НАЦИОНАЛЬНАЯ ФЕДЕРАЦИЯ БАДМИНТОНА 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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Contents

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).

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[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.

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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.

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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);
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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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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

MOSCOW
2017

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.

ISBN 978-5-9950-0782-1

This instructive manual focuses on the content of the program of physical training with elements of badminton for secondary school teachers, methods of the organization of activities for the prevention and correction of visual impairment in school children grades 1–11. A consistent training program is outlined inclusive of specialized exercises, outdoor games with elements of badminton and exercise to improve badminton technique.

The manual is recommended for teachers of physical education, staff of basic, preparatory and special medical needs groups of physical education, and coaches. The manual may aid in the development and implementation of basic and supplemental educational programs of primary, basic general, secondary (complete) general education.

Format: 145 × 215 mm
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ISBN 978-5-9950-0782-1

Preface

This instructional manual is created with the goal of expansion the horizons of our understanding of the possible ways of development of the game of badminton.

Once you finish this manual, you will see that badminton is much more than just a sport.

Badminton can become the key to solving one of the most pressing public health problems worldwide: the progressive deterioration of vision. In this manual we aim, first of all, to describe the methods and ways to address this problem in children and adolescents.

Ninety percent of the information perceived by an average person comes to him through the gift of sight. In some countries, myopia (also commonly referred to as nearsightedness) has reached the scale of a national disaster. For example, in Japan myopia affects about 70% of the population, in South Korea and Singapore — over 80%, in China — an average of 70% and in Taiwan — 96% (among students and young people aged 18–20 years). Today myopia affects a quarter of the world population, and by 2050 this figure will double.

Badminton can beat this disease.

Thence, the main idea of this book: it is time to get rid of myopia!

When we discuss the future of badminton, the prospects of our federation, our sport looks to us primarily as a professional sport.

We believe it is a manifestation of a kind of "myopia". If we try to be objective, we will understand that new perspectives can provide a strategy for the development of badminton as a mass sport. Also, they will be useful for the development of both the badminton federations and professional play.

What do we mean? Any grantor of funds or investor, be it the State or a private entrepreneur, would like to see the maximum return on funds invested in the project. In this case, in badminton.

In today's rapidly changing world, the term return on investment refers not only to financial profit. Today, much attention is paid to the ability of a project to solve some of the urgent problems of the society, to produce positive social change, that is, produce a specific volume of social impact.

Such projects — with a large social impact — are provided with an opportunity to be developed and receive financial support. This applies not only to sports. We are talking about all kinds of projects.

The project "Badminton and Vision" can turn badminton into a sport for the masses!

In turn, the development of badminton as a mass sport, will allow, as we say in Russia, to kill two or three hares with one shot.

First. Introduction of badminton lessons in schools, creation of badminton courts in city yards and garths, as well as on college campuses will be positively received by parents and children. And most importantly, will be supported by local and regional authorities and benefactors.

Since we are talking about implementation of a healthy lifestyle, prevention of illnesses, especially myopia. As well as a decrease in rates of youth crime on the local level, because children will be involved in sports activities.

Second. The growing interest of young people in the game of badminton increases the chances of early detection and development of the future stars and Olympic champions. One can see a simple logical chain of events:

— More people get involved in badminton,

— More talented players are identified,

— Higher entertainment value,
— More public comes to stadiums,
— Advertising budget grows,
— Greater opportunities for sports federations.

Third. Expansion of the mass base of badminton increases the public interest in our sport, and thus attracts the attention of the authorities and sponsors.

Our pilot project in Kazan provides proof for these theses.

Initially, the National Federation of Badminton Russia did not have in its budget the necessary funds for the construction of the Badminton Center in Kazan. Everything — a luxurious building with spacious rooms and necessary equipment — appeared only as a result of active promotion of the concept of badminton as a mass sport and a part of the healthy lifestyle.

It took holding a lot of meetings before we succeeded in convincing the authorities and sponsors regarding the social significance of the project. Convincing arguments, including patents, have helped to prove that the project will create a lot of positive changes for the inhabitants of the region and, above all, to young people.

Two years later, the center was built — in a record time. The videos from the opening can be seen at https://youtu.be/LJY-2qQvubFk and https://youtu.be/tGIvOS2A08U

Badminton World Federation President Poul-Erik Hoyer, who honored us by taking part in the opening ceremony of the Kazan Centre saw how much interest and enthusiasm was caused by the event. We can say that in day we had involved in the orbit of our sport, the equivalent of a whole European country, since Kazan's population exceeds 1.2 million, and the republic's population reaches nearly 4 million!

Most importantly, we now have not only the practical experience, but a complete finished project with construction plans and financial estimates, which can be replicated not only in Russia but in other countries.

We are making every effort to open similar badminton centers in 11 major Russian cities by 2021.

Evidence of the effectiveness of badminton in the treatment of children's myopia, as explicated in patents and supported by medical statistics is extremely convincing. The Ministry of Education and Science of Russia made a decision to include badminton in the program of all schools in the country as an additional part of the physical education curriculum.

In September 2016, we hosted the World Badminton Championship among students. In February 2018 Russia will once again host the European Badminton Championship. This is also a testament to the success of our strategy.

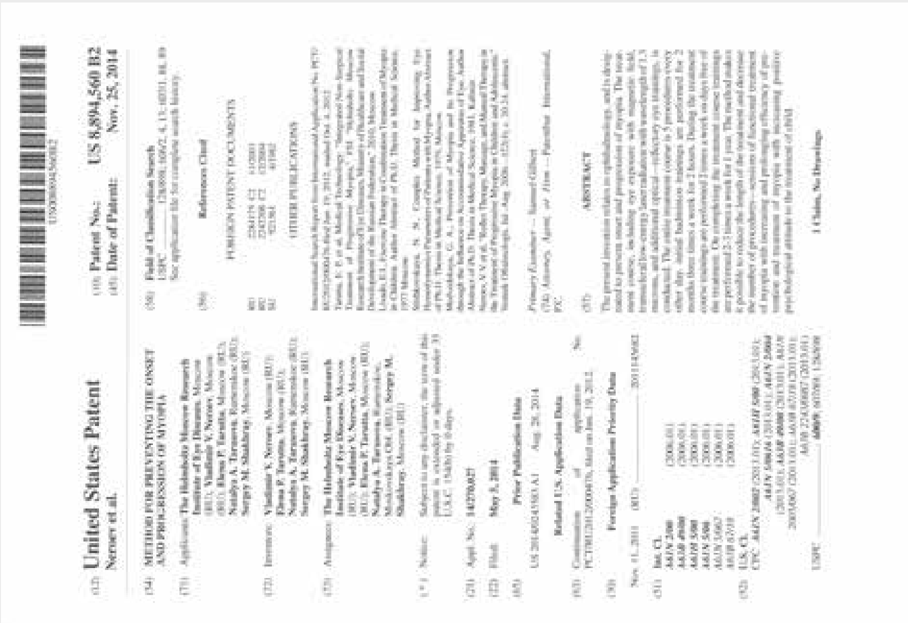
In conclusion, it is worth noting the following:

Russian National Badminton Federation is open to all forms of consulting and cooperation. Everyone who is willing to act outside the box and make an investment into the expansion of the mass base of badminton, can utilize our experience. We are ready to share it in a completely open fashion.

First, it is the experience of promoting badminton in schools and universities. Second, the experience of cooperation (interaction) with physicians and centers of correction of myopia. Third, the accumulated skill of interaction with the central and local authorities. And finally, it is an experience of cooperation with the media.

National Badminton Federation Russia is ready to cooperate with all interested sports federations and partners!

Sergey Shakhrai



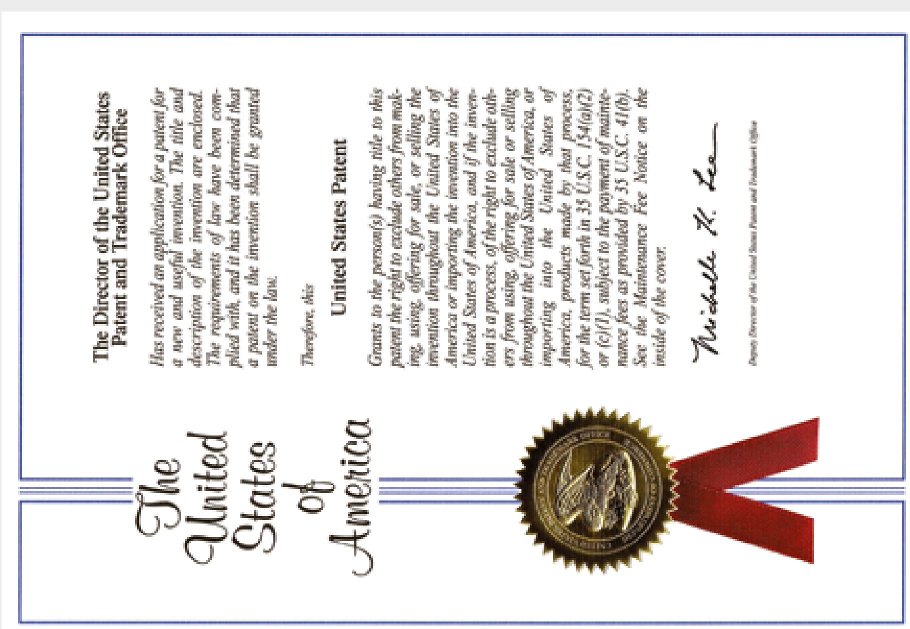
United States Patent

Nersev et al.

Patent No.: US 8,894,560 B2

Date of Patent: Nov. 25, 2014

METHOD FOR PREVENTING THE ONSET AND PROGRESSION OF MYOPIA



The United States of America

The Director of the United States Patent and Trademark Office

Has received an application for a patent for a new and useful invention. The title and description of the invention are enclosed. The requirements of law have been complied with, and it has been determined that a patent on the invention shall be granted under the law.

Therefore, this

United States Patent

Grants to the person(s) having title to this patent the right to exclude others from making, using, offering for sale, or selling the invention throughout the United States of America or importing the invention into the United States of America, and if the invention is a process, of the right to exclude others from using, offering for sale or selling throughout the United States of America, or importing into the United States of America, products made by that process, for the term set forth in 35 U.S.C. 154(a)(2) or (c)(1), subject to the payment of maintenance fees as provided by 35 U.S.C. 41(b). See the Maintenance Fee Notice on the inside of the cover.

Michelle K. Lee

Deputy Director of the United States Patent and Trademark Office

Method for preventing the onset and progression of myopia

Introduction

Vision is the most powerful source of information about the outside world. As we already noted, 85–90% of the information comes to the brain from the visual pathway originating at the eye. The partial or total disruption of its function causes a number of complications in the physical and even psychological state of students.

The number of people suffering from myopia (commonly known as nearsightedness or shortsightedness) has increased significantly in recent decades. For many people eyeglasses or contact lenses are an inherent part of everyday life, since about 1 billion men and women in the world require eyeglasses. Myopia usually develops in childhood and adolescence. According to various authors, incidence of myopia in school children increases from 2.3% in the first grade to 26.2% or more in the tenth grade. This percentage is even higher among university students. Although the hereditary factors play a fairly large role in the development of myopia, they are not always decisive. At the same time a large number of people, even with minor deficiencies in vision, obtain exemption from physical education, thereby exacerbating their condition.

We distinguish five basic visual functions:

1) central vision;
2) peripheral vision;
3) binocular vision;

4) light perception;
5) color vision.

Please note that the central vision in students is involved mainly while studying theoretical disciplines. Physical education classes put more emphasis on peripheral vision, color- and light perception.

Causes of myopia can be divided into hereditary (inheritable), congenital (developed in utero) and acquired (caused by external factors).

As time progressed, the opinions of scientists about the mechanisms of development and progression of myopia had undergone fundamental changes. Specialists began to evaluate the possibility and need for regular physical training in myopia anew. Previously, people with myopia were strongly recommended to avoid physical training and limit their activity to physical therapy, i. e., myopia and physical culture in general were considered to be incompatible.

Currently moderate physical exercise is recommended as an effective means of preventing disease progression. Results of scientific studies show that sufficient and regular physical activity helps to increase the efficiency of functioning of all organs and body systems, including the ciliary muscles of the eye responsible for the visual accommodation, as well as the strengthening of the eye vessels and improvement of blood circulation.

Upon restriction of physical activity the opposite is observed: deterioration of blood supply to various organs, including the eyes, and the diminishment of the accommodation capacity. Reduction of total physical activity and the hypodynamic lifestyle combined with significant visual loads commonly seen in schoolchildren and students contribute to the development and progression of myopia. The goal of prevention and treatment of myopia in children and young people is achieved with a complex approach inclusive of the combination of general physical activity, aimed at overall development, with special exercises that improve blood flow to the eyes and cause the strengthening of the ciliary muscle.

Currently, students of educational institutions is most susceptible to myopia. It is 4 times more common in families where myopia had beeb traced in a number of generations. This implies that the occurrence of myopia can be due to heredity, past illnesses, and adverse conditions of visual work.

Myopia is fairly widespread and is due to increased visual load, as well as social and geographical aspects. It is also noted that among students who are often and chronically ill or physically underdeveloped, myopia often develops and progresses faster than in those engaged in physical activity.

The teaching of badminton in educational institutions is based on a common method of learning of the game at the initial stages, which includes preparatory, primary and final parts of the training.

General Developmental Exercises for Children with Diminished Vision

General Recommendations and Contraindications

General developmental exercises must be performed in the strict sequence: from the top down (neck, upper body, trunk, lower limbs), from small joints to large (hands, elbows and shoulder joints, foot, knee and hip joints), from simple exercises to the more complex. This is to avoid injury and to properly prepare the body to subsequent loads. We believe that such exercises are best performed at an average pace, while making frequent pauses for oculomotor exercises and breathing exercises. Not recommended: abrupt changes in body position, jumping on hard surfaces, sharp slopes, holding the breath.

General Developmental Exercises on the Spot

In the preparatory sessions a great amount of attention is paid to the general developmental exercises (GDE) in place, involving all muscle groups, with emphasis on the neck and spinal sections, wrist and hand. Next stage is walking on toes, on heels, on the inner and outer edges of the feet, rises from heel to toe while extending arms and tilting the head upwards; breathing exercises combined with stretching.

General Developmental Exercises in Motion

For the physical training with children of elementary grades we recommend to use the general developmental exercises that mimic the movements of animals and birds. This helps to interest children, providing lessons in an entertaining way to prepare them for the main exercises.

1. Walking in a circle (on the toes, hands on waist; on the heels, hands behind head; on the outer edge of the foot, lifting hips high);
2. Walking like an elephant (straight back, hands on waist, big steps, front leg is bent at the knee, the rear foot remains straight);
3. Walking like a penguin (straight back, small frequent steps);
4. Moving like a bird: roosters, egrets (thigh of the forward leg is lifted high, back straight, shoulders are wide and straight, looking forward and upward);
5. Moving like a goose (exercise from the starting position (SP) in the squat, hands on waist, back straight);
6. "Flying" like a bird (moving hands up and down like a flap, performed while running).

General Developmental Exercises Combined with Oculomotor Gymnastics

When exercising, do not turn the head and keep the eye movement slow.

1. Starting position (SP): lying on the back, arms to the side, holding a colored tennis ball or a shuttlecock in the right hand. Unite hands above the chest, pass the ball to the left

hand and back to the SP, all the time looking at the ball. Repeat 10–12 times (depending on age).

2. SP: lying on the back, arms to the side. In the right hand hold a shuttlecock or a ball of red color, in the left hand of yellow color. Perform crosswise movements with straight arms. With your eyes follow the motion of the object in one, then the other hand. Breathe in when arms are extended, breathe out when arms are crossed. Perform 5–6 sets.
3. SP: sitting, support with hands behind the back, legs are straight and elevated. Move the legs in a crosswise motion. With your eyes follow the toe of one foot (on feet one can wear thick colored elastic hair bands (scrunchies) or brightly colored socks of different colors). Do not turn your head. Breathing is arbitrary. Perform 10–12 sets.
4. SP: stand in the basic position, holding a hoop in the right hand. Rotate the hoop, first clockwise, then counterclockwise for 20–30 seconds. Keep the eyes fixated on the hand. Repeat the same with the left hand.
5. SP: stand in the basic position looking forward. Turn head to the right, then left. Repeat 8–10 times in each direction. Look at an object located at a distance of 3 meters (9 feet) or more (the mark on the wall).

Therapeutic Physical Training for People with Diminished Vision

Indications for the therapeutic physical training are: various kinds of abnormal posture such as myopic posture adapted during reading and writing. Incorrect, abnormal posture subsequently negatively affects the respiratory system, leading to decreased chest excursions. People with visual issues often unconsciously hold their breath on the exhale while looking at an object. Therefore it is necessary to increase the activity of the cervical spine movement and the upper body to improve hemodynamics.

Contraindications: cyclic high intensity exercise, as well as acrobatics, jumping, exercises on gymnastic apparatus, causing increase of the heart rate up to 180 beats per minute. Exercises with held breath (long jumps, high jumps, jumps from elevated apparatus and so forth) may lead to a significant long-lasting ischemia of the eyes, therefore these are contraindicated in people with myopia. It is advisable to move from the basic stance to the position of lying on the back/stomach and vice versa through the sitting position, since a sharp change in body position can lead to increased blood pressure and heart rate.

Sample Exercise Therapy for People with Visual Impairment

1. SP: the basic stance, hands on waist, head tilts from side to side. Perform 7–8 times in each direction;
2. SP: the basic stance, hands on waist, the head tilts back and forth. Perform 7–8 times in each direction;
3. SP: the basic stance, hands on waist, the head turns to the right and left. Perform 7–8 times in each direction;
4. SP: the basic stance, hands on waist, circular movements of the head, first clockwise, then counterclockwise. Perform 7–8 times;
5. Walking on toes, with a small pillow (filled with sand) on the head;

6. SP: sitting on a gymnastic bench, hands on the head. Tilt the head forward, then pull back, providing some resistance with the arms;
7. SP: the basic stance, hands locked behind the head, move the hands back, arching the back (while looking straight ahead or up);
8. SP: the basic stance, gymnastic stick is held in the back, move the stick backwards, arching the back (while looking straight ahead or up);
9. SP: lying on the stomach, arms along the body. Raise the head and shoulders, arching the back (while looking straight ahead or up);
10. “Boat” exercise. SP: lying on the stomach, arms along the body. Raise the head, shoulders and legs, keeping the legs straight and arching the back;
11. Self-massage of the neck muscles and the back of the head for 60 seconds;
12. SP: the basic stance, feet at shoulder width, ball held in the hands. Hands rise up, reach up, look at the ball, put it on the chest, then return to the starting position. Repeat 5–6 times;
13. SP: the basic stance, holding a ball in the hands. Hands up, move elbows apart, connect the shoulder blades, while looking ahead. Bend to the right, to the left. 4–6 tilts to each side;
14. SP: lying on the back, one hand on the chest, the other on the stomach. Diaphragmatic breathing. 3–4 respiratory movements;
15. SP: lying on the stomach, hands on the head, the shoulder blades are connected, while looking straight forward. Raise the upper body up and stay for 5–10 seconds. Do not hold the breath. Repeat 3–4 times;
16. SP: lying on the back, arms along the body, perform the “bicycle” exercise. Do not hold the breath. Perform for 60 seconds;
17. SP: lying on the back, arms bent at the elbows. Perform the “bridge” exercise. Arch the back while supporting the body by hips and elbows. Repeat 3–4 times;
18. SP: support the body by knees and hands. Raise both right hand and left foot, not caving the backbone too much and

stay in this position for 3–5 seconds. The same repeat with the other hand and leg. Perform 5–6 sets;

19. SP: support the body by knees and hands. Perform the "kitty" exercise. Bend back and inhale while looking up, arch the back and exhale pressing the chin against the chest. Perform 5–6 sets.

For people with diminished vision, in particular myopia of low, medium and high degrees, we recommend exercises with the shuttlecock, to be performed both in the first part of the session during the warm-up, and in the primary part of the session during specific training and acquisition of various game-related skills and abilities. Throws must be performed strictly while holding the shuttlecock over the head, and the head rolled in the direction of the throw. This will allow the student to adapt to the constant eye tracking of the shuttlecock during the game.

Sample Exercises with Elements of Badminton Gameplay for the Correction and Prevention of Visual Impairment

The Physical Education (PE) curriculum based on the game of badminton for elementary school students (grades 1–4) and middle school students (grades 5–9) has been developed in accordance with the requirements of the Russian Federal State Educational Standard of general education; the program for senior students (grades 10–11) is in line with State Educational Standards for the secondary complete education.

The program is intended for the prevention of myopia and correction of visual impairment in school children with mild to moderate degree of myopia.

We believe that the developed technique is to be utilized in every PE lesson, 3 times a week, during the main and the final parts of the lesson. Estimated duration of the exercises with elements of badminton gameplay is up to 15 minutes in the main part of each PE lesson and up to 5 minutes in the final part of the lesson.

All students involved in PE lessons according to our method, from the 1st to the 11th grade, must maintain self-observation diaries. We assume that at least 2 times a year, each student will pass medical examination by an ophthalmologist and will enter the results of such examination in his or her self-observation diary. Before and after each PE lesson with the use of our methods, the students should record the symptoms of eye fatigue, if they present. Guidelines: when using this technique, it is desirable to divide the children into 2 groups: group 1, students with intact vision and with mild myopia, and group 2, students with a moderate degree of myopia.

Grades 1–4, students with intact vision or with a low degree of myopia (myopia is of the acquired etiology). Exercises with a shuttlecock at the first stage include light, free movements around the gym in a playful way, then work with a shuttlecock according to our method. Also, from the very first lessons we employ exercises in pairs (including the light relays with a shuttlecock and movement-oriented games: tag with a shuttlecock, throw the shuttlecock, etc.)

Grades 1–4, students with moderate myopia (congenital and acquired etiology). In order not to harm the health of the students, all lessons are held under the supervision of a teacher who had been trained in working with individuals, classified due to their health to special medical needs PE groups or teachers who possess Bachelor-level degrees in adaptive physical culture.

