seminar "Badminton and Vision" (Kazan, Russia, 2018), which was attended by sports coaches and school sports teachers from around the world. BWF certificates were presented to the participants of the seminar by David Cabello, The Chair of the Development and Sport for All Committee and BWF Executive Board Member.

REPORT

Introduction

This report focuses on the outputs of research on the benefits of badminton in the prevention and treatment of myopia, organized and conducted by the NBFR with the financial support of the Badminton World Federation (BWF).

The document presents the evidence-based results of a systematic long-term (during a year) research aimed at studying the impact of regular badminton playing on the prevention and treatment of children not only myopia but also other visual pathologies associated with modern lifestyles.

The subject of the analysis is the impact of features of the badminton exercises (the need to track a moving shuttlecock in combination with deep breathing and various active movements of the head, neck and body) on the change in the physiological characteristics of the visual organ and, accordingly, various ophthalmic diseases associated with reduced visual acuity.

The group of diseases, selected for analysis, is characterized in general by a violation of the focus of the image on the retina. We are talking about the so-called *refractive errors* of different origins.

The refraction errors can be due to both the progression of *myopia* ("true myopia"), which occurs due to the anatomical and optical features of the eyes, and various functional disorders, for example, the effects of *cycloplegia* (a pathological condition associated with paralysis of the ciliary muscle), *spasm of accommodation* (so-called *pseudomyopia*, or" false myopia", which occurs as a result of violations of the ocular (ciliary) muscle).

Attention to the problems of pseudomyopia is especially crucial because false myopia occurs mostly in children older than six years, adolescents and young people. The leading cause of spasm of accommodation is an excessive strain of the organs of vision, for a long time focused on a close object (monitor screen, various gadgets).

Due to the lack of attention to the problem, false myopia almost inevitably turns into true myopia, since overstrain and fatigue of the eyes can lead to irreversible anatomical and physiological changes in the organ of vision.

Research design

Objectives

We conduct this research:

- to assess the effectiveness of badminton for the treatment and prevention of myopia and other eye diseases associated with reduced visual acuity due to functional disorders.

- to analyze changes in various parameters (refraction, accommodation, blood flow in the vessels of the eye, etc.) at children with various functional disorders of the organs of vision on the background of regular badminton exercises;

- to identify the presence/absence of a relationship between regular badminton exercises and positive changes in the state of visual organs with various functional disorders (myopia, spasm of accommodation, cycloplegia, etc.).

Characteristics of the group under analysis

40 children (80 eyes) with refractive errors from +6.63 to -6.75 D (average -1.28±2.28 D) aged 7 to 11 years (average 9.24±1.06 years) were examined.

Of these, 67 eyes were myopic: 51 eyes with low myopia, 12 with moderate myopia and 4 with high myopia. The remaining 13 eyes were hyperopic or emmetropic.

From the total cohort of patients, a group with spasm and habitually excessive accommodation strain (HEAS) was isolated that counted 20 eyes, of which 7 were myopic, 6 hyperopic and 7 emmetropic.

6 months after badminton practice start, 38 children were examined, and after 1 year of regular badminton playing 27 children (54 eyes) aged 8 to 12 (average 9.42±1.19 years) with various refraction levels (averagely -1.62±1,81 D) underwent through examination.

Of the 54 eyes, 46 eyes were myopic: 37 had low myopia, 7, moderate myopia, and 2, high myopia. The remaining 8 eyes were hyperopic or emmetropic,

Again, from the total cohort of patients, a group with spasm and HEAS) was isolated. It included 14 eyes: 6 were myopic, 4 hyperopic and 4 emmetropic.

Methodology

All patients were measured for uncorrected visual acuity, optimal visual acuity, and visual acuity when wearing their own spectacles. Relative accommodation reserve (RAR), absolute accommodation volume (AAV), far (FPCV) and nearest points of clear vision (NPCV) were determined. Objective measurements of refraction and accommodation response (OAR) were performed using a Grand Seiko Binocular Open Field Autorefkeratometer WR-5100K device (Japan), which enables measuring both uncorrected and optically corrected eye refraction under the conditions of simultaneous presentation of the fixation object in the open field. First, the patient's refraction was determined during the gaze into the distance (with the fixation target located at a distance of 5 m).

The accommodation response was measured in the following way: based on autorefractometry data spherical and cylindrical lenses enabling full correction of the refraction anomaly revealed were mounted into a trial frame, whereupon near dynamic refraction was measured by presenting a viewing object (text No. 4 from the near vision eye chart) at a distance of 33 cm under conditions of binocular (BAR) and monocular fixation (MAR).

The habitual accommodation tone (HAT) was determined as a difference between the readings of the autorefractometer before and after cycloplegia. Besides, all patients were measured for the difference of Grand Seiko WR-5100K Open field autorefractometer readings during the gaze into the distance before and after cycloplegia. The obtained parameter was referred to as the habitual accommodation tone in the open field (HAT OF).

The accommodation tone was considered positive if refraction before cycloplegia was higher (more myopic) than the refraction under cycloplegic conditions, and negative in the reverse case. The positive accommodation tone was marked with the minus sign and the negative, with the plus sign.

To assess the blood flow in the vessels of the eyeball and the retrobulbar space, colour and power Doppler imaging (CDI and PDI) was performed using a VOLUSON-730 Pro ultrasound scanner and a linear sensor with a radiation frequency of 10-16 MHz. The state of the blood flow was tested in the ophthalmic artery (OA) and the central retinal artery (CRA).

Choroid thickness was measured with a spectral OCT RS–3000 Advance device (Nidek, Japan) using the Maculaline scanning protocol in the Choroidal mode. The subfoveal thickness of the choroid was measured manually in microns as the perpendicular distance between the retinal pigment epithelium/Bruch membrane complex and the inner edge of the sclera (chorioscleral interface).

All patients underwent wavefront aberrometry in a darkened room before and after medical cycloplegia on an OPD-Scan III (Nidek) aberrometer. 1% cyclopentolate dehydrochloride was used twice, with an interval of 10 minutes, aberrometry was performed 40 minutes after the first instillation).

Since the action of cycloplegics is accompanied by mydriasis, which increases the level of many aberrations, we analyzed the wavefront before and after instillation of cyclopentolate with a fixed pupil width in order to assess the impact of cycloplegia alone, and not that of mydriasis. Aberrations were analyzed with a pupil width of 3 mm both without cycloplegia and under cycloplegic conditions (in the latter case, with the option of selecting a 3 mm zone). We analyzed Zernike coefficients up to the 12th order inclusive: vertical and horizontal slope (tilt 1, tilt 2), vertical and horizontal trefoil (trefoil 6, trefoil 9), vertical and horizontal coma (coma 7, coma 8), spherical aberration (SA), mean square deviation from the ideal wavefront (RMS).

All tests were taken before badminton practice start, 6 months into the practice, and 1 year after start of badminton practice according to the technique proposed by by the method of Valery Turmanidze, Elena Tarutta, Sergei Shakhray (see Annexes 1 and 2).

Research Devices

The instrumental base of the research consisted of the following devices:

- Grand Seiko Binocular Open Field Autorefkeratometer WR-5100K (Japan);
- ultrasound scanner VOLUSON-730 Pro (GE Healthcare, USA) and a linear sensor with a frequency of 10-16 MHz;
- Optical Coherence Tomography RS–3000 Advance (Nidek, Japan);
- Wavefront Analyzer OPD-Scan III (Nidek, Japan).

Evidences

Refraction, accommodation, and hemodynamics:

Refraction measured on an autorefractometer with a narrow pupil before workout averaged –2.11 D. After 6 months of workouts, the average refraction was –2.39 D, and after a year from workout start it dropped to –2.21 D. Refraction measured on an autorefractometer with a dilated pupil before workout averaged –1.62 D. After 6 months of workouts, the average refraction was –1.96 D, and after a year from workout start it was still –1.96 D. Thus, on average, the refraction only showed an increase of 0.34 D over the first 6 months, whereas in the next 6 months it remained stable. The yearly progression rate (YPR) was 0.34 D. In myopic cases, average YPR was 0.43 D; specifically, in low myopia it was 0.42 D, in moderate myopia, 0.37 D and in high myopia (both eyes of one child) it was 0.63 D. In patients with spasm and HEAS, over the year the refraction fell by 0.92 D for a narrow pupil and by 0.07 D for a dilated pupil.