Particular attention is paid to the general developmental exercises (GDE) and special exercises to strengthen the muscular system of the eye. In the first part of the lesson, must use GDE to prepare the body for the main part of the special exercises. Since children with visual impairments, as a rule, present also with certain concomitant conditions of the musculoskeletal system (e. g., students slouch while reading and writing) as well as impaired orientation in space, it is necessary to use exercises to strengthen the muscles of the back and upper body. Exercises for the musculoskeletal system are to be performed in the first part of the session. In the main part of the session, among the special exercises we include the oculomotor gymnastics, such as “the point on the glass”, squinting, blinking, circular movements of the eyeballs with open and closed eyes. A small pause between exercises contributes to the relaxation of the long-term excessive strain of the circular and meridional portions of the ciliary muscle.

Great significance is assigned to the color of the shuttlecock. A white shuttlecock visually merges with the ceiling of the sports/exercise hall (since white color of the ceiling is the approved requirement for sports facilities) and may temporarily disappear from the visual field of children with myopia. Shuttlecocks of orange, green, red and yellow colors are easily noticeable in flight. This will allow the pupils to follow the shuttlecock throughout its flight path[1].

The factor of uninterrupted visual tracking, presumably, will help to improve the training effect on the ciliary muscles. For pupils who use in their daily lives corrective glasses and lenses, the number of throws in each shuttlecock exercise at the initial stage should not exceed 10–15 times. This should exclude excessive strain on the eyes and as a result, tearing, increased intraocular pressure, and exit from the usual comfort zone. The rate of execution of throws is kept as low or medium.

The variety of exercises used in our method, presumably, allows to normalize and improve the efficiency and contractile activity of the main portions of the ciliary muscle, causing the accommodative system of the eye to adapt to the unique flying trajectory of the shuttlecock, which presents with unusual ballistics and flight path.

Complex combined exercises in threes and fours, we assume, will provide targeted training of the visual apparatus, since the students have to quickly switch attention to another shuttlecock and the throwing partner, as well as to use peripheral vision during diagonal throws.

[1] Authors’ note: When making educational aids for children with diminished vision, red, yellow, orange and green colors are preferred. (Reference: “Specific Methods of Adaptive Physical Education”, prof. L. V. Shapkova, ed., Moscow, 2007, p. 95).

1st grade students only perform exercises with shuttlecocks (individually and in pairs, including group outdoor games).

2nd grade students are trained in the same way. Additionally, students are trained the correct racquet grip and learn juggling utilizing forehand and backhand grips. Also, work in pairs by passing air balloons with a diameter of 20 cm in the same color as the shuttlecocks (red, green, orange, green) to each other at a distance of 2–2.5 meters.

Students of the *3rd grade* repeat the exercises recommended for the 1st and 2nd grades. Also at this stage, the following is introduced: juggling of shuttlecocks with both sides of the racquet (passes the shuttlecock to the partner, the partner accepts — that is, catches with the forehand side of the racquet, bounces 2–3 times and then passes to the first player, the same is repeated utilizing the backhand side). Next step is the juggling with the forehand side of the racquet 2 times, then with the backhand side, also 2 times, and passing to the partner. All exercises consist of 4 sets of 5 repetitions each for each color of the shuttlecock. With each new set the color of the shuttlecock is changed. Also introduced are relays with racquets and shuttlecocks (holding the shuttlecock on the forehand side of the racquet, then on the backhand side). The number of exercises and repetitions increases gradually by 1–3 sets.

The *4th grade* begins with a repetition of exercises performed in grades 1 through 3. New exercises are introduced such as the study of serves (short shot off the backhand side, shots with the top forehand side of the racquet are introduced at the end of the 4th grade), complicated relays (trainees bounce the shuttlecock on the forehand and backhand sides of the racquet). Also included in the program are various outdoor games (basketball with shuttlecock, clear shuttlecocks from your area), and so on.

The *5th grade* program includes a recap of the exercises learned in 1–4 grades, plus additional active games incorporating the racquet and shuttlecock and played over the net. Ongoing study of serving and receiving techniques continues. Included are all the exercises with shuttlecock and racquet over the net, the study of high serve with the top forehand side of the racquet across the ground, and then through the net (training for the high serve is held in a group, trainees serve one after another). Color of the shuttlecock is recommended to be changed every 2 minutes.

For the *6th grade*, exercises with shuttlecock in pairs, higher complexity individual exercises with two shuttlecocks, relay races and outdoor games are added. At this stage, the students study the rules of singles and doubles play, exploring high serve technique, shortened stroke and blocks. Study of the rules of the game of badminton by each student is organized in a dual fashion: first, each student judges the game as the umpire (tower judge) and then the student judges the game as the line judge, switching the position after 11 points have been scored. This is necessary to provide training for the eyes: the shuttlecock flight length increases, the amplitude and speed are constantly changing.

Constant monitoring of shuttlecock from different angles, we believe, accelerates the process of training the eye, thus our teaching methods become more complex. The more during the game the play will change the combination of the action from the rear area to the front and vice versa, the more attention will be paid to the shuttlecock trajectory. In our view, the involvement of the neck muscles will contribute to a good flow of arterial blood to the brain hemispheres and the ciliary muscle of the eye responsible for visual accommodation, as well as strengthen eye vessels by improving blood circulation of various organs.

During the game of badminton the judges must implement the changing of the colors of the shuttlecock, which should be changed twice in one game, for example: up to 11 points — yellow shuttlecock, up to 21 points, orange shuttlecock, in the second game up to 11 points utilize a red shuttlecock, and up to 21 points, a green shuttlecock.

We recommend that the above explicated scheme apply to judging during all of the following stages of training.

In the 7th grade students begin learning the technique of badminton (block, relief, shortened stroke, transitions, and so on, according to the already described methods of training) [See Reference 2]. This is the first stage of the general development of the myopia group, comprising mainly exercises with one or two shuttlecocks in the preparatory and final part of the class. In the main part of the lesson, exercises from the repertory of grades 1–4 are utilized, including alternating relay and outdoor games. In order not to overload the ciliary muscle, one needs to alternate techniques with shuttlecock and racquet (learning specific techniques, relays with the racquet and the shuttlecock, reinforcing the already learned techniques and so on). Also, we recommend that after every exercise students are obligated to perform oculomotor exercises.

In the 8th grade students perform the whole set of exercises with a shuttlecock individually and in pairs, the number of sets gradually increasing. Also students consolidate the previously covered material and study all varieties of moves through the court. The pace of training is medium without expressly fast movements.

Grade 9 students complete the entire set of exercises with the shuttlecock individually and in pairs, the number of sets gradually increasing. Also students consolidate methods learned in grades 6–8, devote considerable attention to refereeing in the doubles category with multicolored shuttlecocks and the gradually introduced white shuttlecock. We also introduce the game-task “Hit the target”.

Grades 10–11 students complete the entire set of exercises with a shuttlecock individually and in pairs, the number of sets gradually increasing. They are engaged in the study of techniques and tactical actions in badminton singles, doubles and mixed with shuttlecocks of different colors according to the previously described methods. [See Reference 1]. To improve the mastery of techniques used in badminton we recommend the game-task “Hit the target”.

Individual Exercises with Shuttlecock and Racquet

1. Juggling with the forehand side of the racquet (5 times with shuttlecocks of each color). The player assumes the game stand, kicks the shuttlecock with the racquets (forehand), sending it upwards. Recommended number of sets: 1 or 2.
2. Juggling with the backhand side of the racquet (5 times with shuttlecocks of each color). Recommended number of sets: 1 or 2.
3. Juggling alternately with the forehand and the backhand sides of the racquet (10 times with shuttlecocks of each color). Recommended number of sets: 1 or 2.
4. The same exercise, but with the forehand side sending the shuttlecock up as high as possible, and the backhand side only used to land the shuttlecock (without any impact movement). Number of repetitions: 6 times for each of the yellow, orange, red and green shuttlecocks. Recommended number of sets: 1 or 2.
5. The same exercise, but this time the backhand side is used to propel the shuttlecock as high as possible, and the forehand side is used only to land the shuttlecock on it. Number of repetitions: 6 times for each of the yellow, orange, red and green shuttlecocks. Recommended number of sets: 1 or 2.
6. High juggling. Each time to the goal is to send the shuttlecock up as high as possible. Number of repetitions: 6 times for each of the yellow, orange, red and green shuttlecocks. Recommended number of sets: 1 or 2. **(Fig. 1)**
7. Juggling (one of the possible variations) with the free hand touching the floor every time after hitting the shuttlecock. Number of repetitions: 6 times for each of the yellow, orange, red and green shuttlecocks. Recommended number of sets: 1 or 2. **(Fig. 2)**
8. Juggling: after hitting the shuttlecock perform two circular rotations of the left arm in the shoulder joint. Number of repetitions: 6 times for each of the yellow, orange, red and green shuttlecocks. Recommended number of sets: 1 or 2. **(Fig. 3)**

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9. Juggling: after hitting the shuttlecock perform 2–4 hand rotations, turning the racquet forehand and backhand side up. Number of repetitions: 6 times for each of the yellow, orange, red and green shuttlecocks. Recommended number of sets: 1 or 2. (Fig. 4)
10. Juggling: after hitting the shuttlecock perform 2–3 rotating movements with the racquet a) in front of the chest, b) above the head. Number of repetitions: 6 times for each of the yellow, orange, red and green shuttlecocks. Recommended number of sets: 1 or 2. (Fig. 5)
11. Juggling from side to side: sending the shuttlecock up, hitting it on the right side with the forehand side of the racquet, and on the left with the backhand side. During the exercise the student can do lunges with the right foot in the direction of the shuttle, but every time needs to return to the standard game stance. Number of repetitions: 6 times for each of the yellow, orange, red and green shuttlecocks. Recommended number of sets: 1 or 2. (Fig. 6)
12. Juggling front to back: a player serves with the forehand side, sending the shuttlecock over the head behind his back, turns 180° and performs a similar strike with the backhand side. Then everything is repeated. Number of repetitions: 6 times for each of the yellow, orange, red and green shuttlecocks. Recommended number of sets: 1 or 2. (Fig. 7)
13. Juggling in conjunction with the movement along the court. The student stands behind the sideline of the court, performing juggling alternately with the forehand and the backhand sides of the racquet while moving to the opposite sideline. When the student reaches the opposite sideline, s/he sends the shuttlecock behind her head and turns around. Then, without stopping the juggling, begins to move in the opposite direction. After reaching the sideline, s/he concludes the exercise and catches the shuttlecock with the free hand. All strikes must come only from below and the student needs to be sure to alternate between the forehand and the backhand sides of the racquet. Hitting from above is regarded as loss of the shuttle. This exercise is often used as an examination test. Number of repetitions: 5 times for each of the yellow,

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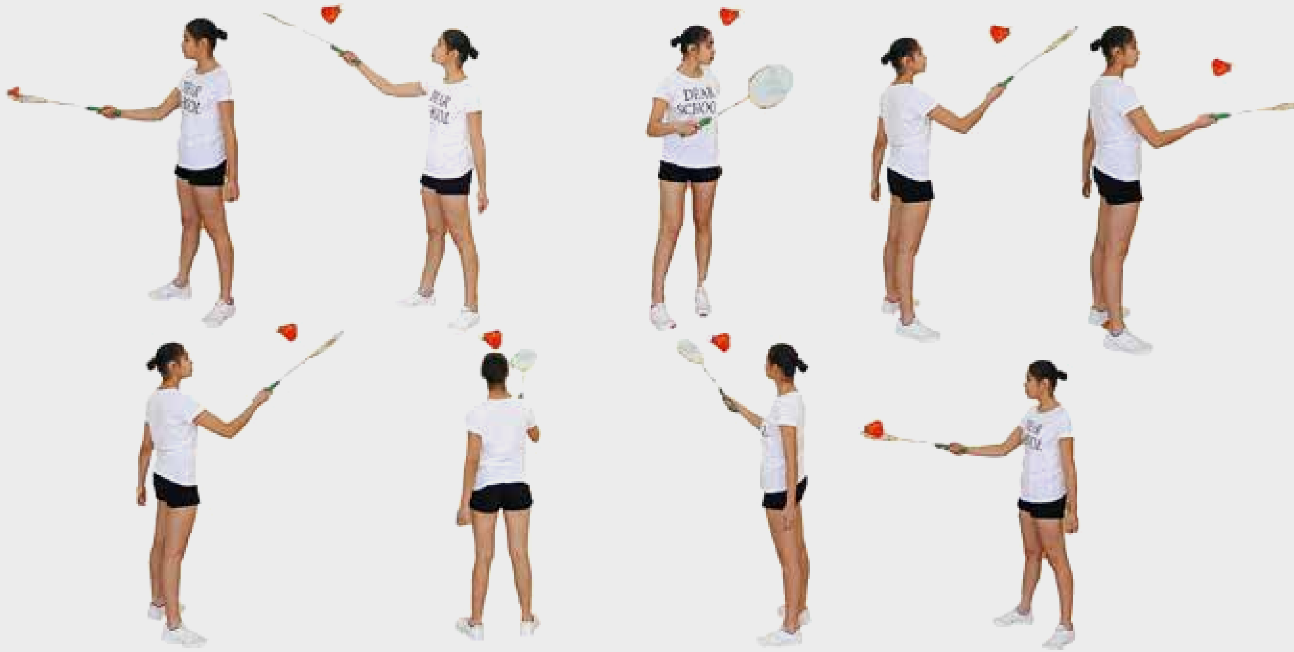

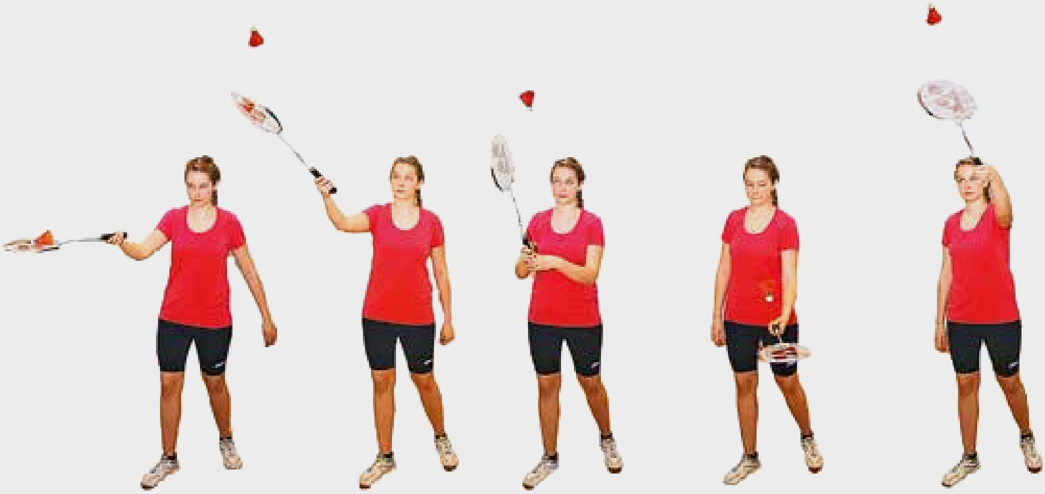

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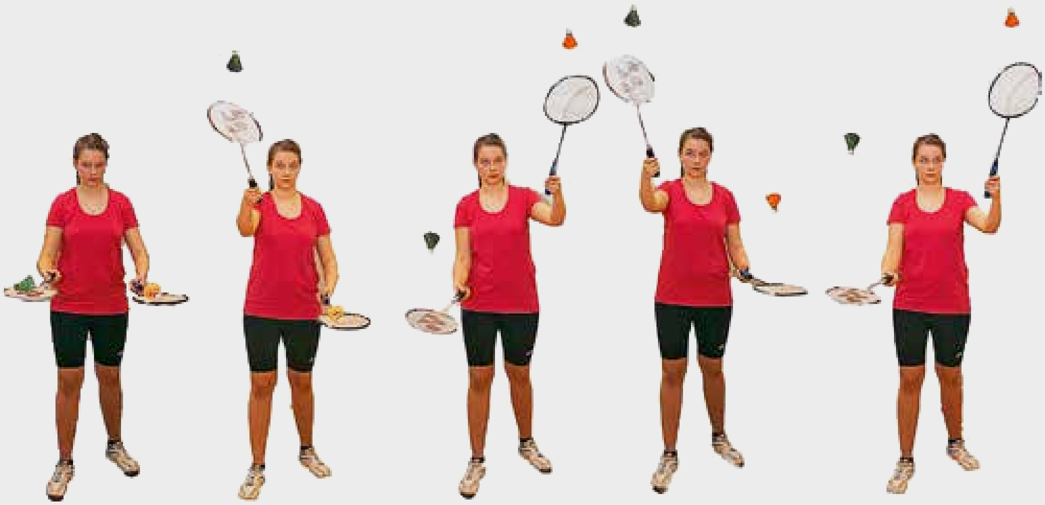

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orange, red and green shuttlecocks. Recommended number of sets: 1 or 2. (Fig. 8)

14. Juggling alternately with the right and the left hand. Exercise can be performed with the forehand side, backhand side or alternating. Number of repetitions: 4 times for each of the yellow, orange, red and green shuttlecocks. Recommended number of sets: 1 or 2. (Fig. 9)
15. Catching the shuttlecock with the racquet. Launch the shuttlecock with the racquet underneath it (or launch with the free hand). Then put the head of the racquet under the descending movement of the shuttlecock and with a downward motion catch the falling shuttlecock smoothly with the racquet head. Exercise is performed both forehand and backhand. Number of repetitions: 4 times for each of the yellow, orange, red and green shuttlecocks. Recommended number of sets: 1 or 2.
16. Alternate juggling with two racquets (one in the right, the other in the left hand). The student may perform any movements as described above. Number of repetitions: 4 times for each of the yellow, orange, red and green shuttlecocks. Recommended number of sets: 1 or 2. (Fig. 10)

Exercises with Shuttlecock and Racquet in Pairs

1. Two juggling motions above oneself, then pass the shuttlecock to the partner. Without stopping the partner performs two juggling motions and returns the shuttlecock, and so on. Repeat 5 times with shuttlecocks of each color.
2. Two juggling motions above oneself, then pass the shuttlecock to the partner by hitting it from the right. For the pass the shuttlecock is launched under the right arm with the free hand. Repeat 5 times with shuttlecocks of each color.
3. Two juggling motions above oneself, then pass the shuttlecock to the partner with a left shot. Repeat 5 times with shuttlecocks of each color.

4. Two juggling motions above oneself, then pass the shuttlecock to the partner with a bottom shot. Repeat 5 times with shuttlecocks of each color.
5. Two juggling motions above oneself, then pass the shuttlecock to the partner with a bottom forehand shot. Repeat 5 times with shuttlecocks of each color.
6. Two juggling motions above oneself, then pass the shuttlecock to the partner with a top backhand shot. Repeat 5 times with shuttlecocks of each color.
7. Two juggling motions above oneself, then serve to the partner. The second juggling is performed as a block (without oncoming racquet movement). Repeat 5 times with shuttlecocks of each color.
8. Hit the shuttlecock alternately with the right and the left hand. While the shuttlecock is in the air, the racquet passes from hand to hand. Number of repetitions: 6 times with the yellow, orange, red and green shuttlecocks. Recommended number of sets: 1 or 2.
9. The student hits the shuttlecock from the bottom up so that while it is flying up and is in the air in the front of the student, s/he strikes it, sending it in the direction of the partner who is trying to block it with the racquet. Then the exercise is carried out in the other direction. Number of repetitions: 10 times for each of the yellow, orange, red and green shuttlecock. Recommended number of sets: 1 or 2.
10. The same exercise as 9, but the partner tries not just to block the shuttlecock but to return to the side of the opponent. Number of repetitions: 6 times for each of the yellow, orange, red and green shuttlecock. Recommended number of sets: 1 or 2.
11. The first student hits the shuttlecock so that it flies over her head and behind her back. Then, making 180 degree turn, the student transfers the shuttlecock with the forehand side of the racquet to the partner, while her back is turned towards the partner. The shuttlecock is hit while overhead or higher, otherwise, the shuttlecock will not fly in the backward direction. The second student hits the shuttlecock upwards and catches it with his free hand, then returns it to the

first student. Number of repetitions: 6 times for each of the yellow, orange, red and green shuttlecock. Recommended number of sets: 1 or 2.

12. The same exercise as 11, but the first student uses the backhand side of the racquet. Number of repetitions: 6 times for each of the yellow, orange, red and green shuttlecock. Recommended number of sets: 1 or 2.
13. The same exercise as 11, but the first student uses the backhand side of the racquet if the shuttlecock is on the right, and the forehand side of the racquet, if the shuttlecock waves. Number of repetitions: 6 times for each of the yellow, orange, red and green shuttlecock. Recommended number of sets: 1 or 2.
14. The first student is serving on a high trajectory, and the second hits from above. After 2–4 serves, switch the sides. Number of repetitions: 6 times for each of the yellow, orange, red and green shuttlecock. Recommended number of sets: 1 or 2.
15. The first student is serving at a low trajectory, and the second hits from below with the backhand side of the racquet. After 2–4 serves, switch the sides. Number of repetitions: 6 times for each of the yellow, orange, red and green shuttlecock. Recommended number of sets: 1 or 2.
16. The game is short strokes from below. Students standing next to the net (or without the net) and perform the strikes so that the shuttlecock is flying as low and as close to the net as possible. Strikes are carried out in the front and on the left with the backhand side of the racquet, on the right — with the forehand side. Contact with the shuttlecock should be below the level of the net. Number of repetitions: 10–30 times for each of the yellow, orange, red and green shuttlecock. Recommended number of sets: 1 or 2.
17. Pair juggling with stepping forward. Students are placed behind the sidelines of the badminton court. One student goes out to midline, strikes straight up and quickly returns to the free space. Next student strikes the shuttlecock in the same fashion, stepping forward and coming back. So, one by one, they perform juggling. Number of repetitions: 10–30 times

for each of the yellow, orange, red and green shuttlecock. Recommended number of sets: 1 or 2.

After the exercise sequence consisting of 3–4 tasks, we believe it is necessary to take a break and perform exercises to strengthen the muscle system of the eye.

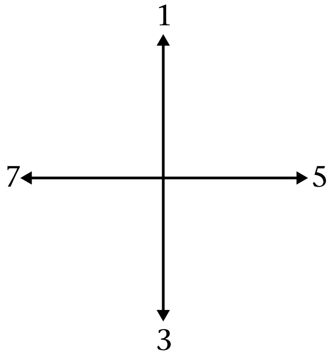
Oculomotor Exercises Performed During the Breaks[1]

1. SP: Stand with legs apart. The right hand in the front in the half-bent position, hand made into a fist with index finger raised. The hand is moved to the right. Without turning the head, try to see in the corner of the eye the index finger of the hand. Then slowly move the finger from right to left, intently watching the finger, then move to the left. Repeat 10–12 times.