Before workouts, average HAT was –0.49 D. 6 months into the workouts, it was –0.43 D and after a year of workouts was –0.25 D. In spasms and HESA, HAT sank from –1.7 D to 0.85 D, i.e. by 0.85 D.

This means that in practice the HAT parameter dropped by half over the year. The results of previous studies demonstrated that lowered accommodation tone is a favourable sign, associated with slower myopia progression.

Refraction measured on an Open Field autorefractometer with a narrow pupil before workout averaged –1.49 D. After 6 months of workouts, the average refraction was –1.9 D, and after a year from workout start it was –2.1 D. Refraction measured on an open field autorefractometer with a dilated pupil before workout averaged –1.4 D. After 6 months of workouts, the average refraction was –1.63 D, and after a year from workout start it was –1.76 D. Thus, the average refraction increased by 0.23 D after 6 months and by 0.13 over the next 6 months. YPG was 0.36 D, which means that, on average, the figures coincide with those shown by a conventional autorefractometer.

HAT OF amounted to –0.19 D averagely before workouts, 6 months into the workout practice it was –0.17 D, and 1 year after workout start it was –0.34 D. This means that if a really distant object is fixed in the open field, the accommodation tone showed the least level at all times.

Binocular accommodation response before badminton practice showed an average of –1.99 D. After 6 months of workouts BAO was –2.04 D and after 1 year it was –2.09 D. The maximum BAO increase was observed in high myopia, where it grew by 0.37 D, and in moderate myopia (by 0.35 D).

Monocular accommodation response before badminton practice was –1.78 D on average. After 6 months of workouts MAO was –1.84 D and after 1 year it was –1.89 D. The maximum MAO increase was observed in hyperopia and emmetropia – by 0.35 D and in cases of spasm and HEAS with myopia (by 0.37 D). It is thus seen that the accommodation response tended to increase after badminton activities, where the main element of the game is tracking a moving shuttlecock. The data obtained indicate an increase in accommodative ability in children practicing badminton.

Before workouts, RAR showed an average of 1.8 D (with the norm being 3.0 D). After 6 months of workouts, RAR reached the level of 2.22 D on average, i.e. it grew by 0.42 D (23.3%). A year after practice start, RAR increased by 0.55 D (30.5%) against the initial values and reached, averagely, the level of 2.35 D. The maximum RAR increase of 2.0 D was observed in moderater myopia. As a matter of fact, in moderate myopia, spasm and HEAS with myopia, RAR increased to achieve nearly the normal values. In spasm and HEAS with emmetropia and hyperopia RAR had normal values and did not change.

FPCV revealed, before workouts, an average value of –1.45 D. After six months of practice it moved closer to the eye by 0.22 D and reached the level of –1.67 D, which approximately corresponded to the degree of myopia progression. After another 6 months, FPCV moved another 0.05 D to the eye. In hyperopia and emmetropia, FPCV moved further from the eye by 0.81 D, which indicated an increase of negative accommodation reserves.

NPCV revealed, before workouts, an average value of –6.76 D. After six months of practice it was –6.56 D. After another 6 months, NPCV was, on average, –7.15 D, i.e. it moved closer to the eye by 0.39 D.

Thus, after one year of practice, AAV tended to increase due to NPCV getting closer to the eye, i.e. due to an increase in accommodation ability.

Before workouts, the average level of AAV was 5.31 D. After six months of workouts, AAV was 4.89 D and after one year it was 5.43 D. In high myopia, AAV dropped by 1.37 D, which however may be accounted for by the peculiarities of the device, since, due to device characteristics, NPCV can be determined up to a maximum of –9.0 D whilst, in young age, NPCV may be located much closer to the eye. In spasm and HEAS with emmetropia, AAV fell by 1.5 D. In hyperopia and emmetropia, it increased by 1.38 D.

Choroid thickness (CT) was, before badminton activities, 303 microns on average. On the whole, CT correlated before these activities with the anteroposterior (AP) axis, varying from 360 microns in hyperopia to 292 microns in high myopia. A group of moderate myopia could be isolated: it had the least CT, which was 273 microns (whilst low myopia revealed 307 microns and high myopia, 292 microns!). After 6 months of workouts, CT dropped to 306.8 microns and in another 6 months it was 306.6 microns.

The maximum tendency toward CT increase was observed in high myopia. In the group of patients with spasm and HEAS, CT remained the same.

The AP axis, before badminton activities, averaged 23.89 mm. It was minimal in hyperopia (22.5 mm) and maximal in high myopia (26. 72 mm). After 6 months of workouts, the average AP axis was 24.12 mm, and after a year, 24.15 mm so that the yearly increase amounted to 0.26 mm.

According to the data of Marina Sitka, AP axis grows naturally in patients with stable emmetropia, too: at the age of 8-9 years, the average growth amounts to 0.132±0,02 mm/year. The author proposed to make appropriate adjustments for the natural eye growth. So it can be said that AP axis grew 0.13 mm on average, which corresponds with myopia progression rate in this group. In our group of patients with hyperopia and emmetropia, AP axis increased by 0.17 mm in a year with the refraction unchanged, which can be viewed as physiological eye growth. The maximum increase of eye length was observed in the first 6 months of the follow-up. In the group with spasm and HEAS with hyperopia, the AP axis did not change. Across the myopic group, AP axis revealed an average increase of 0.31 mm a year, but the eye length actually occurred in the first 6 months of the follow-up. Considering the amendment of 0.17 mm for natural eye growth, the increase of AP axis amounted to 0.14 mm, which is consistent with refraction change.

The anterior chamber depth (ACD) before badminton activities averaged 3.64 mm, was minimal in hyperopia with spasm (3.1 mm±), and maximal in low myopia (3.71 mm). In myopia, ACD is decreasing from 3.71 mm in low myopia to 3.68 in moderate myopia and 3.49 in high myopia. As compared to emmetropia and hyperopia, ACD displays an increase as big as 0.19 mm, which is a factor of emmetropization. After 6 months, ACD amounted to 3.67 mm and after a year, 3.69 mm. Low myopia reveals the maximum deepening of the anterior chamber by 6 microns a year. Anterior chamber deepening is a factor of emmetropization as it brings the focal point closer to the retina.

The blood flow rate in the ophthalmic artery (OA) before badminton activity was, averagely, 36.28 mm/sec. After 6 months of workouts the parameter grew to 39.3 mm/sec and after a year it was 40.34 mm/sec. In CRA, before badminton activities, the blood flow rate showed an average of 9.7 mm/sec, whilst after 6 months of workouts it rose to reach 10.58 mm/sec and after a year it was 10.74 mm/sec. The lowest blood flow rate in OA was observed in the group of moderate myopia and the highest rate, in high myopia! In CRA, the lowest blood flow rate was noted in high myopia, and the fastest in hyperopia and emmetropia. An increase in yearly blood flow rate was noted for all groups in both OA and CRA: the OA maximum addition was in high myopia (5.5), and the CRA maximum addition was in HEAS with myopia (1.8).

Aberrations:

Spherical aberrations (SA) in myopia were higher than those in hyperopia and had a negative value: In hyperopia, their value was positive. In HEAS, SA were positive but they were lower than in hyperopia. After cycloplegia, SA showed a twofold decrease in myopia, a 2.5-fold increase in hyperopia, and a 5-fold increase in HEAS, remaining positive. After 6 months of workouts, negative SAs showed a 20-fold reduction and transferred to positive. In hyperopia, SA did not change, while in HEAS they showed a 1.5-fold growth and became equal to those for hyperopia. After cycloplegia, SA showed almost no change in myopia; in contrast, they showed a 5-fold growth in hyperopia and a 9-fold growth in HEAS. After 1 year, SA remained to be lower in myopia as compared with the original values, and the difference was 10-fold. There was no response to cycloplegia. In hyperopia, SA showed a 2-fold reduction, and the reduction with respect to the original values was also 2-fold. Under cycloplegia, SA showed a 3-fold growth. In HEAS, SA returned to the original values and moreover, they showed an 11-fold increase against the original values. Under cycloplegia , SA showed a 15-fold decrease.

RMS showed an increase after 6-month-long badminton workouts for the narrow pupil and revealed no change for the dilated pupil. After 1 year, the total aberrations decreased in all groups for the narrow and the dilated pupil, which may indicate improved vision quality. In myopia and emmetropia, RMS showed no significant difference and after a year decreased in both cases.