2. SP: sitting on your lap (knee squat) or in the Lotus position (Lotus yogi asana), hands on waist. Do not tilt the head while moving 1) eyes up, 2) and return, 3) eyes down, 4) and return. Perform 2 sets.

[1] Based on the methods by E. Avetisov, E. Livado, and Yu. Kurpan (1996), and G. Demirchoglian (1997).

3. SP: sitting on your lap or in the Lotus position, hands on waist. No tilting or turning the head while moving 1) eyes up, 2) and return; 3) eyes down, and 4) to return; 5) eyes to the right, 6) and return; 7) eyes to the left, 8) and return. Perform 2 sets.

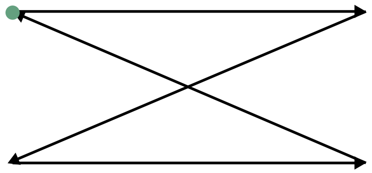


4. SP: sitting on your lap or in the Lotus position, hands on waist. The head is not tilted or rotated. From the top right corner of the visual field trace with your eyes a straight line to the top left corner, then a straight line to the bottom left corner and from the bottom left to the bottom right. Then return your gaze to the upper-right corner. Perform 2 sets.

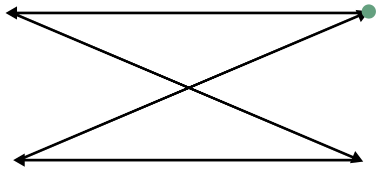
Repeat the same movements, but in the opposite direction. Perform 2 sets.

During these exercises, the eye movement velocity is 16–17 cm per second. Between the sets take a break of 30 seconds and blink several times.

5. SP: sitting on your lap or in the Lotus position. From the top right corner of the visual field trace a straight line with your eyes in the top left corner, then to the bottom right corner, then the bottom left corner and return to the top right corner. Perform 2 sets.



Then repeat the same movements, but in the opposite direction. Perform 2 sets.

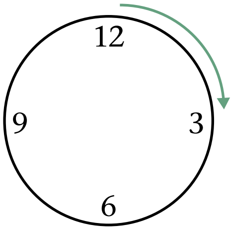


During these exercises, the eye movement velocity is 16–17 cm per second. Between the sets take a break of 30 seconds and blink frequently times.

After the exercise, look at a point in the front, concentrate (gaze intently) on it and relax the eye muscles. Repeat 2–4 times.

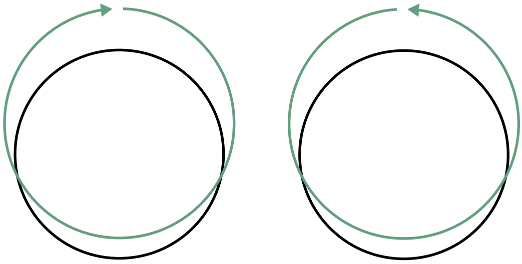
6. SP: sitting on your lap or in the Lotus position. Eyes are looking up, and in an arc-like movement the gaze is shifted to the right, then down and to the left, back to the initial position.

Such movements mimic the moves of the hands of a clock: look at the 12, 3, 6, 9 positions and again at 12. Perform 2 sets.

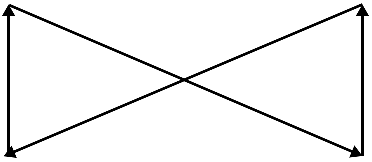


Furthermore, perform the same exercise in the other direction: look at 12, followed by 9, 6, 3, positions and again at 12. Perform 2 sets.

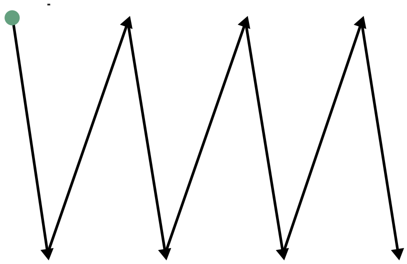
7. SP: sitting on your lap or in the Lotus position. Eyes are looking up. Trace a circle with your gaze, first to the right, then to the left. Exercise is repeated 2–3 times in each direction.



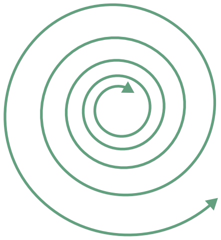
8. SP: sitting on your lap or in the Lotus position. The eyes look at the lower left corner. From the lower left corner lift the gaze to the upper left corner, then move diagonally to the lower right, then to the upper right and diagonally back to the lower left corner of the visual field. Also repeat in the other direction. Perform 2–3 sets.



9. SP: saddle (squat) on the heels, hands on knees. Eyes looking in the upper left corner. Lowers the gaze down and then lift up. Repeat 3 times. On the 4th move, leave the eyes looking at the bottom right corner. Repeat exercise in the other direction. Perform 2–3 sets.



10. SP: saddle (squat) on the heels, hands on knees. The gaze is fixated straight forward and then moved outwards in a spiral. Then return to the starting point. Perform 2–3 sets.



The Badminton Center in Kazan

V. G. Turmanidze giving a badminton lesson to schoolschildren

Ophtalmologist’s office in the Badminton Center in Kazan

P. E. Hoyer, S. M. Shakhrai and Y. V. Chaplygin visiting the ophtalmologist
in the Badminton Center in Kazan

Active Games and Game Tasks with Shuttlecock, Racquet and Tennis Ball

"Tag with Shuttlecock" (Grades 1–3)

Select 4 taggers, who hold shuttlecocks of different colors. Throwing the shuttlecock to the players, the tagger will try to tag them. In case of a miss the tagger must pick the shuttlecock and throw again, and so on. Throws are executed from the point where the shuttlecock is picked up. In case of a successful tag, the tagged becomes the tagger.

You can also divide all participants into two groups. For example, boys and girls may play separately but on the same court. In this case, each group should have different color shuttlecocks.

"Let the Shuttlecock Through" (Grades 4 and 5)

The court is divided with a badminton net or gymnastic benches into two halves. Students are divided into 2 groups, they stand in a row on their half of the court, at a distance of 2 m from the net (or benches) for the elementary school and 4–5 m for older grades. Players of one team hold shuttlecocks in their hands. At the teacher's mark they throw shuttlecocks with their right hands over the net. The players of the other team pick the shuttlecocks and form a row on their side of the court. At the mark, they try to throw the shuttlecocks over the net. The team, which has succeeded in landing more of shuttlecocks on the opposing side gets one point.

Then the players step back from the net and are standing at the distance of 3 m from the net and repeat their throws. Each time the players step away from the grid farther and farther, until no one (or only a few players) is able to land the shuttlecock on the opposite side.

Then the game starts over again, but the throws are executed with the left hand. The duration of the game is for 2–3 minutes with a shuttlecock of each color (orange — red or yellow — green).

"Clear Your Site of Shuttlecocks" (Grades 4 and 5)

Students are divided into two groups and placed on their halves of the court. Each group has shuttlecocks of only one color (for example, the 1st team has yellow shuttlecocks, the 2nd team — green). The court is divided by a badminton net. At the mark, the players start throwing shuttlecocks at the opponents, trying to get rid of as many shuttlecocks as they can. The player can throw the shuttlecock only from the spot where s/he picked it up or where s/he caught it. The winner is the team in whose half of the courts there remain a smaller number of shuttlecocks after the teacher blows his whistle.

"Relay with the Shuttlecock (1st Version)"(Grades 6 and 7)

All participants are divided into 4 teams. Each team lines up in a file at the top of the court. Next to each team at a distance of 18–20 meters is a hoop in which the shuttlecocks are kept, with every team having its own color. The first team members of each team also have in their hands shuttlecocks but of a different color (for example, the 1st team — green shuttlecock in the hands of the first player, orange shuttlecock in the hoop; 2nd — red and yellow; 3rd — yellow and red; 4th — orange and green).

At the mark the first players throw their shuttlecocks forward as far as possible. They run after them, pick them up and throw forward again, and so on until the shuttlecock touches the opposite wall of the court. Then the player runs to the hoop, located in front of each team, and change his/her shuttlecock to the different color. Then s/he runs throwing the shuttlecock backwards, but not until it touches the wall, but rather until it is possible to pass the shuttlecock to the second player of the team. The second player has no right to pick up the shuttlecock unless it flew over the front line of the file in which his/her team is standing. The second player, after picking up or catching the shuttlecock performs similar tasks.

The relay exercise is performed one by one by all the players of the team. As soon as the shuttlecock is in the hands of the first player again, s/he lifts it up. By the timing of lifting of the shuttlecock the place of each team is determined.

It is necessary to use the peripheral vision to monitor the shuttlecocks of other teams. For example, 1st team oversees the 4th team; and the 2nd team monitors third team, and vice versa. After passing the relay by all players of all 4 teams, the teams change their starting places: 1st to 2nd, and 3rd to 4th.

"Relay with the Shuttlecock (2nd Version)" (Grades 6–8)

All participants are divided into 4 teams. Each team lines up in a file at the top of the court. Next to each team at a distance of 18–20 meters is a hoop in which the shuttlecocks are kept, with every team having its own color. The first team members of each team also have in their hands shuttlecocks but of a different color (for example, the 1st team — green shuttlecock in the hands of the first player, orange shuttlecock in the hoop; 2nd — red and yellow; 3rd — yellow and red; 4th — orange and green).

At the mark the first players throw their shuttlecocks upward and forward with one hand and catch it with both hands. As they reach the hoop, players exchange their shuttlecock for a shuttlecock of a different color and continue in the opposite direction throwing the shuttlecock backwards until they transfer it to the second player. The relay is carried out by all team players. As soon as the shuttlecock is in the hands of the first player again, s/he lifts it up. By the timing of lifting of the shuttlecock the place of each team is determined.

It is necessary to use the peripheral vision to monitor the shuttlecocks of other teams. For example, 1st team oversees the 4th team; and the 2nd team monitors third team, and vice versa. After passing the relay by all players of all 4 teams, the teams change their starting places: 1st to 2nd, and 3rd to 4th.

"The Goalkeeper" (Grades 5–7)

The game is played against a wall, on which an outline of a gate may be drawn with chalk. Students play in pairs. The player with racquet stands at the gate, and the other throws the shuttlecock from the distance of 4–5 m. The goalkeeper is trying not to let the shuttlecock into the gate, hitting it with the racquet.

After completing 5 shots with shuttlecock of each color, the players change places. There are 2 scoring options: 1) hitting the goal (the wall within the boundaries of the gate) gives one point to the thrower; 2) hitting the goal — two points to the thrower, but if the goalkeeper did not allow the shuttlecock to hit the goal but failed to return it to the thrower — one point.

“Basketball with Shuttlecock”
(Grades 5–7)

Students are divided into 2 or 4 teams. Players of one team, passing the shuttlecock to one another, are trying to throw it into the basketball hoop of the opposing team. Running with a shuttlecock in the hands is prohibited, it must be in flight at all times the player moves. A player can not grab the shuttlecock out of the hands of the opponent, s/he can only intercept.

The game is played with a single shuttlecock, when the group is divided into 2 independent teams that simultaneously play on a basketball court. Or, when the group is divided into 4 teams — 2 teams for each ring. Every 2–3 minutes of the game the color of the shuttlecock is changed.

“Wolf Hunting”
(3, 4, 5 classes)

Students are divided into groups of 3–4, and all play at the same time across the court. Each group has a shuttlecock. One player in each group is the wolf, and the rest are hunters. Wolf running freely around the court for 30 seconds or 1 minute. Hunters, passing the shuttlecock to each other, trying to catch up with the wolf and “shoot” him with their shuttlecock. While holding the shuttlecock a player can make no more than two steps, without the shuttlecock the moves are unlimited. When you hit the “wolf”, s/he is not out of the game, but only receives penalty points. On a mark (upon preset time is over) the wolf changes places with one of the hunters, and this change is carried out alternately until everyone had played the wolf. The winner is the player with the fewest penalty points. The color of the shuttlecock is changed every 30–60 seconds.

"Hit the Target" (Grades 9–11)

Exercises with a tennis balls of yellow, orange, red and green colors.

Preparatory exercises: juggling tennis balls of different colors (yellow + red, orange + green). SP: stand with your feet shoulder width apart, holding a yellow ball in the right hand and a red ball in the left hand. Toss the ball with the right hand to a height of 2 m, pass the other ball from the left hand to the right hand and catch the ball with the left hand. Then, toss the ball with the left hand to a height of 2 m, pass the other ball from the right hand to the left hand and catch the ball with the right hand. Perform the throws, passes and catches on each side 5 times. Repeat 4 sets and on each approach change the color of the balls.

Next, go to the main exercise. The student stands 3–4 m from a wall on which is drawn a circular target with the diameter of approximately 80 cm at a height of 2–3 m from the floor, depending on the average height of the participating students. In his/her hands the student is holding a yellow tennis ball. Option 1: on the teacher's mark the student throws the ball at the target with his right hand and catches it with both hands. The same is repeated with the left hand. Option 2: on the teacher's mark, the student throws and catches the ball with his right hand. The same is repeated with the left hand. Option 3: on the teacher's mark, the student throws the ball at the target with his right hand and catches it with his left hand, then throws with the left and catches with the right, etc. Perform 5 sets with each hand, and 4 series of sets, changing the color of the ball after each set.

Then, the same task is performed by teams of 4–6 people. Students stand in a file in front of the target, in the hands of the first player is a yellow tennis ball. Option 1: The first player throws the ball into the target with his right hand, catches it and passes to the second player, etc. Option 2 (more demanding): The first player throws the ball with his right hand at the target and runs to the end of the file, the second catches and throws and so forth. Option 3 (more complex): The first player throws the ball with his right hand onto a target drawn on the floor or in the basketball hoop so that the ball bounces off the wall. The first player catches the ball after a rebound, passes the ball to the second player and runs to the end of the file. Exercises are perform by each team member. Perform 5 sets with each hand and 4 series of sets, changing the color of the ball after each set.

Our methodology in conducting PE classes focuses on the overall physical fitness of the students, and the teachers can decide for themselves what kind of game is to be used in which grade.

Individual Exercises with One Shuttlecock n the Vertical Plane

1. Toss the shuttlecock with the right hand from the hip level, catch at the waist level with the right hand. 10 throws with each hand, a total 3 sets. Follow shuttlecock with your eyes throughout its flight. Take breaks between sets for 90 seconds (blinking fast for 10 seconds, rest 20 seconds, repeat twice).
2. Same exercise as 1, except with the left hand and a shuttlecock of different color. (Fig. 11)
3. SP: the basic stance, arms stretched to the sides, shuttlecock in the right hand. Toss the shuttlecock with the right hand over the head to the left and catch with both hands. Then throw the shuttlecock with the left hand over the head to the right and catch with both hands. The set is 10 throws with each hand, a total of 3 sets. Follow the shuttlecock with your eyes throughout its flight, change the color of the shuttlecock between sets. Take breaks between sets for 90 seconds (blinking fast for 10 seconds, rest for 20 seconds, repeat twice). (Fig. 12)
4. Toss the shuttlecock upward and forward from behind the back with the right hand and over the left shoulder, and with the left hand — over the right shoulder, catching it in the front with both hands. Take 10 shots with each hand, for the total of 3 sets. Follow the shuttlecock with your eyes throughout its flight, changing the color of the shuttlecock between the sets. Take breaks between sets for 90 seconds (stare intently at an object or target on the eye level but do not blink for 10 seconds, rest for 20 seconds, repeat twice). (Fig. 13)

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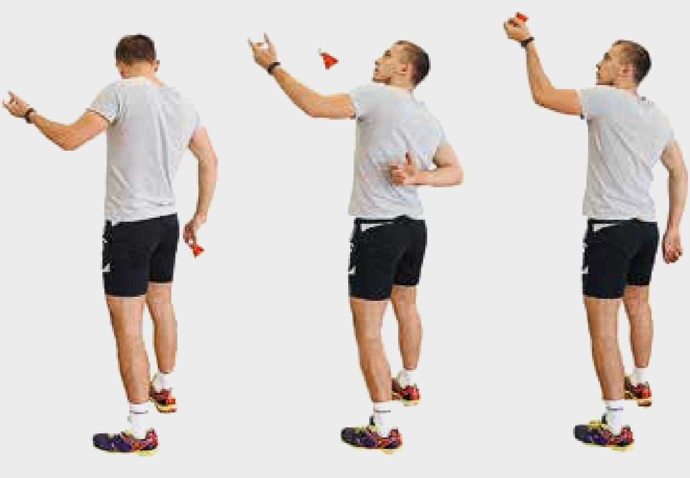

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5. Perform the same exercise as 4, but toss the shuttlecock with the right hand over the right shoulder and with the left hand over the left shoulder.
6. SP: the basic stance, shuttlecock in the right hand. Toss the shuttlecock with the right hand upward and over the left shoulder so it is caught with the left hand behind the back. The same exercise is repeated, throwing shuttlecock with the left hand.

Perform 10 throws with each hand, for the total of 3 sets. Follow the shuttlecock with your eyes throughout its flight, change the color of the shuttlecock between sets. Take breaks between sets for 90 seconds (blinking fast for 10 seconds, rest for 20 seconds, repeat twice).

7. Perform the same exercise as 6, but toss the shuttlecock with the right hand over the right shoulder and with the left over the left shoulder. **(Fig. 14)**
8. SP: the basic stance, shuttlecock in the right hand. Simultaneously bend the right leg at the knee and throw the shuttlecock with the right hand up under the right leg, catching the it with both hands. Then repeat, this time bending the left leg, throwing with the left hand under the leg and catching with both hands. Make 6–8 throws with each hand, for the total of 3 sets. Follow the shuttlecock with your eyes throughout its flight, changing the color of the shuttlecock between the sets. Take breaks between sets for 90 seconds (stare intently at an object or target on the eye level but do not blink for 10 seconds, rest for 20 seconds, repeat twice). **(Fig. 15)**
9. SP: the basic stance, shuttlecock in the left hand, arm stretched forward.

Let go of the shuttlecock as if serving, kick it with the ball of the right foot so that the shuttlecock flies up and is caught with both hands.

Repeat the same exercise with the left foot. Perform 10–12 times alternating right and left foot, for the total of 3 sets. Follow the shuttlecock with your eyes throughout its flight, change the color of the shuttlecock between sets. **(Fig. 16)**

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10. SP: the basic stance, shuttlecock in the left hand, arm stretched forward, the hand is at eye level. Release the shuttlecock as if serving, quickly touch the left hip with the left hand, catch the shuttlecock with his left hand as it falls.

Perform this exercise 10–12 times with each hand, for the total of 3 sets. Follow the shuttlecock throughout its flight with your eyes. To increase complexity, change the initial position to keep the hand with a shuttlecock on the chest or waist level. (Fig. 17)

11. Perform the same exercise as 10 but touch your forehead. Change the color of the shuttlecock. (Fig. 18)
12. Perform the same exercise as 10 but instead of touching clap your hands twice. Change the color of the shuttlecock. (Fig. 19)
13. Perform the same exercise as 10, except touch your lower back. Change the color of the shuttlecock. (Fig. 20)
14. Perform the same exercise as 10, except clap your hands behind your back. (Fig. 21)
15. Perform the same exercise as 10, except after letting the shuttlecock go, rotate 360 degrees and catch the shuttlecock. Change the color of the shuttlecock. (Fig. 22)
16. The whole set of exercises is to be repeated, this time letting the shuttlecock from the right hand. Change the color of the shuttlecock after each exercise.