In myopic patients, Tilt 1 was two times higher and had a positive value while in hyperopia its value was negative. Under cycloplegia, in myopic patients Tilt 1 increased and in hyperopic patients it decreased in absolute values. Dynamically, myopic patients showed a statistically significant increase of Tilt 1, whereas hyperopic patients showed a decrease in Tilt 1 after 6 months, which returned to the original level after a year. In spasm and HEAS, Tilt 1 had a minimum value and was decreasing for a dilated pupil; after 6 months, this type of aberrations showed a reduction but by the end of the year Tilt 1 returned to its original values.

Tilt 2 in myopic patients was significantly higher than in hyperopic patients. In patient with spasm and HEAS Tilt 2 had minimal values. Under cycloplegia, Tilt 2 showed a 1.5-fold reduction in myopic patients (50%), in hyperopic patients it showed an impressive 25-fold reduction and in HEAS, a 2-fold reduction. After 6 months, Tilt 2 reduced 2.5 times in the myopic group but did not change in hyperopia. There was practically no response to cycloplegia from myopic patients; however, in hyperopia Tilt 2 showed an 8-fold decrease and in HEAS a 1.5-fold increase. After a year, the effect remained in myopia, whilst in hyperopia Tilt 2 showed a steep increase and transferred to positive values, and the response to cycloplegia remained the same (it showed a 1.5-fold reduction). In HEAS, Tilt 2 fell even more but the response to cycloplegia was reverse as it increased by a factor of 25.

Trefoil 6, before badminton activities, did not show notable differences in patients with myopia, hyperopia and HEAS. Under cycloplegia, Trefoil 6 did not change in any of the patients. After 6 months, these aberrations did not change in myopic patients, yet they showed a 2-fold reduction under cyclopliegia. In hyperopia, Trefoil 6 showed no change and no response to cycloplegia. In patients with spasm and HEAS, these aberrations showed a 1.5-fold increase, which decreased 5 times after cycloplegia. After 1 year, Trefoil 6 reduced 1.7 times in myopic patients, who revealed no response to cycloplegia. In hyperopia, these aberrations had the same values and the response to cycloplegia was statistically insignificant. In patients with spasm and HEAS, Trefoil 6 dropped 4 to 5 times and the response to cycloplegia was statistically insignificant, too.

Trefoil 9 was, before badminton activities, 5 times higher in patients with myopia than in those with hyperopia, and had a positive value while in hyperopic patients its value was negative. Myopic patients did not respond to cycloplegia, while hyperopic patients showed a 5-fold increase in Trefoil 9 in absolute values. After 6 months of badminton workouts, Trefoil 9 reduced 12 times in myopic patients, while after cycloplegia these aberrations transferred from positive to negative values. In patients with hyperopia, Trefoil 9 showed almost no change and no response to cycloplegia. In patients with spasm and HEAS these aberrations did not change but showed a triple reduction after cycloplegia. After a year of workouts, Trefoil 9 in myopia remained lower than the initial values and after cycloplegia its values increased by a factor of 5 and transferred from negative to positive. In patients with hyperopia, Trefoil 9 showed almost no change, and the response to cycloplegia was completely nonexistent. In patients with spasm and HEAS, these aberrations showed an approximate 1/7-fold increase in absolute values, and after cycloplegia these aberration increased 5 times and transferred from negative to positive values.

Coma 7 in myopic patients before badminton activities was positive and its value was 4 times as high as in hyperopic patients, for whom the value was negative. In patients with spasm and HEAS, the absolute values of these aberrations were the same as in myopic patients but they were negative. After cycloplegia, Coma 7 did not change at all in myopic patients and almost did not change in hyperopia, whereas in spasm and HEAS it showed an 8-fold increase and transferred from negative to positive values. After 6 months of workouts, у пациентов с миопией Coma 7 showed a 1.5-fold increase in myopic patients, and these aberrations increased 1.5 times after cycloplegia. In patients with hyperopia, Coma 7 showed no changes after 6 months, either for the narrow or for the dilated pupil. In patients with spasm and HEAS, Coma 7 did not change, while after cycloplegia the aberrations increased by a factor of 6 and transferred from positive to negative values. After 1 year, in myopic patients Coma 7 showed a double increase against the initial values but dropped somewhat after cycloplegia. In patients with hyperopia, no changes were observed but the value dropped slightly after cycloplegia. In patients with HEAS, Coma 7 increased 3 times compared with the original values and negative values transferred to positive values. After cycloplegia, aberrations increased 1.7 times.

Coma 8, before badminton activities, was 10 times lower in patients with myopia than in hyperopic patients, and after cycloplegia the values increased 3 times in myopes, and 1.5 times in hyperopic patients. The values of Coma 8 in patients with HEAS were close to those in hyperopia. After cycloplegia, these aberrations sank 4.5 times. After 6 months, Coma 8 values in myopic patients decreased and transferred to negative values. After cycloplegia, aberration values did not change. In patients with hyperopia after 6 months the values of Coma 8 did not change, yet after cycloplegia they increased and transferred from negative values to positive ones. In HEAS patients, Coma 8 remained unchanged while cycloplegia caused a slight response. After a year, myopic patients showed a reduction in these aberrations, whose values transferred from positive to negative. After cycloplegia, Coma 8 remained at the same level. In hyperopic patients the aberrations grew and from negative transferred to positive values. After cycloplegia, Coma 8 reduced by 3.5 times. In patients with HEAS, Coma 8 dropped and transferred from positive to ncgative values. After cycloplegia, its values did not change.

Data Analysis

Thus, after 1-year-long regular badminton workouts the following changes were noted.

1. Uncorrected visual acuity of the whole group rose from 0.34 to 0.42: in children with emmetropia and hyperopia it remained equal to 1.0, in myopic children it did not change, in HEAS and accommodation spasm it grew from 0.66 to 0.8. The optimally corrected visual acuity in all children remained the same: 1.0. The power of the correcting lens (subjective refraction) decreased in hyperopia and HEAS from –0.16 D to 0.07 D in hyperopia and increased in myopia from –1.57 D to –1.84 D in myopia.

2. During the year, the refraction increased by 0.1 D for the narrow pupil and by 0.34 D for the dilated pupil. The best effect, among all students, was achieved in children with spasm and habitually excessive accommodation strain: after a year, they showed a refraction decrease of 0.92 D for the narrow pupil, which means that spasm was eliminated altogether. This is also evidenced by a nearly 2-fold decrease in the habitual accommodation tone for tall groups.

3. RAR (accommodation) increased by 30%.

4. Over the year, the length of the eye increased by 0.17 mm in children without myopia and by 0.14 mm in children with myopia (adjusted for natural eye growth). Both the eye length and refraction changes testify to a very slow myopia progression in children practicing badminton for a year.

5. With badminton activities, blood flow increase in the ophthalmic artery and the central retinal artery could be noted in all groups of children.

6. A tendency towards choroid thickness increase (i.e. blood supply increase in the choroid) was noted, especially for high myopia.

7. Aberrations of eye wavefront were investigated: RMS Исследовали аберрации волнового фронта глаза: RMS (mean square deviation of wavefront aberrations – the cumulative index of aberrations), SA (spherical aberrations), Tilt (wavefront slope), Trefoil, Coma (they testify to the consistency of the anatomical and optical elements of the eye).

With regular badminton activities, a positive dynamics of the following aberrations were noted: a) a reduction in negative SAs and even their transition to positive ones; this may indicate a normalization of the tone of the ciliary muscle, which correlates with the increase in accommodative ability established in our research; b) a decrease in RMS, indicating an improvement in the quality of vision; c) reduction of Trefoil 9 in case of myopia and spasm of accommodation, decrease in Coma 8, which may indicate some strengthening of the ligamentous apparatus of the lens.

8. The research into the effect of badminton practice on the functional state, blood supply of the eye and the dynamics of refraction enable a positive assessment of this type of physical activity as a method for treating accommodation spasm and other functional disorders, prevention of myopia and its progression.

Publications and Conferences

With the support of the NBFR and the BWF, the key outcomes of the research were published in leading peer-reviewed scientific journals in Russian and English (details see Annexes 3 and 4).