Individual Work with Two Shuttlecocks in the Vertical Plane

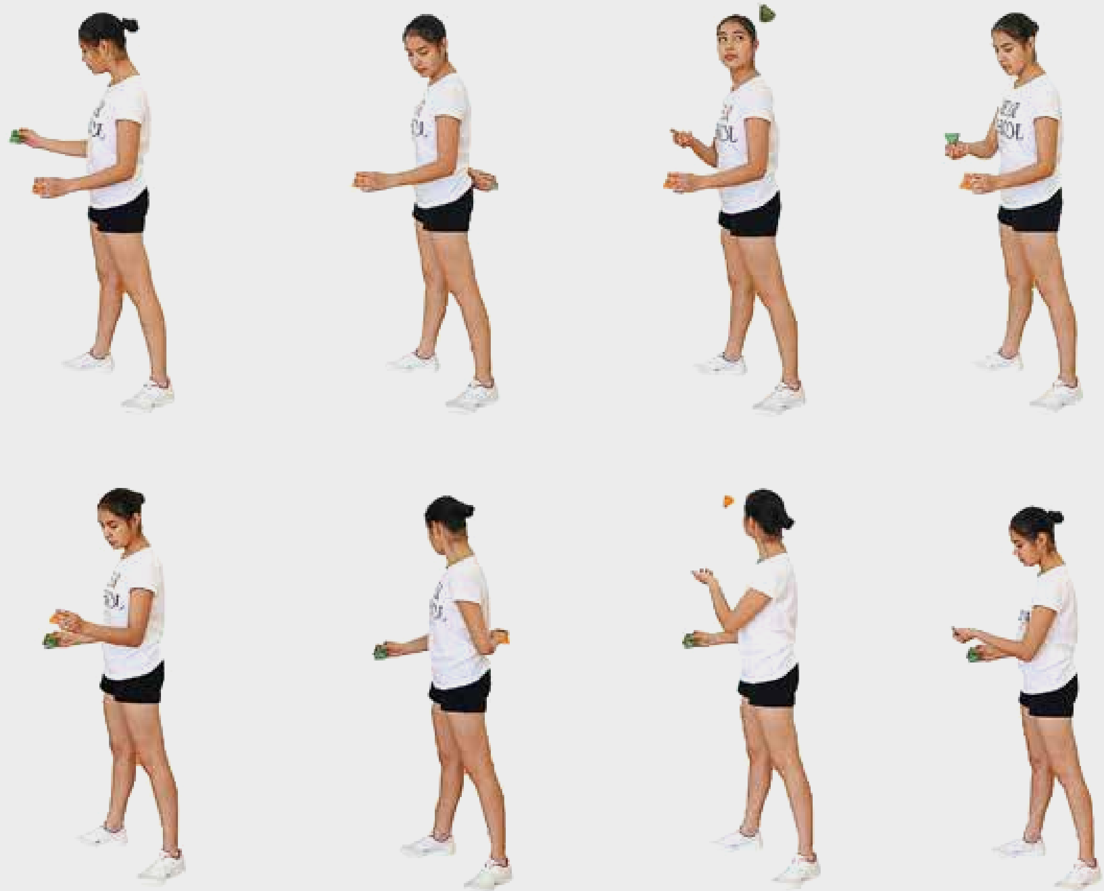
1. SP: the basic stance, take two shuttlecocks of different colors, extend your arms forward. Toss the shuttlecock up with the right hand and catch with the right hand; then toss and catch the shuttlecock with the left hand. Repeat 6–8 times with each hand, for the total of 3 sets. Follow shuttlecock throughout its flight with your eyes, then quickly transferred your gaze to another shuttlecock. Change the color of shuttlecocks between sets. Take breaks between sets for 90 seconds (stare intently at an object or target on the eye level

but do not blink for 10 seconds, rest for 20 seconds, repeat twice). (Fig. 23)

2. Alternately toss shuttlecocks of different color: with the right hand under the right leg (leg bending at the knee), left hand under the left leg, catching with the same hand. Repeat 6–8 times with each hand, for the total of 3 sets. Follow shuttlecock throughout its flight with your eyes, then quickly transferred your gaze to another shuttlecock. Change the color of shuttlecocks between sets. Take breaks between sets for 90 seconds (blinking fast for 10 seconds, rest for 20 seconds, repeat twice). (Fig. 24)
3. SP: the basic stance, shuttlecocks of different colors in the right and left hand. Alternately toss the shuttlecock up and down from behind with the right hand over the left shoulder, catching with the right hand in the front and with the left hand over the right shoulder, catching with the left hand in the front. Repeat 6–8 times with each hand, for the total of 3 sets. Follow shuttlecocks throughout their flight with your eyes, quickly transferring your gaze from one to another shuttlecock. Change the color of shuttlecocks between sets. Take breaks between sets for 90 seconds (stare intently at an object or target on the eye level but do not blink for 10 seconds, rest for 20 seconds, repeat twice). (Fig. 25)
4. The same as 3, except mirrored.
5. SP: the basic stance, hold shuttlecocks of different colors in the right and in the left hand:

Toss shuttlecock with the right hand upwards, quickly pass another shuttlecock from the left hand to the right, and catch the falling shuttlecock with left hand. Repeat 8–10 times, for the total of 2 sets. Follow shuttlecocks throughout their flight with your eyes, quickly transferring your gaze from one to another shuttlecock. Change the color of shuttlecocks between sets. Take breaks between sets for 90 seconds (stare intently at an object or target on the eye level but do not blink for 10 seconds, rest for 20 seconds, repeat twice). (Fig. 26)

6. Same exercise as 5, except starting with the left hand.
7. Toss shuttlecocks of different colors alternately, with a short interval, with the right and the left hand, catch with the



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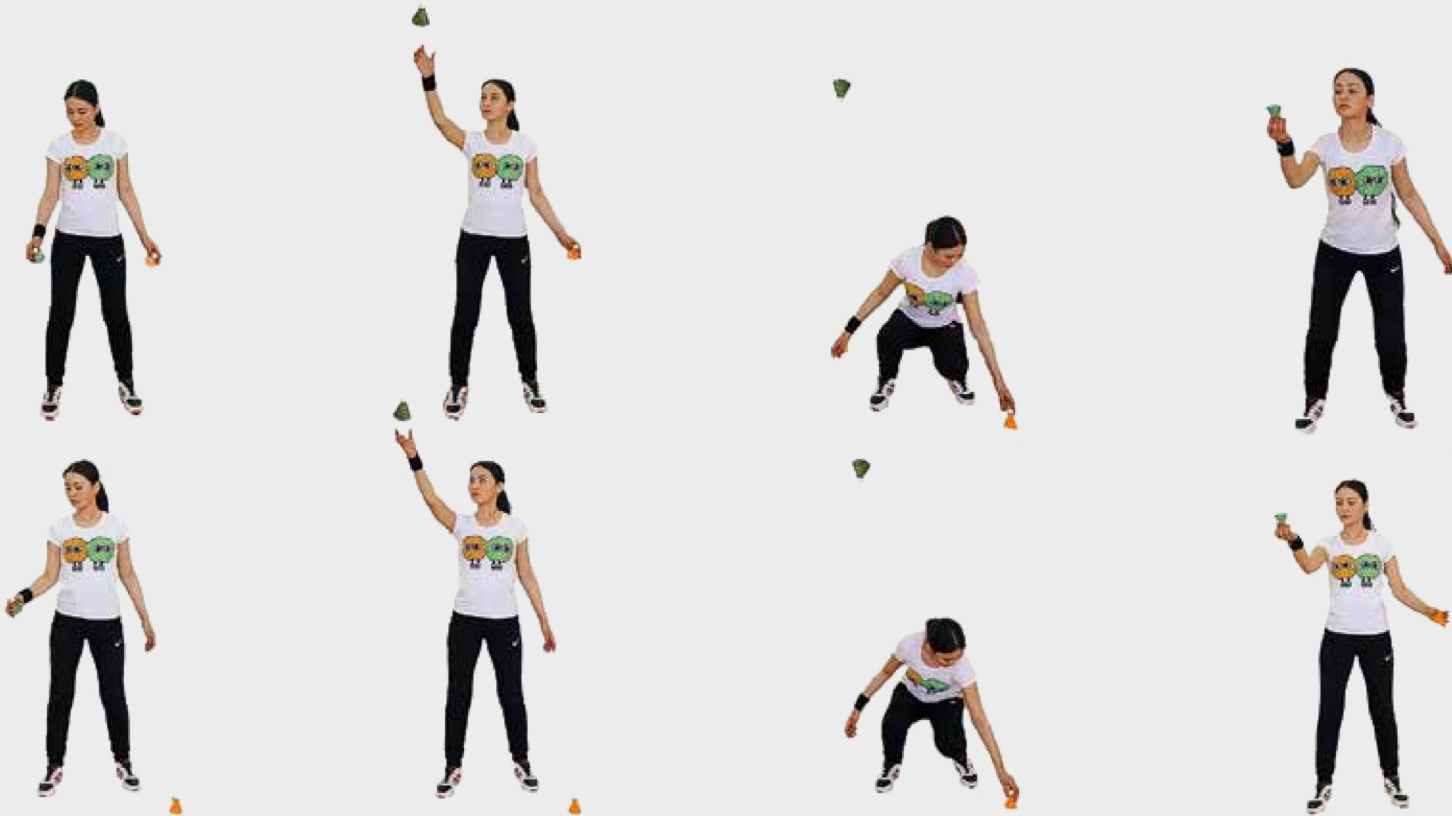
throwing hand. Repeat 8–10 times, for the total of 2 sets. Follow shuttlecocks throughout their flight with your eyes, quickly transferring your gaze from one to another shuttlecock. Change the color of shuttlecocks between sets. Take breaks between sets for 90 seconds (stare intently at an object or target on the eye level but do not blink for 10 seconds, rest for 20 seconds, repeat twice). **(Fig. 27)**

8. SP: the basic stance, shuttlecocks of different colors in the right and in the left hands. Toss the shuttlecock with the right hand from the front upwards and a bit later toss another shuttlecock from the left hand from the back and over the right shoulder. Catch the first shuttlecock with the right hand, the second shuttlecock — with the left hand. Repeat 4–6 times, for the total of 2 sets. **(Fig. 28)**
9. Same exercise as 8, except both shuttlecocks are tossed simultaneously.
10. SP: the basic stance, shuttlecocks of different colors in the right and in the left hands. Toss the right shuttlecock in the front, and the left shuttlecock under the bent at the knee left leg. Catch the left shuttlecock with the left hand, and the right shuttlecock with the right hand. Repeat 6–8 times, for the total of 2 sets. **(Fig. 29)**
11. SP: the basic stance, shuttlecocks of different colors in the right and in the left hands. Toss the shuttlecock up with the left hand in the front, and toss the shuttlecock with the right hand, aiming to hit the left shuttlecock as it falls. If the tossed shuttlecock misses the falling one, catch both of them with appropriate hands, if there is a hit, catch at least one of the shuttlecocks. Repeat 6–8 times, for the total of 2 sets. **(Fig. 30)**
12. Same exercise as 11 but throw the shuttlecocks without pausing, trying to hit each next shuttlecock that is tossed.
13. SP: the basic stance. Toss the right shuttlecock upwards, put the left shuttlecock on the floor, catch the right shuttlecock with the right hand (or both hands), return to the SP, toss the right shuttlecock up, take the left shuttlecock from the floor and catch the right shuttlecock with the right hand. Repeat 6–8 times, for the total of 2 sets. **(Fig. 31)**




DEAR
DEAR
DEAR
DEAR

14. Repeat the same exercise as 13, but do not put the shuttlecock on the floor, rather put and hold it between the knees.
15. SP: the basic stance. The right shuttlecock is tossed up, while the left shuttlecock is thrown under the bent at the knee left leg. Catch the left shuttlecock with the left hand, the right shuttlecock with the right hand. (Fig. 32)
16. SP: the basic stance, arms extended forward and a bit to the sides. Throw differently colored shuttlecocks towards one another, trying to hit one with the other. In case of a miss, catch both, in case of a hit, catch at least one. Repeat 4–6 times. The hit may be intended to happen on different levels: in front of the chest, knees, head or above the head.
17. One shuttlecock is on the floor, head-up, in front of the student, the second shuttlecock the student tosses with the right hand downward, trying to hit the first shuttlecock. Repeat 4–6 times, for the total of 2 sets.
18. The same exercise is repeated with the left hand.

Paired Exercises with One Shuttlecock

1. Pitch the shuttlecock with the right hand to each other on a low trajectory. Catching the shuttlecock is mandatory. Repeat 10 times, for the total of 2–3 sets. The pitch should be aimed at the chest of the partner, who is standing at the distance of 2–3 meters. (Fig. 33, 34)
2. Pitch the shuttlecock with the right hand to each other on a high trajectory. Catching the shuttlecock is mandatory. This is the imitation of a high shot in badminton with the free hand swing in the front. Repeat 10–12 times. The partners stand at the distance of 2–3 meters. (Fig. 35)
3. Perform the same exercises as 1 and 2, but the pitches are executed with the left hand.
4. Pitch the shuttlecock aiming to the partner's hand, which the partner holds raised to shoulder level. Repeat 10–12 times. Next the partner raises his left hand, and the exercise is repeated. The distance between the partners is 2–3 meters. (Fig. 36)

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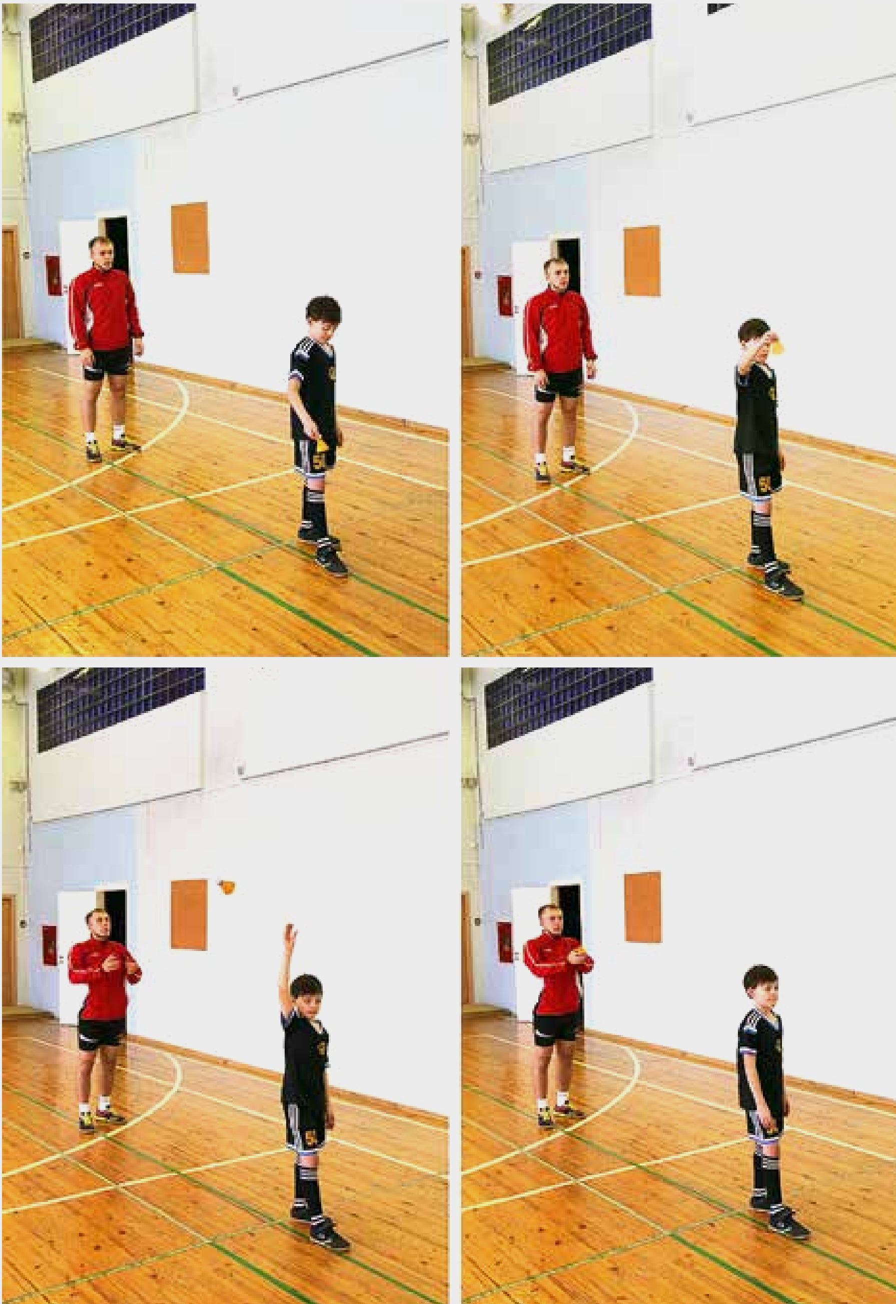


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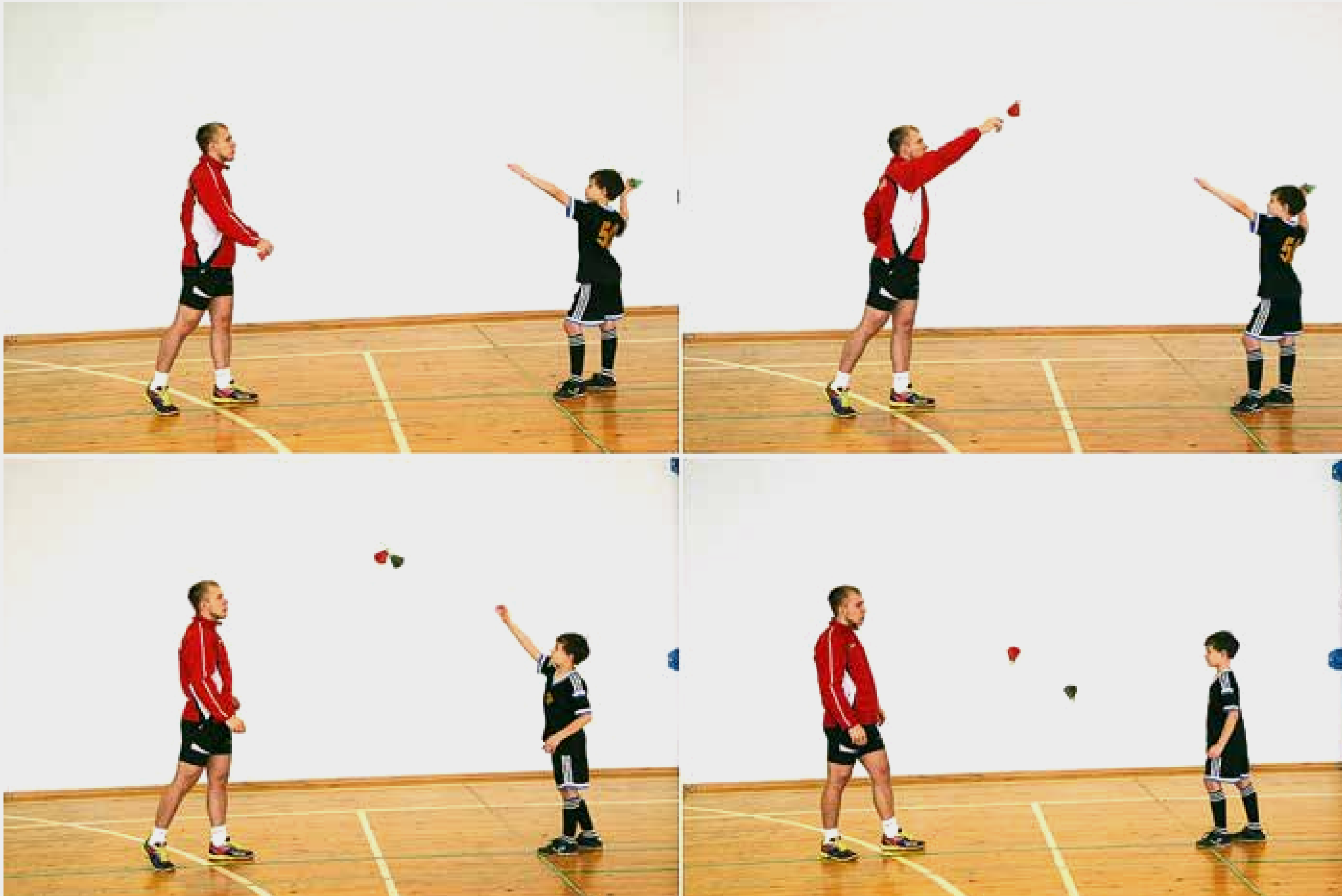
5. SP: stance as for the short serve, the shuttlecock in the left hand, left arm extended forward. Release the shuttlecock as if serving, then kick the shuttlecock with the outer side of the foot toward the partner. Partner catches shuttlecock with one or two hands. Attempt to perform alternately with right and left leg. Repeat the exercise 10 times, for the total of 2 sets. The distance between the partners is 2–3 meters. (Fig. 37)
6. The first player pitches the shuttlecock backwards over his head — to be performed alternately with left and right hand. The catcher faces the back of the pitcher. Repeat 10 times, for the total of 2 sets. The distance between the partners is 2–4 meters. (Fig. 38)
7. Pitch the shuttlecock sideways from below. Perform the pitch standing sideways in the direction of the pitch, alternating right and left hands. Repeat 10 times, for the total of 2 sets. The distance between the partners is 2–4 meters. (Fig. 39)

Paired Exercises with Two Shuttlecocks

1. SP: the basic stance, both partners holding shuttlecocks in their right hands. Partners stand facing each other. Simultaneously pitch the shuttlecocks at each other on a low trajectory, catching the shuttlecock is mandatory. Repeat 10 times, for the total of 2 sets. The distance between the partners is 2–4 meters. (Fig. 40)
2. SP: the basic stance, both partners holding shuttlecocks in their right hands. Partners stand facing each other. Simultaneously pitch the shuttlecocks at each other on a high trajectory, catching the shuttlecock is mandatory. Repeat 10 times, for the total of 2 sets. The distance between the partners is 2–4 meters. (Fig. 41)
3. SP: the basic stance, both partners holding shuttlecocks in their right hands. Partners stand sidewise to each other. Simultaneously pitch the shuttlecocks from the low position sidewise to each other. Repeat 10 times, for the total of 2 sets. The distance between the partners is 2–4 meters. (Fig. 42)



4. SP: the basic stance, both partners holding shuttlecocks in their right hands. Partners stand facing each other and simultaneously pitch the shuttlecocks at each other on a high overhead trajectory. Then rapidly change places, running to the right in a half-circle, catching the shuttlecock of the partner. Repeat 10 times, for the total of 2 sets. The distance between the partners is 2–4 meters. (Fig. 43)
5. SP: the basic stance. Both partners holding shuttlecocks in their right hands. Partners stand facing each other. The first player pitches the shuttlecock to the second player along the low or the high trajectory, while the second player attempts to hit the flying shuttlecock with his shuttlecock. In case of a miss, catch both shuttlecocks, in case of a hit, catch at least one and return to the SP. Repeat 10 times, for the total of 2 sets. The distance between the partners is 2–4 meters.

Afterwards, change positions (the pitcher is now the catcher and vice versa) and repeat the exercise. (Fig. 44)

Logistics of the Instructional Process

Selection of equipment is determined by the lesson objectives. Dimensions and forms of equipment must meet the age characteristics, its amount is determined in accordance with the number of participants.

The most important requirement — safety of the equipment. It is necessary to ensure proper smooth finishing of wooden objects (such as gymnastic stick).

Equipment

- Badminton racquets;
- Shuttlecocks in different colors;
- Tennis balls in different colors;
- Balls in different colors;
- Inflatable balls in different colors;
- Gymnastic sticks.

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Contents

Appendix 2

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

The Badminton World Federation

The National Badminton Federation of Russia

MODERN SCIENTIFIC AND METHODOLOGICAL ASPECTS OF BADMINTON

Turmanidze Valeriy Grigorievich

Candidate of Pedagogy, Professor of RAE, Dean of faculty of Physical Education, Rehabilitation and Sport

Fomenko Anatoliy Aleksandrovich

Assistant to the Professor

Mass sport

Mass badminton is a key to **development** of social and international relationships in the frameworks of
mass cultural events, because **physical activity in the form of a game** triggers positive emotions, enables to detect leaders, and works as a team-building practice in order to achieve goals of diverse complexity.

While playing badminton people can demonstrate **their personalities**, which are reflected in their gaming style, and reveal different **traits of their character**, such as purposefulness, will-power, ability for operational thinking, and creativity in decision-making during an episodic activity.

Mass sport

The positive feature of mass badminton is availability of different types of ***game disciplines***: men’s singles, women’s singles, men’s doubles, women's doubles, and mixed events. This helps to satisfy individual level of **sport aspirations** including gender differences, which are not only characteristics of male and female organisms, but also social, cultural, age- and behavior-specific categories.