Tarutta E.P., Tarasova N.A., Markosyan G.A., Milash S.V., Ramazanova K.A. The impact of badminton practice on refraction, accommodation and hemodynamics of eyes with myopia. Sovremennay optometrija, 2019; 1: 22-29. (In Russian);

Tarutta E.P., Tarasova N.A., Markosyan G.A., Milash S.V., Arutyunyan S.G,. Georgiev S. The state and dynamics of the wavefront of the eye in children with different refractions engaged in regular sports (badminton) activities. Russian ophthalmological journal. 2019; 12(2): 49-58. (In Russian). doi: 10.21516/2072-0076-2019-12-2-49-58

Thus, new evidence and recommendations were promptly presented to the attention of international professional communities, in particular, ophthalmologists, sports scientists, and practitioners.

As part of the project, the NBFR organized and held the First international training and practical seminar "Badminton and Vision" (Kazan, Russia, 2018), which was attended by sports coaches and school sports teachers from around the world. BWF certificates were presented to the participants of the seminar by David Cabello, The Chair of the Development and Sport for All Committee and BWF Executive Board Member.

Key Findings

- Outcomes of research have confirmed the positive impact of badminton on the functional state, blood supply to the visual organ and refractive dynamics, which means that this type of physical activity can be used to effective treatment various functional disorders of vision.
- For the first time, the researchers reliably proved the high efficiency of regular badminton playing as a method of treatment of spasm of accommodation (pseudomyopia). The evidence shows that false myopia can entirely disappear after regular badminton exercises, in particular, due to the normalization of the tone of the ciliary muscle and strengthened the ligamentous apparatus of the lens of the eye.
- The data show that regular badminton is one of the effective practices for the prevention of myopia and fight against its progression, in particular, due to the positive effect on the increase in the length of the child's eye (adjusted for natural growth) and a significant improvement in the blood supply of its vascular membrane.

Key Recommendations

- We can reliably recommend the regular badminton exercises as the therapeutic strategies for the treatment of pseudomyopia (along with medication, laser therapy, and conservative treatment), as well as the method to prevent the transition of this disease into true myopia due the subsequent development of irreversible anatomical and physiological changes in the organ of vision.

- The regular badminton exercises have proven value for the treatment of spasm of accommodation and other functional disorders of the organs of vision in children, prevention of myopia, and its progression. Therefore, we believe that they should become part of everyday practice in the education system at all levels – from pre-school educational institutions to universities.

- The methodology of badminton exercises ("Badminton against Myopia"), designed with the support of the NBFR and proven to be useful for the treatment and prevention of eye disease, should be available to all stakeholders (primarily coaches, school and university sport teachers, sports doctors, etc.), for which it is necessary to expand the number of educational activities and various kinds of training. One of the further steps may be the holding of the next international forum "Badminton and Vision" (well-established in Russia) in one of the European countries.

- It is necessary to widely popularize information about the benefits of badminton to combat myopia (in all its forms) - "disease of the digital age", as it will contribute to the solution of several important tasks: the development of badminton as a mass sport, the promotion of healthy lifestyles, improving the overall health of people around the world.

APPENDICES

Appendix 1

V. G. Turmanidze, E. P. Tarutta, S. M. Shakhrai. Badminton Against Myopia. Methods of organization of physical education incorporating elements of the game of badminton for prophylaxis and correction of eyesight impairment (for teachers of comprehensive schools): instructional manual. — M.: Kuchkovo Pole Publishers, 2017. — 80 p.: il.

Appendix 2

Turmanidze V.G., Fomenko A.A. Four Lectures on Badminton and its Health Benefits. Presentations in PowerPoint. – 65 slides.

Appendix 3

Tarutta E.P., Tarasova N.A., Markosyan G.A., Milash S.V., Ramazanova K.A. The impact of badminton practice on refraction, accommodation and hemodynamics of eyes with myopia. Sovremennay optometrija, 2019; 1: 22-29. Russian and English Versions.

Appendix 4

Tarutta E.P., Tarasova N.A., Markosyan G.A., Milash S.V., Arutyunyan S.G., Georgiev S. The state and dynamics of the wavefront of the eye in children with different refractions engaged in regular sports (badminton) activities. Russian ophthalmological journal. 2019; 12(2): 49-58. DOI: 10.21516/2072-0076-2019-12-2-49-58. Russian and English Versions.

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