Joint sport-related activities for both girls and boys create **favorable conditions** for healthy psychological development, enhancement of social adaptation, and improvement of communication skills with representatives of the opposite sex. All this ensures success in students’ future careers and family relationships.

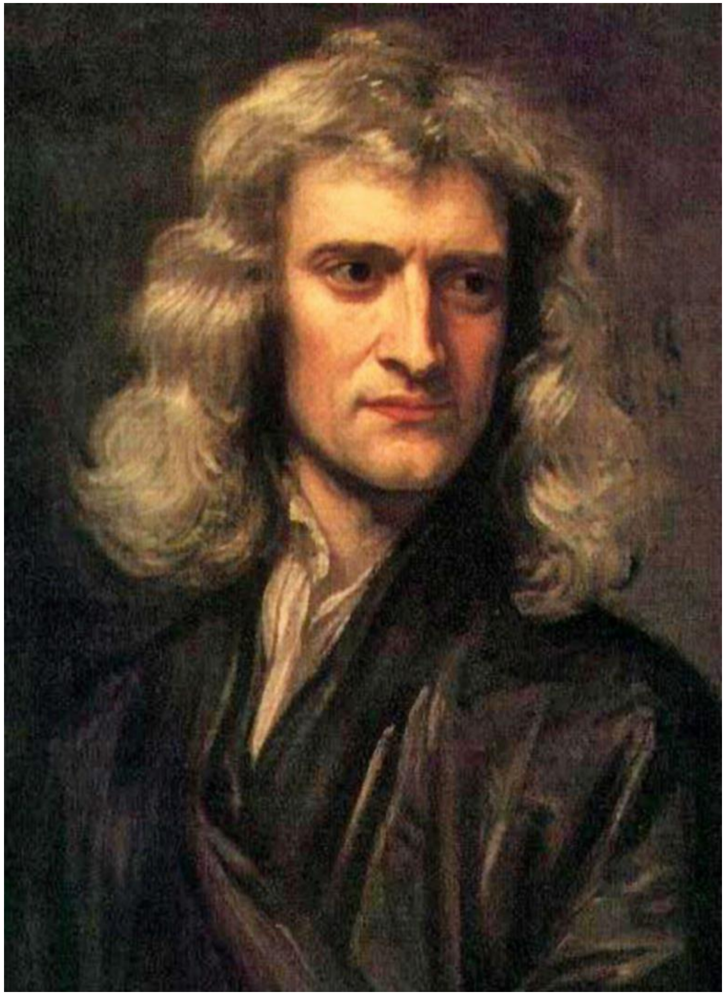
High performance sport

The second aspect is characterized by **integral training** of highly-professional badminton players and upbringing of Olympic Reserve athletes who can take part in world competitions.

Dominating **physical and intellectual parameters** of badminton players are as follows: high level of speed and strength endurance, good coordination, high speed of response to a moving object, good concentration and great spatial orientation.

The last parameter is unique, because during the jump attack it is important to be aware of an optimal body spatial position and its segments' bending angle, taking into consideration limited **time parameters** of body's "hanging-up" in the air, which depend on the height of jump and the athlete's body mass.

Photos are the courtesy of the National Badminton Federation of Russia (http://www.badm.ru)



“...***times and spaces*** are, as it were, the places as well of themselves as of all other things.

All things are placed **in time** as to order of succession; and **in space** as to order of situation.

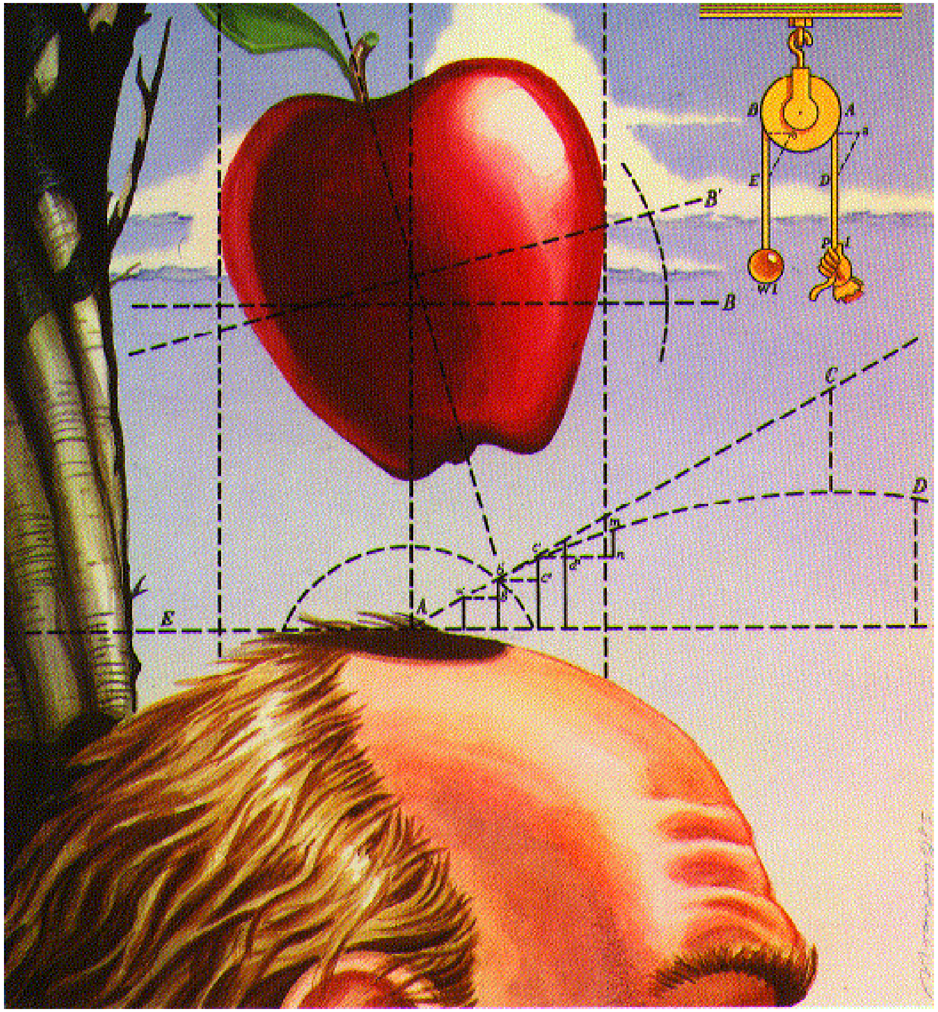
It is from their essence or nature that they are places; and that the primary places of things should be movable, is absurd.

These are therefore the absolute places; and translations out of those places, are the only absolute motions”.

Isaak Newton

Portrait of Newton by Godfrey Kneller (1689)

Newton's second law of motion



"In an inertial reference frame, the vector sum of the ***forces*** on an object is equal to the ***mass*** of that object multiplied by the ***acceleration*** of the object".

$$\vec{F} = m\,\vec{a}$$

$\vec{F}$ is the net force applied (quantitative characteristics of force of one object applied to another one);

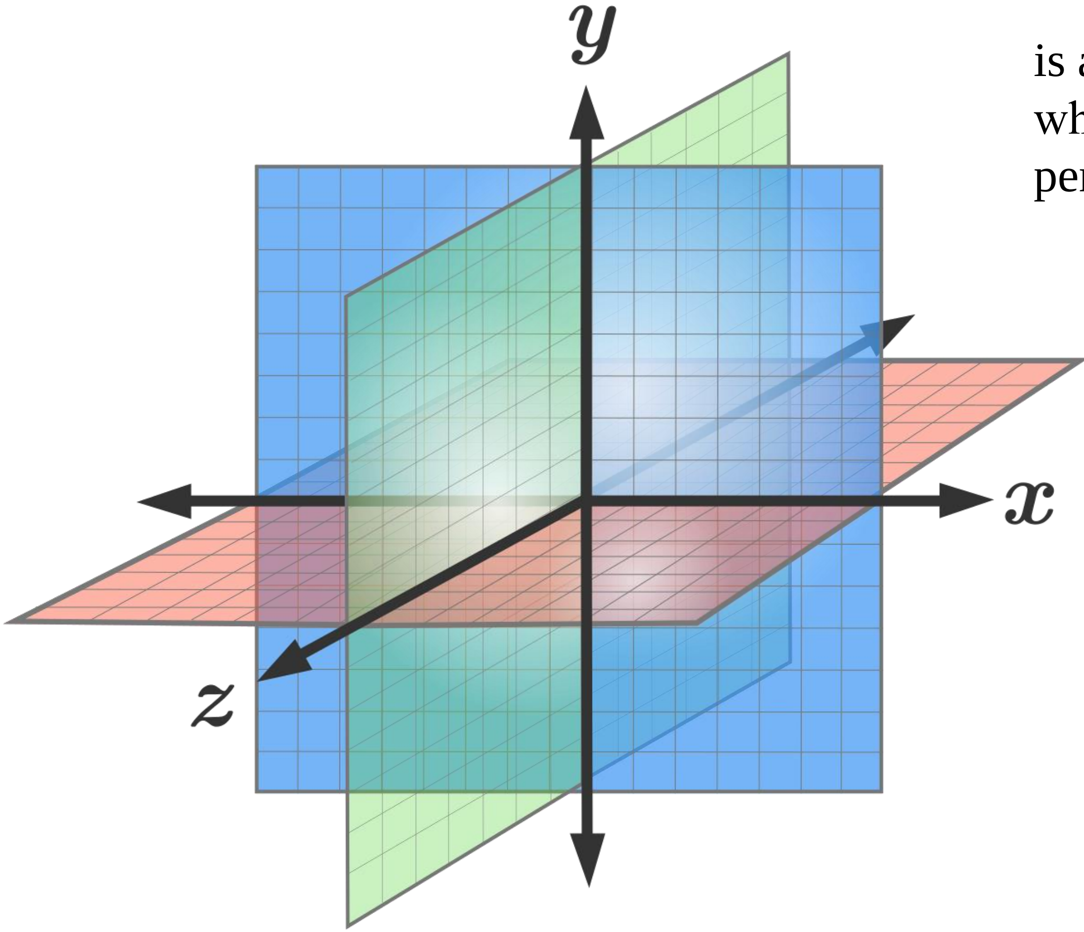
m is the mass of the body (quantitative characteristics of object's inert properties);

$\vec{a}$ is the body's acceleration (quantitative characteristics of object's speed change).

$$\vec{a} = \vec{F} : m$$

"The ***acceleration*** of an object as produced by a net force is directly proportional to the magnitude of the ***net force***, in the same direction as the net force, and inversely proportional to the ***mass*** of the object".

3D space –



is a geometric model of material world, which includes subjects of the world's perception.

Three uniform dimensions:

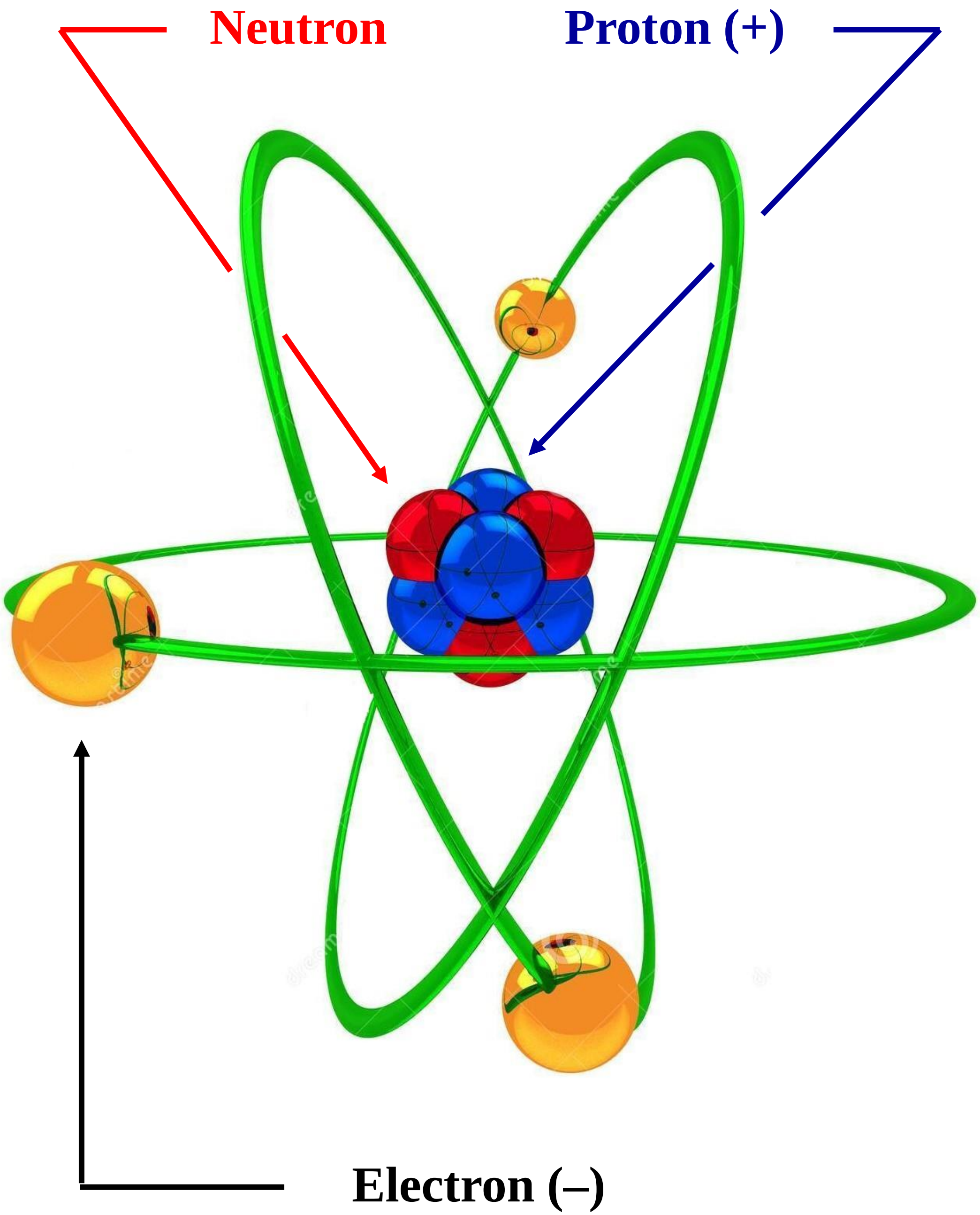
– height (top-bottom);
– width (left-right);
– length (forward-backward).

The model is described by three unit vectors that create **coordinates**.

Physical object can exist in one place at one time.

Comparative analysis of aerodynamic characteristics of sports equipment

No	Characteristics	Shuttlecock (feather), badminton	Ball, tennis	Ball, table tennis
1	Form	complex	spherical	spherical
2	Material	head – cork tail – feathers	felt (matted wool)	celluloid / plastic
3	Diameter (cm)	head – 2.8 feathers' ends – 5.8–6.8	6.67	4.0
4	Weight (g)	4.74–5.50	58.50	2.70
5	Average speed (km/h)	300	200	180
6	Flying height over the net	up to 12 m	up to 15 cm	up to 10 mm
7	Max. allowed flying length (m)	14.72	26.18	3.13



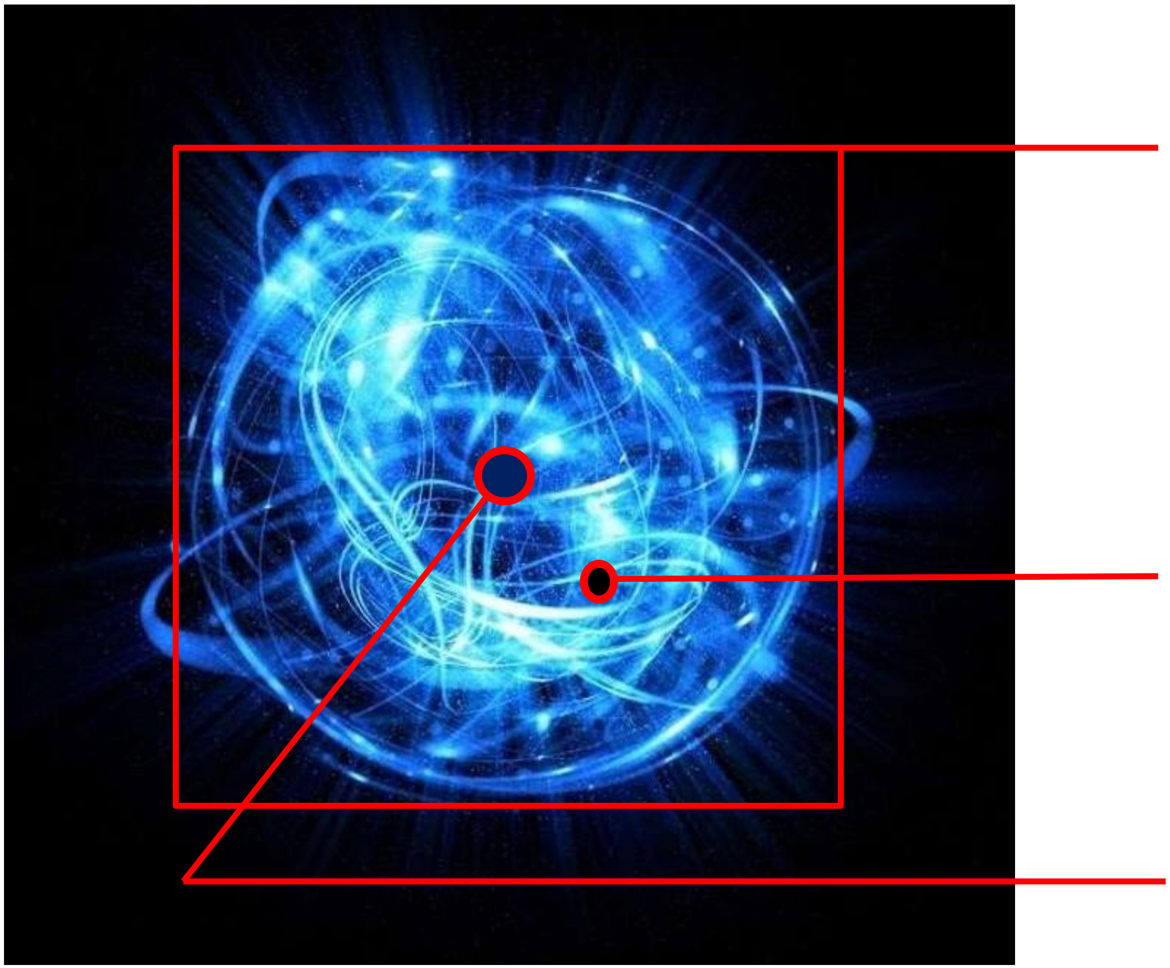
Atomic nuclear model
(The Rutherford model)

The atom is made up of a positive central charge – ***atomic nucleus*** – in which nearly all the mass is concentrated.

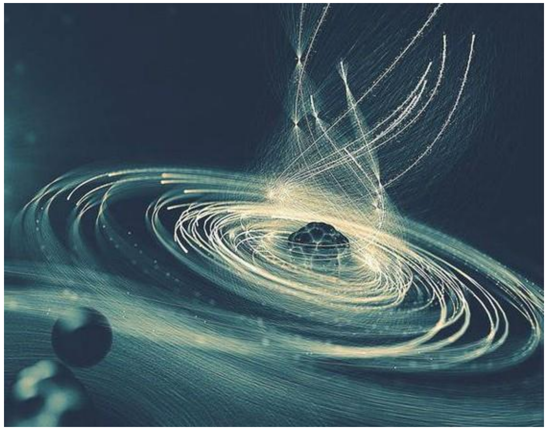
On the whole, atom is neutral. Around the nucleus, negative constituents, called ***electrons***, circulate at some distance due to Coulomb's forces (interactions between static spot electric charges).

Electrons always move, otherwise they would have fallen onto the nucleus.

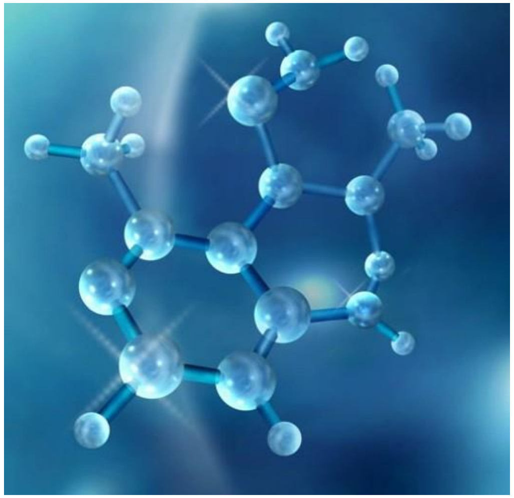
The quantum mechanical model of the atom with electron cloud



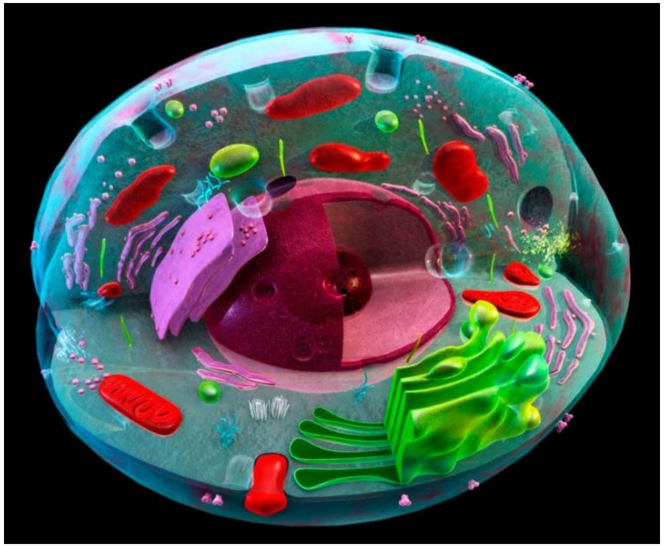
Atom



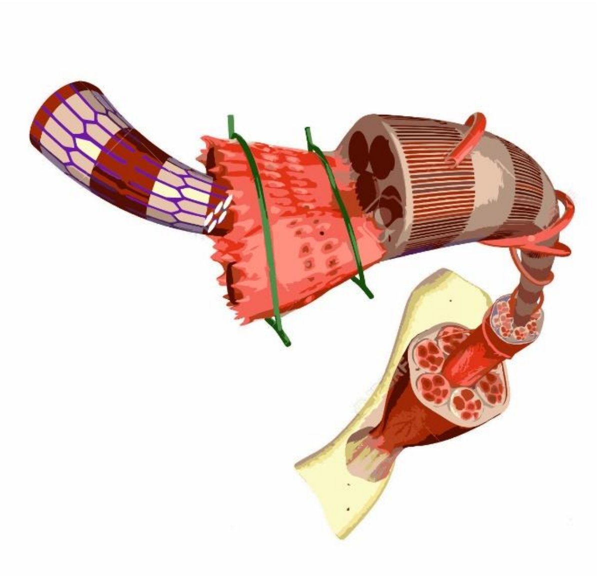
Molecule



Cell



Tissue



Organ

System

A set of neural networks

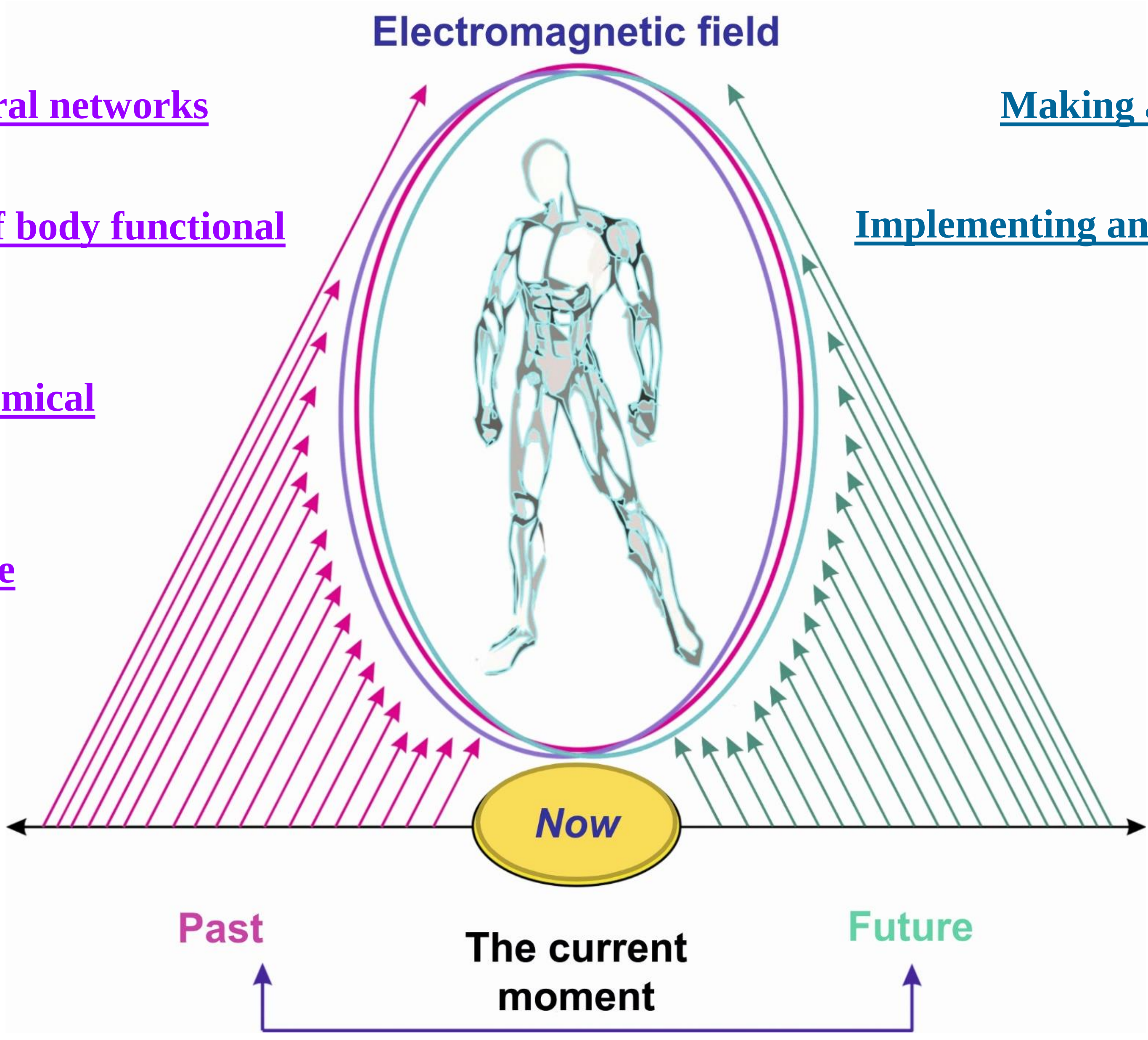
Condition of body functional system

Body biochemical composition

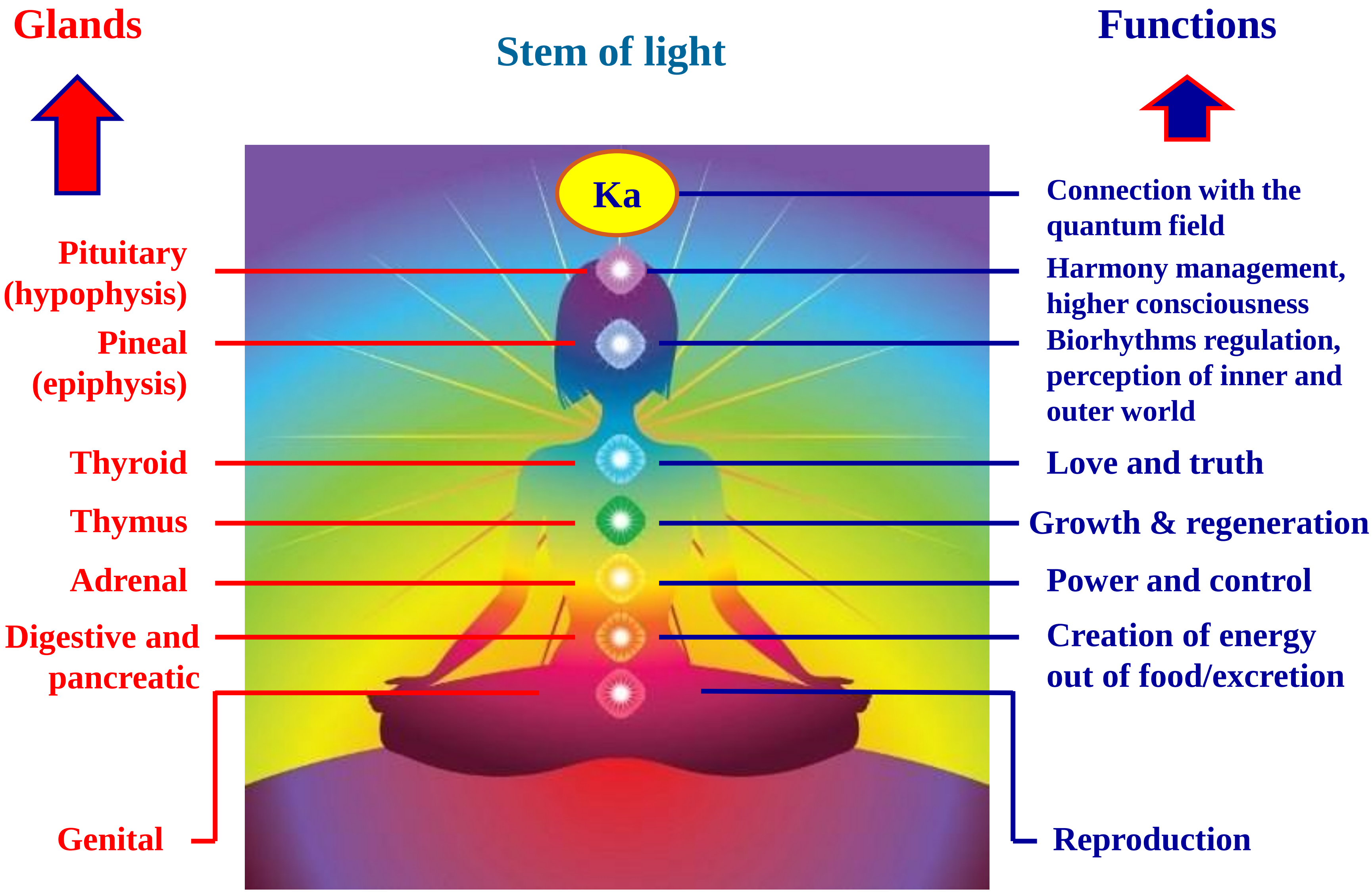
Level of gene expression

Making a decision

Implementing an intention



Time perception



Energy centers of a human being

CEREBRAL ACTIVITY WAVES

Beta	14-30 Hz	Usual state of awakening
Alpha	7-14 Hz	Meditation, a state between sleeping and awakening, immersion into dreams and fantasies
Theta	4-7 Hz	Sleep, deep meditation
Delta	0,5-4 Hz	Very deep sleep, trance, hypnotic trance

Thank you for your attention!

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Federation of Russia

CORRECTIVE-PREVENTIVE MANAGEMENT FOR PEOPLE WITH MYOPIA USING ELEMENTS OF BADMINTON

Turmanidze
Valeriy Grigorievich

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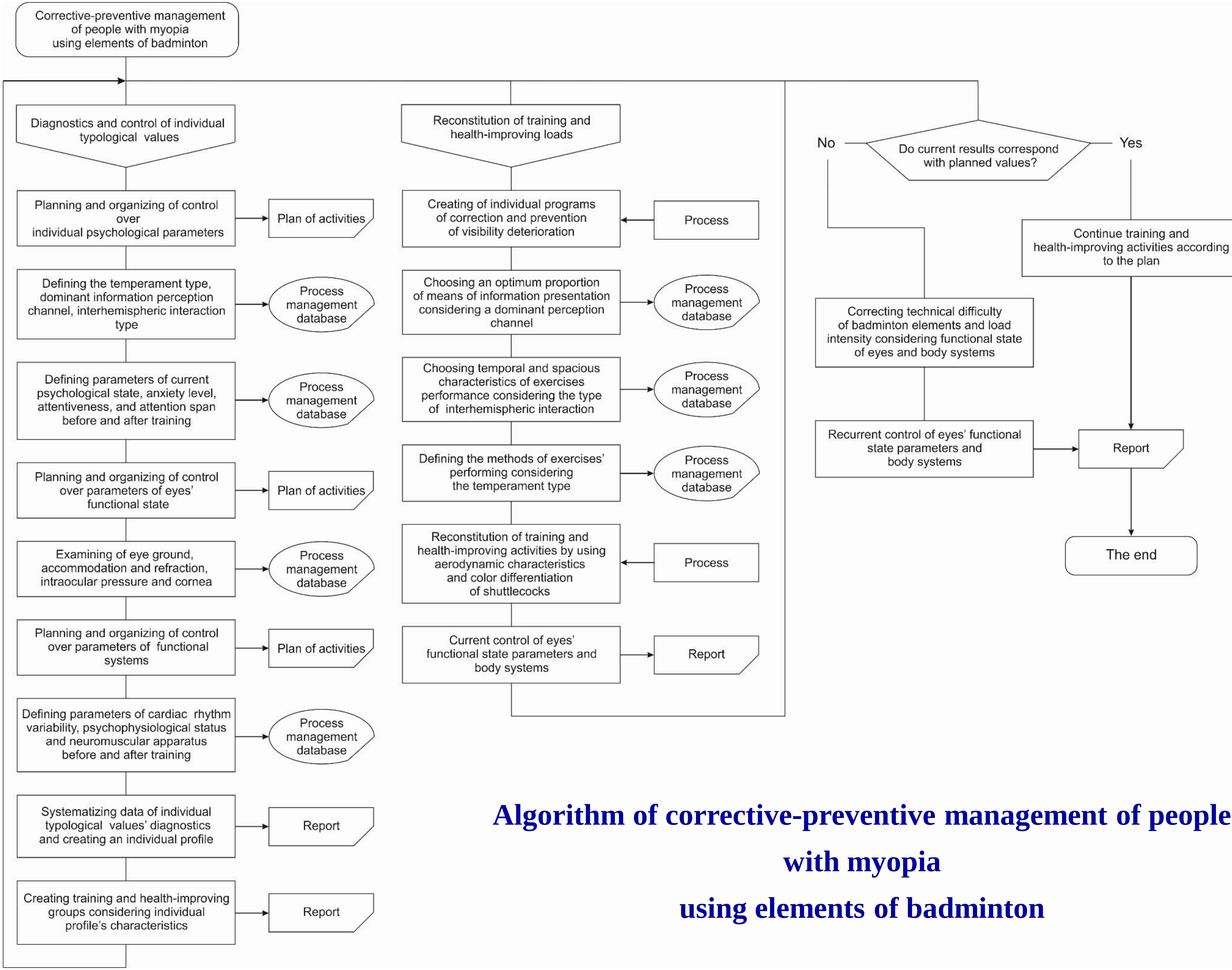
Fomenko
Anatoliy Aleksandrovich

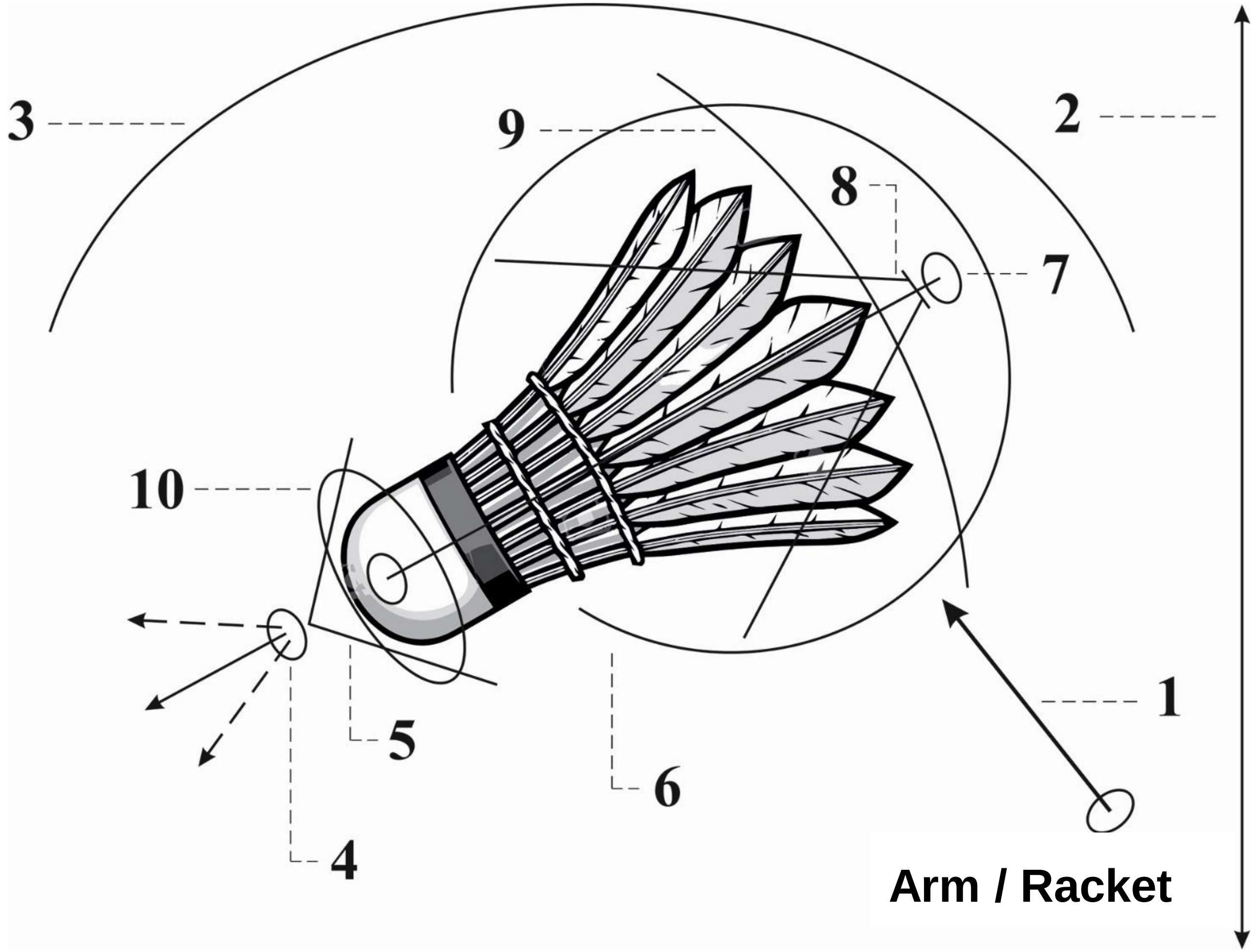
Assistant to the Professor



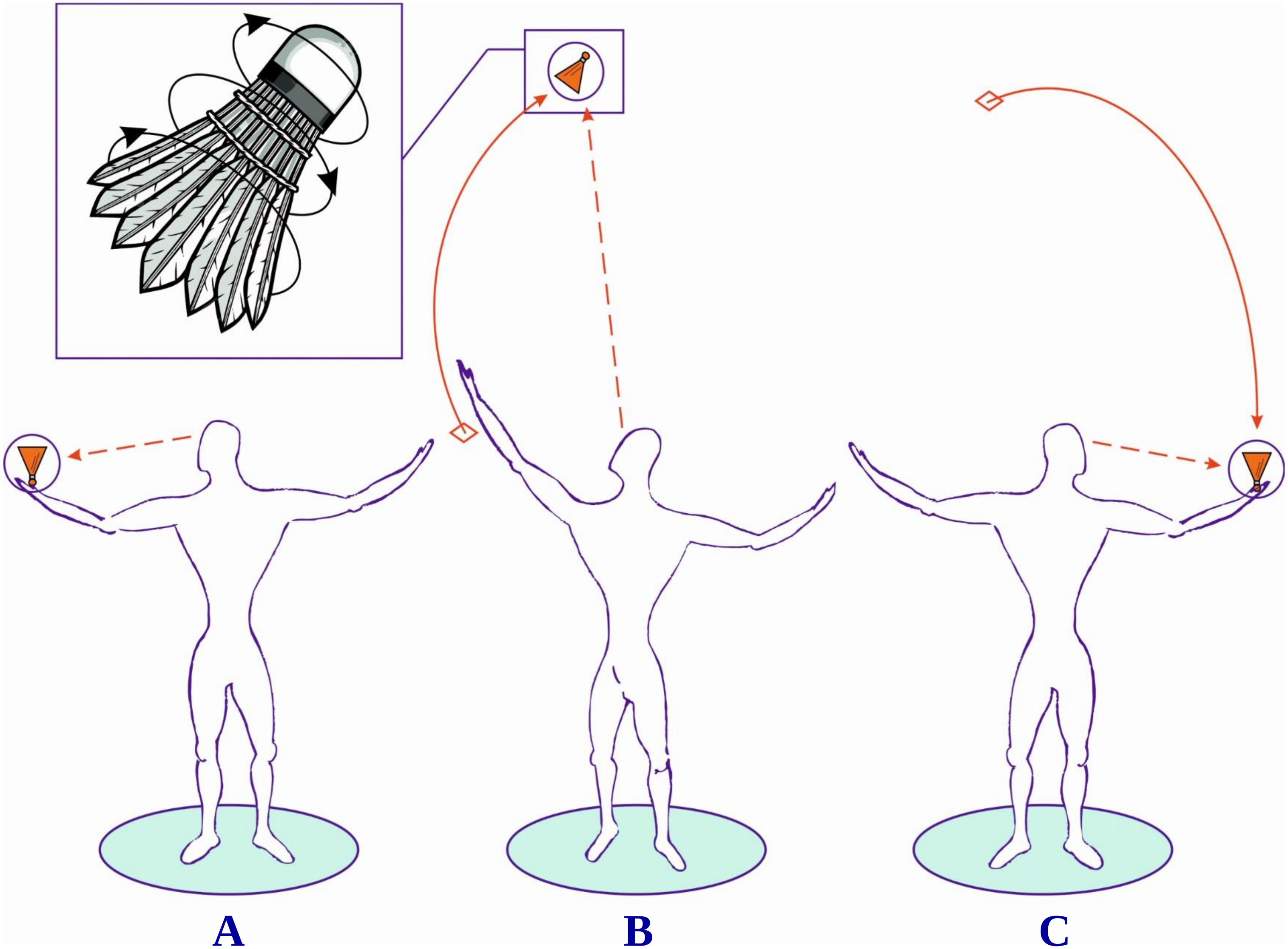
Photos are the courtesy of the National Badminton Federation of Russia (http://www.badm.ru)



Algorithm of corrective-preventive management of people with myopia using elements of badminton



1 – lifting force (arm / racket); 2 – shuttlecock flying height; 3 – motion path; 4 – attack angle; 5 – suppression of air resistance by the front fairing (shuttlecock cork);	6 – aerodynamic power field (inner part of the shuttlecock's "body"); 7 – shuttlecock rotation axis; 8 – shuttlecock rotation angle; 9 – shuttlecock rotation range; 10 – lowering aerodynamic force.



Schematic representation of throwing the shuttlecock upwards with the given hand and its catching with the other hand.

Peculiarities of conducting training and health-improving process taking into consideration the type of interhemispheric interaction

The right hemisphere is a dominant one

Nature of information presentation:

Create a coherent picture of all exercises' usage with explanation of the final result. Stimulate the mind to create sensual images: visual images, sounds, scents, tactile and spatial-temporal characteristics of training and health-improving process.

Nature of exercises' performing:

Exercises performed predominantly with the left arm with different ratios (75% : 25% or 60% : 40%). Eyes follow the shuttlecock right-to-left. The bulk of exercises is performed with the shuttlecock in the first (0-3 m) and third (9-12 m) “air corridor” (40% : 20% : 40%).

Modes of exercises' performing:

- alternate interaction of dominant and non-dominant arms;
- active usage of non-dominant arm in doubles;
- usage of dominant arm, when exercises' technique and training process become more complicated.

Peculiarities of conducting training and health-improving process taking into consideration the type of interhemispheric interaction

The left hemisphere is a dominant one

Nature of information presentation:

Demonstrate succession of actions in the form of well-structured algorithm using cognitive schemes and diagrams. Stimulate thinking processes by speaking with different intonation.

Nature of exercises' performing:

Exercises performed predominantly with the right arm with different ratios (75% : 25% or 60% : 40%). Eyes follow the shuttlecock left-to-right. The bulk of exercises is performed with the shuttlecock in the second (3-9 m) "air corridor" (20% : 60% : 20%).

Modes of exercises' performing:

- successive interaction of dominant and non-dominant arms;
- active usage of dominant arm in doubles;
- usage of non-dominant arm, when exercises' technique and training process become more complicated.

Peculiarities of conducting training and health-improving process taking into consideration the type of interhemispheric interaction

The right and the left hemispheres are used simultaneously

Nature of information presentation:

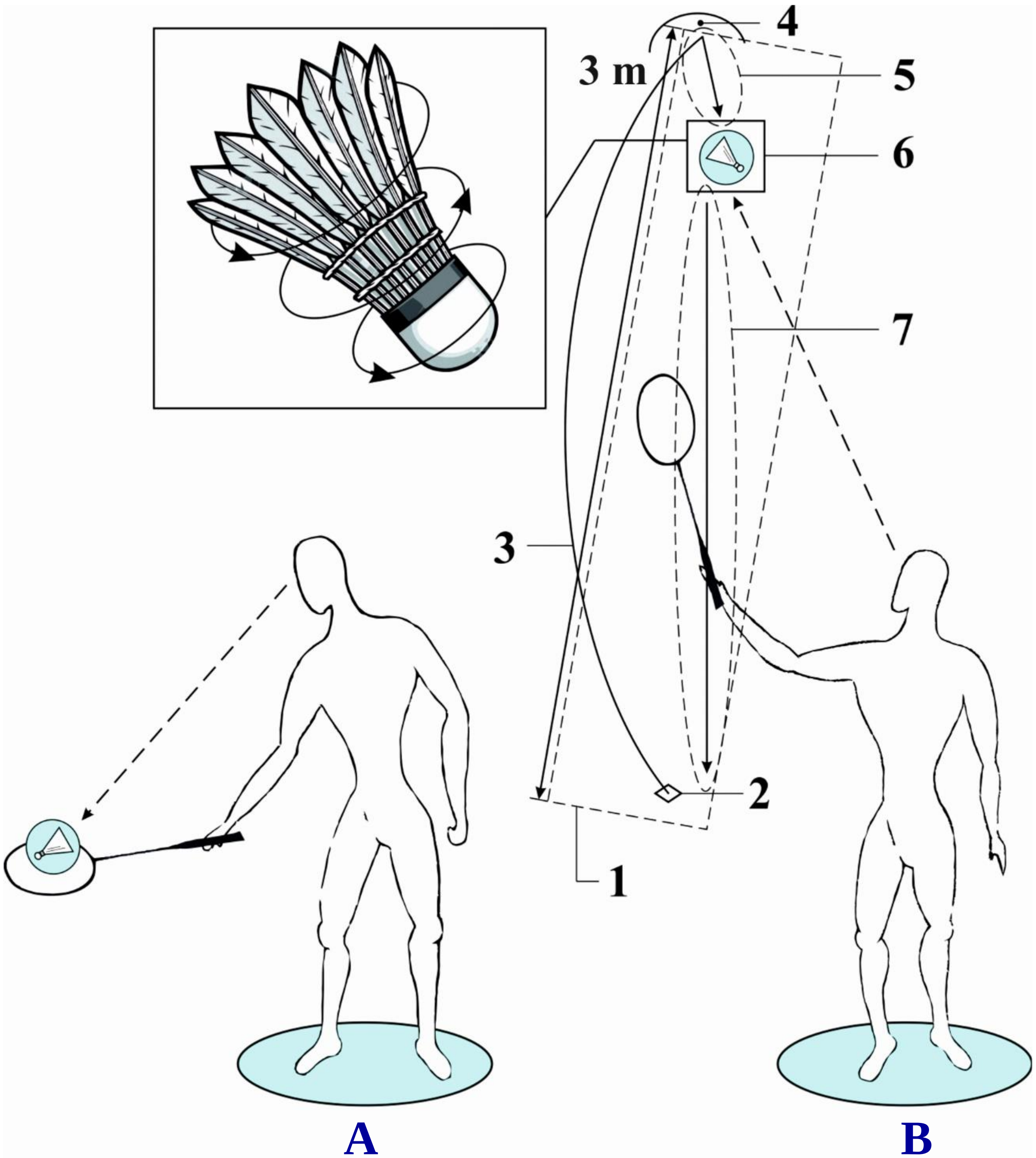
In the beginning of training and health-improving process, information is presented by the means used in the case of people with right hemisphere dominating. When they master the basic technique of exercises, it is necessary to use two types of information presentation in turns, each time stimulating an opposite hemisphere after mastering an advanced technique level.

Nature of exercises' performing:

Exercises performed with the right and left arms in turn, spending more time working with the dominant arm (75% : 25% or 60% : 40%). Eyes follow the shuttlecock in turns, first right-to-left then left-to-right. Equal amount of exercises is performed with the shuttlecock in all three "air corridor" (30% : 30% : 40%), spending more time working in the third corridor (9-12 m).

Modes of exercises' performing:

- simultaneous interaction of both arms, with the focus on the dominant arm;
- using arms in turns during doubles;
- usage of dominant and non-dominant arm, when exercises' technique and training process become more complicated.



Note:

1 – the first “air corridor” is 3 meters;

2 – elevating force’s (racket) application point;

3 – path of shuttlecock’s continuous ascend;

4 – lowering aerodynamic force’s application point;

5 – zone of shuttlecock’s “hanging”;

6 – shuttlecock’s rotation on its axis;

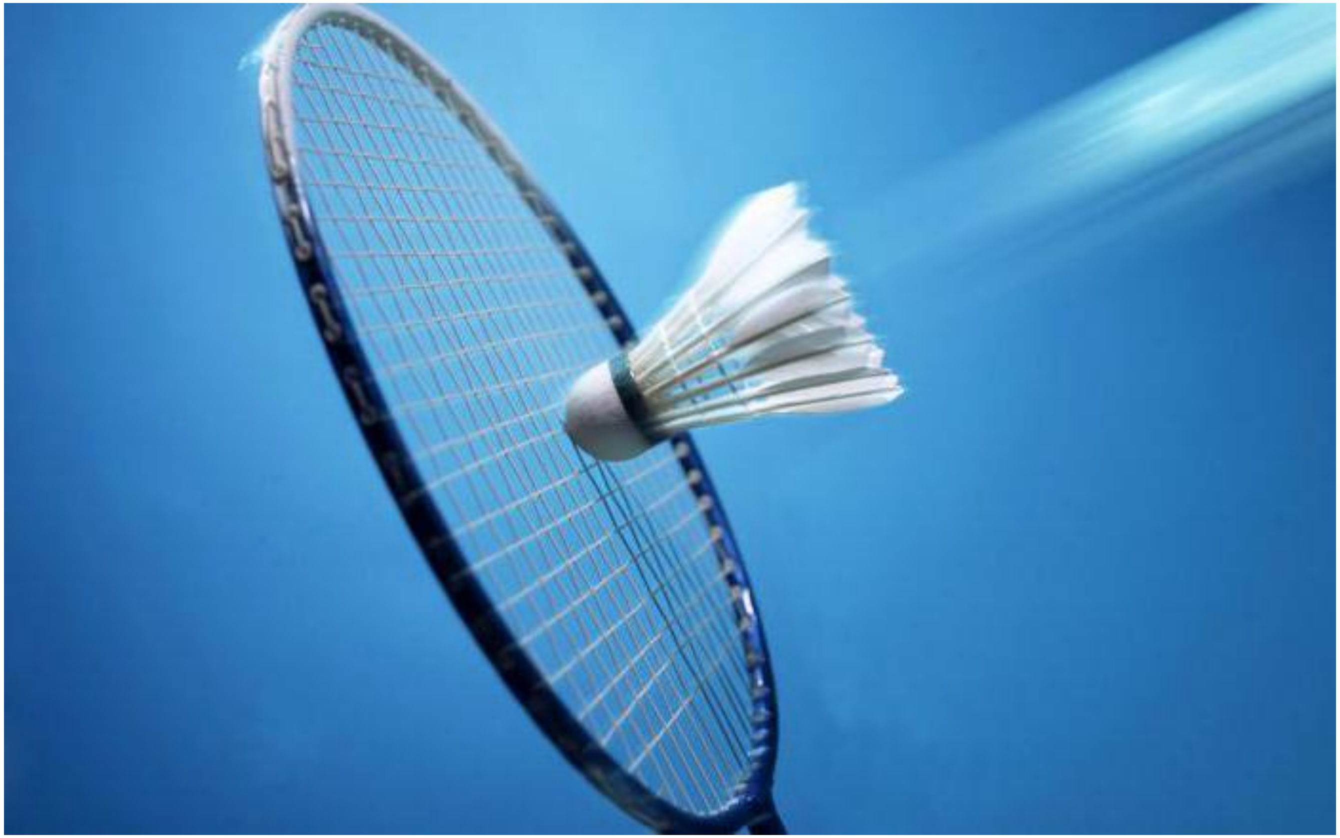
7 – zone of shuttlecock’s falling acceleration.

Shuttlecock juggling in the first “air corridor”

Indicators of psychophysiological status of people doing exercises with elements of badminton before and after the experiment

No	Indicators	Values	
		before training	in 6 months after starting training
Speed of response, ms			
1	Speed of response to light	400.1±43.26*	317.9±49.07*
2	Speed of response to sound	466.5±30.71	435.4±44.12
3	Speed of response to moving object	728.2±64.33*	532.7±59.25*
4	Speed of choice response	579.0±55.38*	411.8±32.17*
Object reconstitution, error in %			
5	Evaluation of the object's speed	9.8±1.43*	6.2±1.20*
6	Time span reconstitution (light)	11.2±2.64*	6.7±1.82*
7	Time span reconstitution (sound)	8.9±2.58	8.2±2.41
8	Evaluation of presented intervals' length	6.7±1.07*	4.9±0.85*
9	Intervals' measuring	17.3±5.22*	8.4±2.39*
10	Evaluation of presented angles' measures	11.2±1.79*	7.3±1,.34*
11	Recognition of presented angles	2.3±1.94	1.1±0.83
Psychomotor and psychological values, grades			
12	Tapping test (max.)	51.8±4.57*	59.6±2.14*
13	Tapping test (min.)	37.3±2.75*	46.5±4.60*
14	Tapping test (difference)	15.4±2.83	12.9±1.28
15	Attentiveness	7.1±0.92*	9.5±1.16*
16	Attention span	6.4±0.85*	9.3±1.42*
17	Trait anxiety	33.2±3.24*	29.7±3.85*
18	State anxiety	35.8±2.61*	27.0±1.82*
Note: differences in the values are accurate when p<0.05			

Thank you for your attention!



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COLOR DIFFERENTIATION OF SHUTTLECOCKS BASED ON INDIVIDUAL PSYCHOLOGICAL CHARACTERISTICS

Turmanidze Valeriy Grigorievich

Candidate of Pedagogy, Professor of RAE, Dean of faculty of Physical Education, Rehabilitation and Sport

Fomenko Anatoliy Aleksandrovich

Assistant to the Professor

Characteristics of shuttlecocks' colors and their application in myopia correction and prevention

Turquois and green shuttlecocks
– symbolize tranquility, equableness of mind, and serenity;
– decrease anxiety level, allow to adapt to new conditions of the environment that helps to increase efficiency and stabilize activity results;
– have a positive impact on inhibitory processes in the central nervous system and humoral regulation balance;
– ensure smooth incorporation of ciliary muscle into training and health-improving process, thus allowing to increase a total volume of correction load, maximum values of possible angular amplitude, and parameters of accommodation, which provide for positive effect of training and health-improving process.

Characteristics of shuttlecocks' colors and their application in myopia correction and prevention

Yellow shuttlecock
– arouses desire to communicate, share positive emotions, and create a favorable atmosphere for others; – cheers up, increases demand for self-presentation and ability to maintain a positive psychological state that has a beneficial effect on coordination and spatial orientation; – activates excitation of the central nervous system, metabolic processes in humoral and regulatory systems; – increases intensity of training and health-improving loads without excessive tension of eye-muscles that allows to vary angular and accommodation amplitude.

Characteristics of shuttlecocks' colors and their application in myopia correction and prevention

Orange and red shuttlecocks

- symbolize energy, moderate aggressiveness, and manifestation of will power;
- increase an ability to clear the obstacles, creates an interest in interpersonal interaction and achievement of common goals that provides for good results in development of trainees' locomotor potential;
- increase an excitation speed of central nervous system, activation of humoral regulation of physiological processes;
- improve blood flow in ophthalmic artery, medial and lateral posterior short ciliary arteries, and central retinal vein that prepares visual apparatus for training and health-improving loads at the very beginning of the workout.

Characteristics of shuttlecocks' colors and their application in myopia correction and prevention

Black-and-white shuttlecock

- characterized by the desire to reach harmony and deal with difficult technical and creative issues;
- stimulates engagement of intellectual potential in training and health-improving process, ensures the possibility to combine locomotor and intellectual abilities;
- provides for quick switching between excitation and suppression processes in the central nervous system, speeds up the reactions of humoral and reflectory systems;
- has a positive impact on eye-muscles' tonus, thus increasing their performance efficiency; that, together with following the key principles of pedagogic and health-improving technology, improves refraction and accommodation of visual apparatus.

Characteristics of shuttlecocks' colors and their application in myopia correction and prevention

Violet, black, brown, and grey shuttlecocks (colors excluded from the technology)

- symbolize anxiety, stress, fear and sadness;
- lower self-assurance, trigger negative psychological state that discourages from interacting with other people, reduces attentiveness and concentration and, as a result, decreases agility and speed of reaction to the moving object;
- cause uncontrollable excitation and suppression processes in the central nervous system, misbalance humoral regulation;
- lead to excessive tension of eye-muscles due to involuntary concentration on an object, which interrupts dynamic interaction of visual and locomotor systems and does not allow to reach an optimal angular and accommodation amplitudes.

Combinations of shuttlecock's colors for performance of corrective and preventive exercises considering temperament type

Sanguine persons
red: increases blood flow in ophthalmic arteries that ensures full readiness of visual analyzer from the very beginning of the workout;
green: suppresses the central nervous system, which increases the net volume of training and health-improving load;
black-and-white: engages the intellectual potential and triggers the mechanism of quick switching between excitation and suppression processes in the central nervous system, thus allowing for high efficiency of visual apparatus' work;
orange: increases excitation of the central nervous system to bear the maximum training and health-improving load on eye-muscles;
turquois calms the central nervous system to continue effective training of visual apparatus by increasing angular or accommodation amplitude;
yellow: reinforces a favorable training and health-improving effect, decreases the load on eye-muscles, prepares the body for the end of the workout.

Combinations of shuttlecock's colors for performance of corrective and preventive exercises considering temperament type

Phlegmatic persons

black-and-white: from the very beginning increases the efficiency of moving and intellectual abilities, affects eye tonus favorably;

turquoise: increases the load on ciliary muscles gradually, increases the maximum possible angular and accommodation amplitudes;

orange: increases the speed of excitation of the central nervous system, which increases the net volume of training and health-improving load;

green: suppresses the central nervous system to avoid an excessive tension of eye-muscles;

red: triggers excitation of the central nervous system to increase refraction and accommodation values of visual analyzer;

yellow: decreases eye-muscles' tension gradually, provides the state of psychological comfort, a good background for improvement of angular and accommodation amplitude.

Combinations of shuttlecock's colors for performance of corrective and preventive exercises considering temperament type

Choleric persons

green: smoothly engages ciliary muscle into training and health-improving process by increasing angular and accommodation amplitude gradually, thus helping to avoid an excessive eye-muscle tension.

orange: increases training and health-improving load gradually, improves the blood flow in ophthalmic arteries;

red: increases excitation of the central nervous system, helps to reach the maximum load on eye-muscles, increases attentiveness, improves refraction and accommodation indicators;

black-and-white: relaxes eye-muscles by switching them to other angular and accommodation parameters of amplitude;

yellow: enhances a positive psychological state, helps to change angular and accommodation parameters of amplitude, prepares the body to the last changing of shuttlecock;

turquoise: triggers the processes of the central nervous system's suppression, gives an optimal load to ciliary muscle, taking into consideration the current psychological state.

Combinations of shuttlecock's colors for performance of corrective and preventive exercises considering temperament type

Melancholic persons

orange: from the very beginning increases excitation of the central nervous system by improving the blood flow in ophthalmic arteries, which increases the maximum of training and health-improving load;

red: helps to activate the mechanisms of the central nervous system excitation, thus allowing to achieve the necessary training and health-improving effect on ciliary muscle;

black-and-white: lowers excitation of the central nervous system by changing angular and accommodation amplitudes;

turquoise: provides minimal tension of ciliary muscle with a consequent change of angular and accommodation amplitude's values;

green: helps to stabilize the load on visual apparatus, which allows to achieve the maximum possible angular and accommodation amplitude;

yellow: wraps up training and health-improving activities in a positive emotional way with a slight increase of training load.

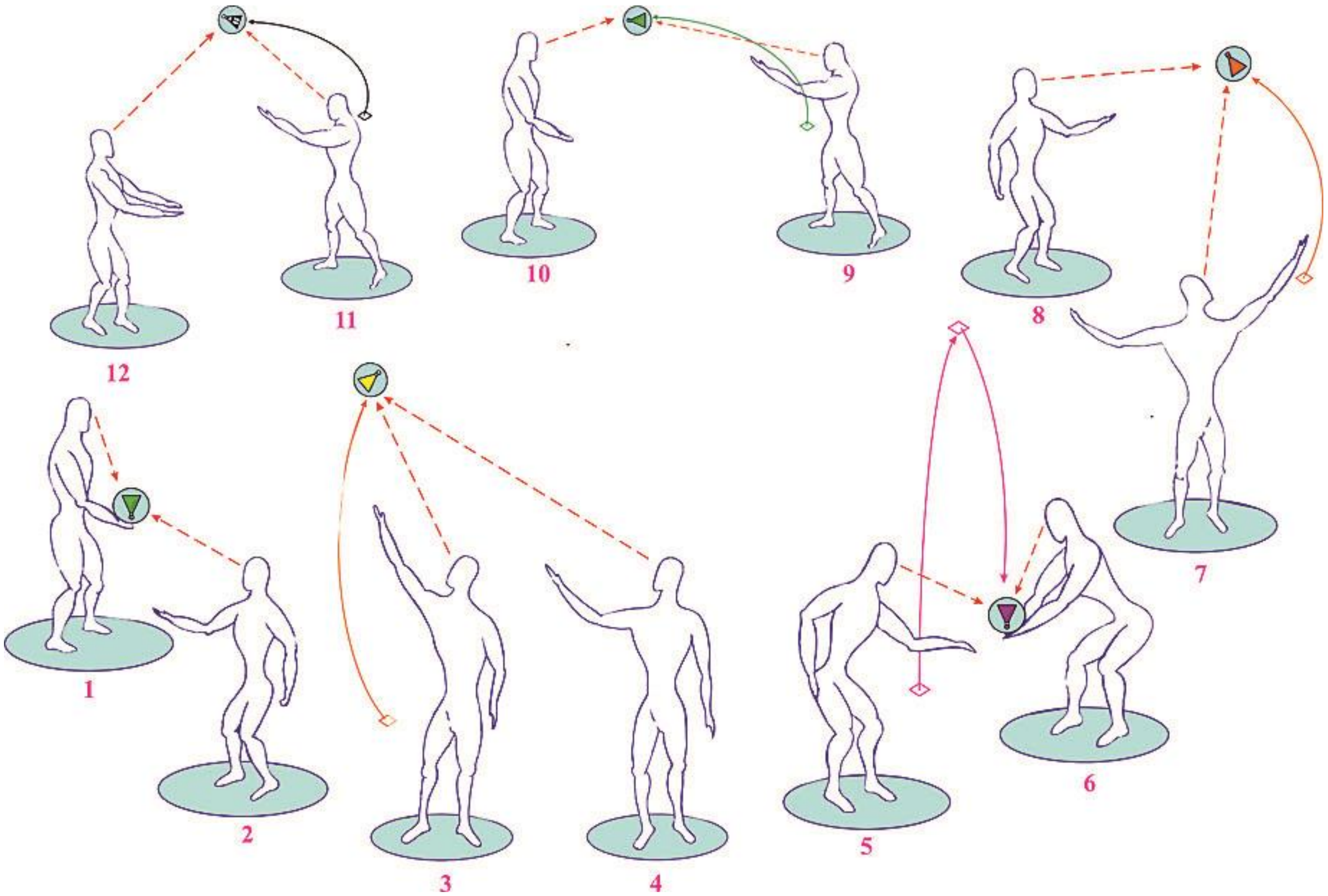
Myopia correction and prevention methods by exercises with elements of badminton based on individual psychological characteristics

Sanguine persons

Group exercises with two / six shuttlecocks:

Task 1: throw shuttlecocks of different colors one by one along the high trajectory – catch shuttlecocks with one and/or another hand at the chest level.
Task 2: throw shuttlecocks of different colors one by one upwards – catch shuttlecocks with the furthest hand at the waist level.
Task 3: one partner throws shuttlecocks of different colors one by one from the hip level upwards with the hand designated – the other partner catches shuttlecocks with both hands at the hip level.
Task 4: throw shuttlecocks of different colors one by one over the head standing with the back to the partner – catch shuttlecocks with both hands while moving to the side.
Task 5: throw shuttlecocks simultaneously circle-wise to the partner next to you, the number of partners is 6-12, the distance between them is 2.5–5.0 m.

Shuttlecock's color changing sequence
red, green, black-and-white, orange, blue, yellow.
Dosage: 15 throws with each hand.
Performance time: 360 sec.



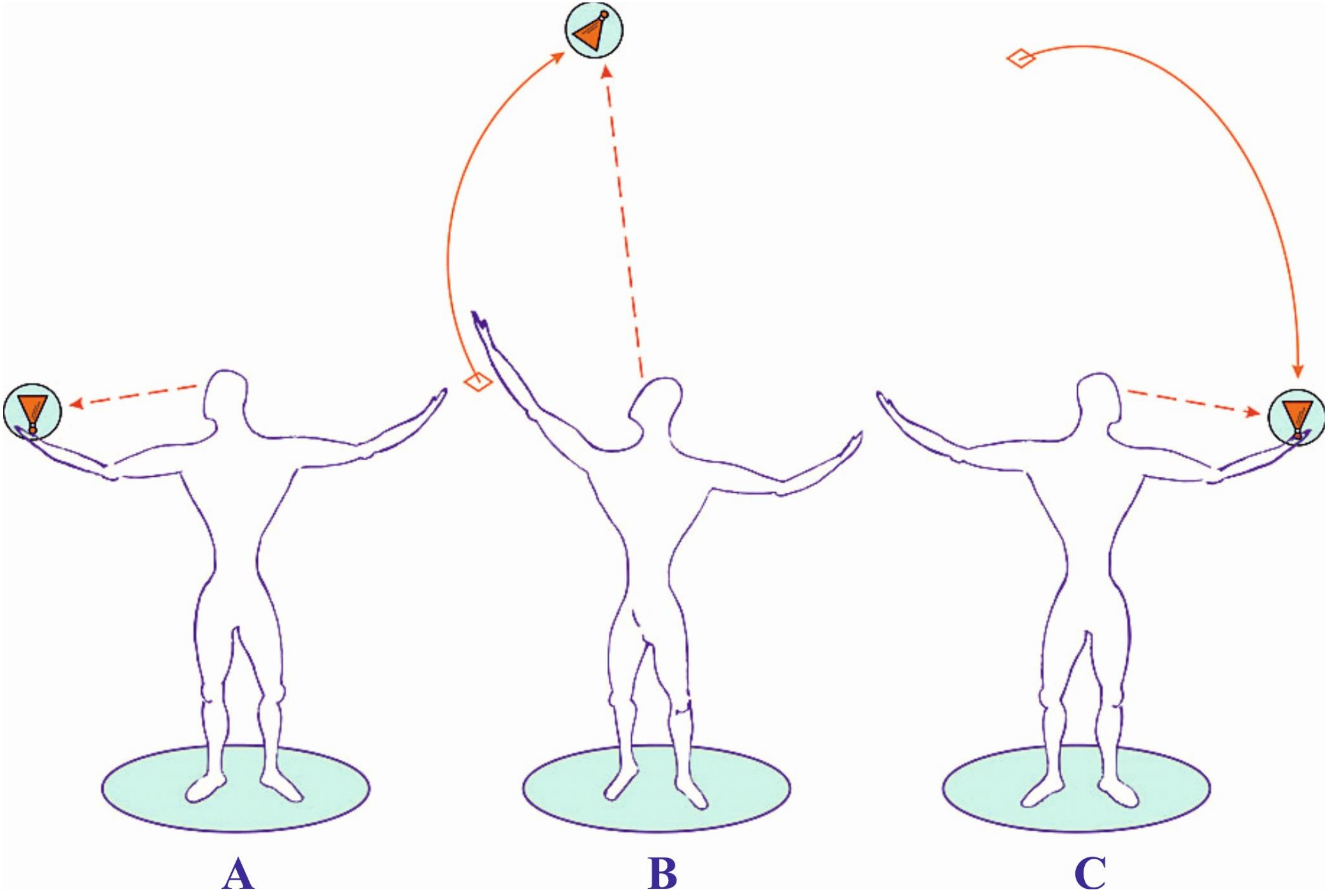
Throw shuttlecocks simultaneously circle-wise to the partner next to you

Phlegmatic persons

Individual exercises with one / two shuttlecocks:

Task 1: throw shuttlecocks of different colors one by one over the head – catch with the hand designated / opposite to designated one / with both hands at the waist level.
Task 2: throw shuttlecocks of different colors one by one forward-upwards from behind the back – catch with the hand designated / opposite to designated one / with both hands at the chest level.
Task 3: throw shuttlecocks of different colors one by one upwards with one hand – catch shuttlecocks with the opposite hand at the waist level.
Task 4: throw shuttlecocks of different colors one by one vertically within a short time span – catch with the hand designated at the waist level.
Task 5: throw the shuttlecock of one color vertically with the hand designated along with throwing another shuttlecock of the other color forward upwards from behind the back with the hand opposite to the designated one – catch with both hands.

Shuttlecock's color changing sequence
black-and-white, blue, orange, green, red, yellow.
Dosage: 10 throws with each hand.
Performance time: 360 sec.



Throw shuttlecock with the hand designated – catch with the opposite hand

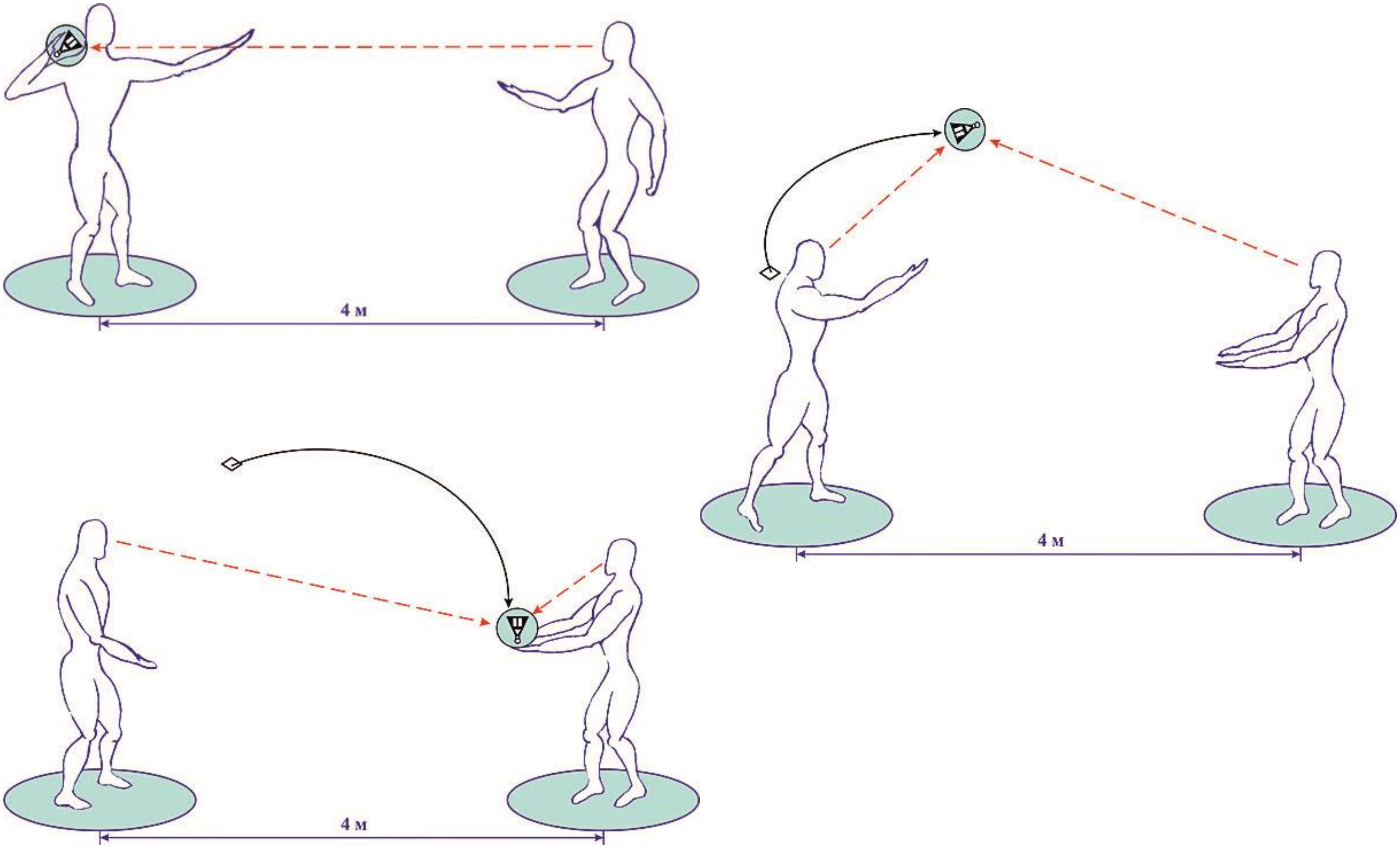
Myopia correction and prevention methods by exercises with elements of badminton based on individual psychological characteristics

Choleric persons

Exercises in pairs with one shuttlecock:

Task 1: throw the shuttlecock to each other along the high trajectory with the hand designated – catch it at the chest level with the hand opposite to the designated one.
Task 2: throw the shuttlecock to each other upwards-forward from behind the back to the partner’s hand – catch it at the waist level with the hand opposite to the designated one.
Task 3: throw the shuttlecock to each other along the high trajectory stepping forward and/or sideward – catch it at the chest level behind the back.
Task 4: throw the shuttlecock over the head while standing with one’s back to the partner – catch it with the hand designated at the waist level, standing with your chest to the partner.
Task 5: throw the shuttlecock to each other from backwards to the side with the hand designated – catch it at the chest level with the hand opposite to the designated one / with both hands.

Shuttlecock’s color changing sequence
green, orange, red, black-and-white, yellow, blue.
Dosage: 15 throws with each hand.
Performance time: 300 sec.



Throw the shuttlecock over the head with the hand designated – the partner catches shuttlecock with both hands

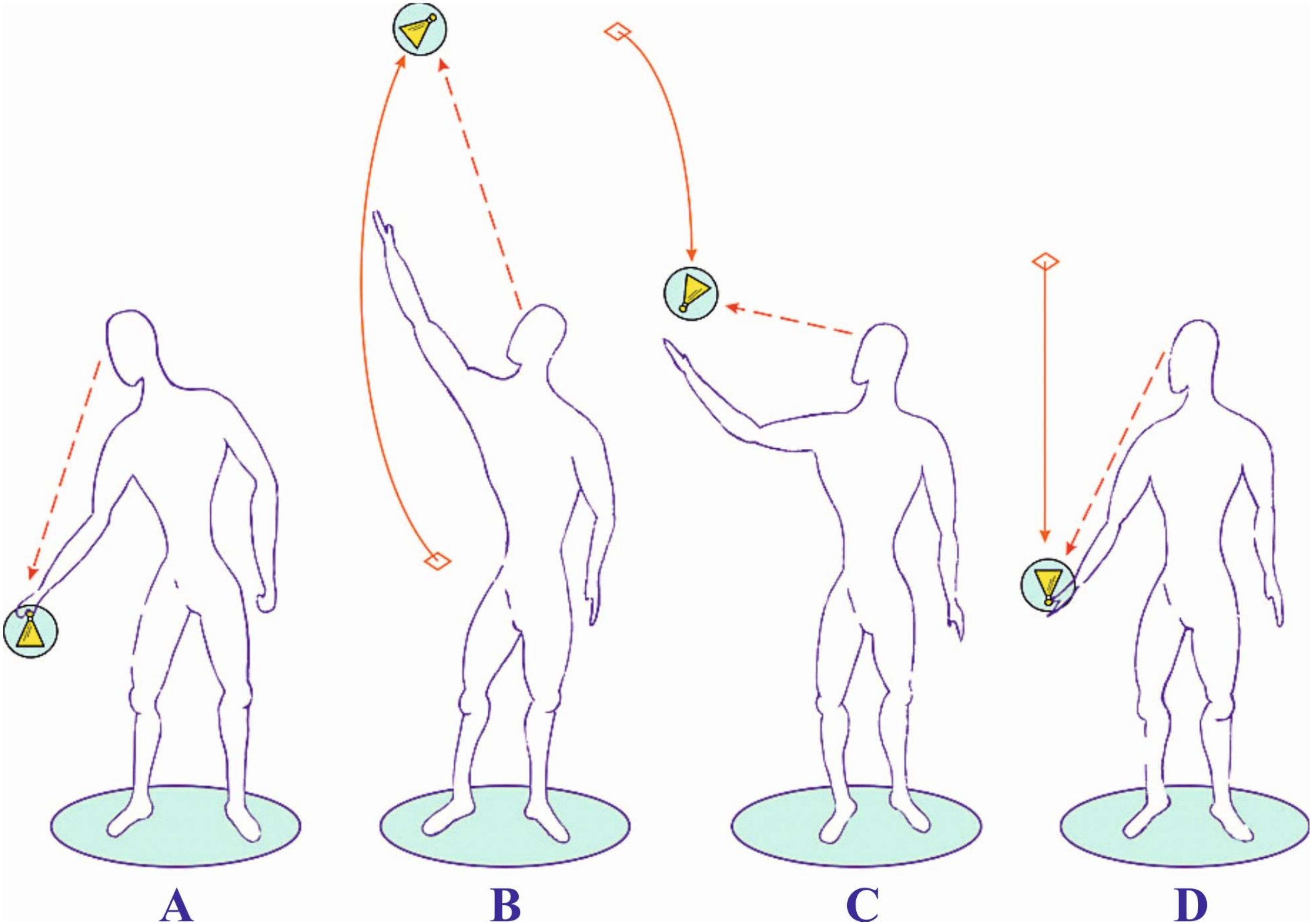
Myopia correction and prevention methods by exercises with elements of badminton based on individual psychological characteristics

Melancholic persons

Individual exercises with one two shuttlecock:

Task 1: throw the shuttlecock upwards with the hand designated – catch with the hand designated / with both hands at the waist level.
Task 2: throw the shuttlecock vertically-horizontally upwards with the hand designated – catch with the hand opposite to the designated one at the waist level.
Task 3: throw the shuttlecock high over the head with the hand designated – catch it with the hand designated / opposite to designated one at the chest level.
Task 4: throw the shuttlecock forward-upwards from behind the back with the hand designated – catch it at the chest level with the hand opposite to the designated one / with both hands.
Task 5: throw the shuttlecock forward backwards with the hand designated – catch it with the hand designated / opposite to the designated one / with both hands at the waist level.

Shuttlecock's color changing sequence
orange, red, black-and-white, blue, green, yellow.
Dosage: 10 throws with each hand.
Performance time: 300 sec.



Throw shuttlecock upwards over the head with the hand designated – catch it with the same hand

Thank you for your attention!

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CROSS-TECHNOLOGIES OF SITUATIONAL CENTER : COGNITIVE INFRASTRUCTURE OF MYOPIA CORRECTION AND PREVENTION BY EXERCISES WITH ELEMENTS OF BADMINTON

Turmanidze Valeriy Grigorievich

Candidate of Pedagogy, Professor of RAE, Dean of faculty of Physical Education, Rehabilitation and Sport

Fomenko Anatoliy Aleksandrovich

Assistant to the Professor

Basic principles of Dr. W. Bates' Method

Firstly**,** eye accommodation is performed not by the process of changing the curvature of the lens, but by the external eyeball muscles responsible for contraction and relaxing of visual apparatus' muscles.

Secondly**,** the main reason for low refraction performance is a mental strain, which makes it impossible to focus on the objects without difficulty.

Main techniques of Dr. W. Bates' Method

William Horatio Bates

Palming (covering closed eyes with the hands) is used to prevent the light from entering the eye that helps to relax the eye-muscles.

Recreation of pleasant memories is used to normalize the psychical state.

Working with eyesight test charts is used to produce a favorable effect on cognitive functions.

Key methods of M.S. Norbekov's method

Mirzakarim Sanakulovich Norbekov

Collecting ***oriental practices*** to get a person immersed into spiritual renewal state.

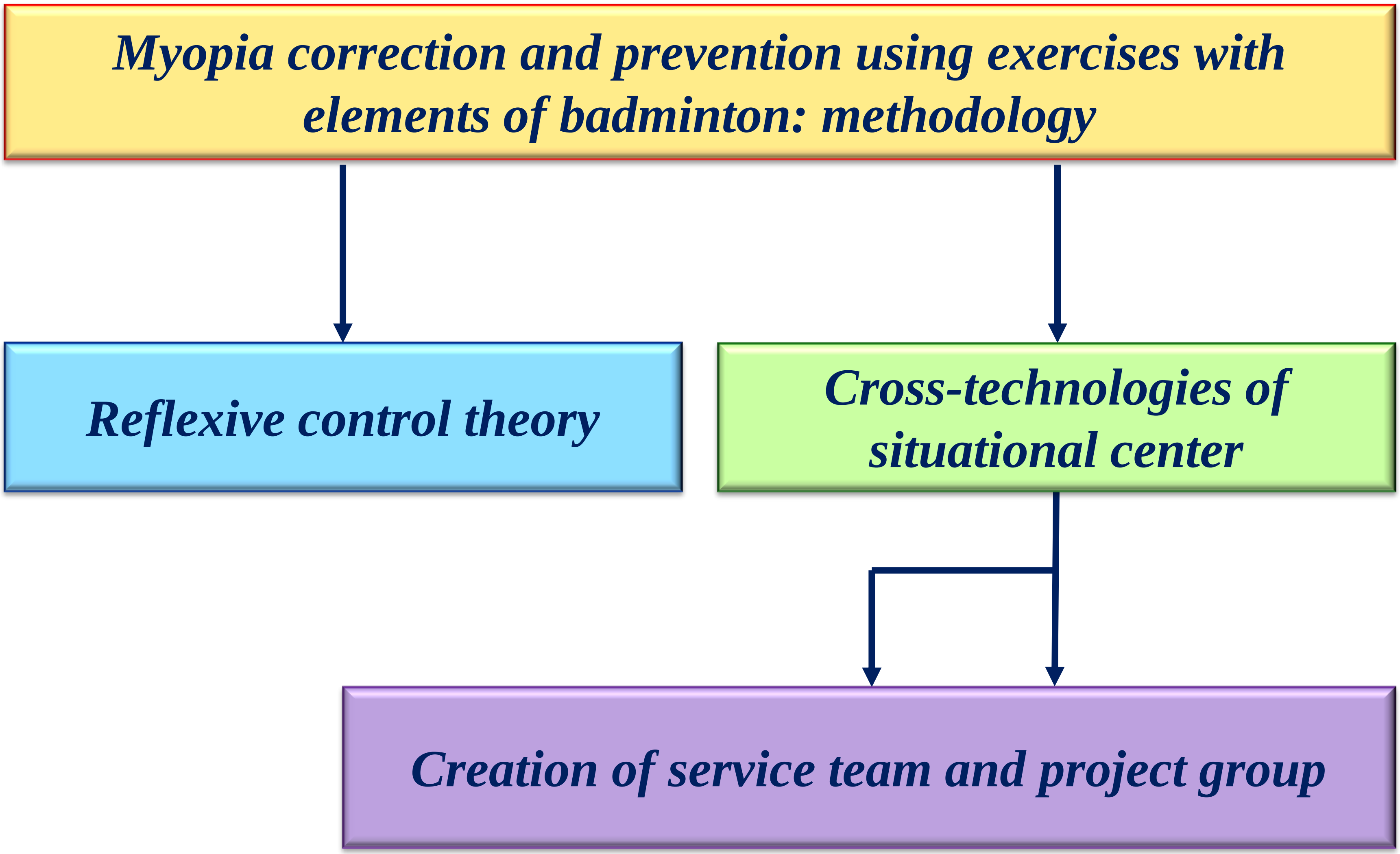
Using ***modern complexes of exercises*** for visual apparatus, partly borrowed from Bates Method.

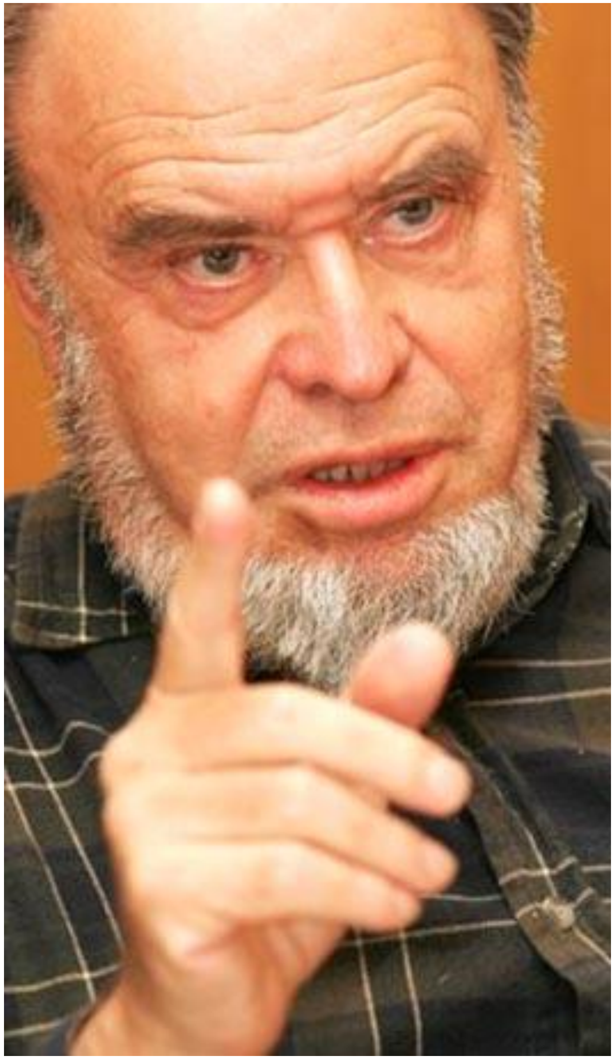
Myopia correction and prevention using exercises with elements of badminton (counter-indications)

Full range of game activities	*NO*
Jumping	*NO*
Attack techniques	*NO*
High intensity playing	*NO*
Frequent changing of spatial orientation	*NO*

Myopia correction and prevention using exercises with elements of badminton

Throwing the shuttlecock with the hand	*YES*
Juggling the shuttlecock with the racket	*YES*
Passing the shuttlecock to the partner	*YES*
Playing in a limited area of the court	*YES*
Making steps and lunges	*YES*


Myopia correction and prevention using exercises with elements of badminton: methodology
Reflexive control theory
Cross-technologies of situational center
Creation of service team and project group



Vladimir Aleksandrovich Lefebvre

Reflexive control is defined as a means of conveying to a partner or an opponent specially prepared information to incline him to voluntarily make the predetermined decision desired by the initiator of the action.

Initiator of the action coordinates not only the subjects' movements and other types of activities, but also defines peculiarities of their individual choices and searches for an opportunity to control these choices in order to reach the programmed result.

Cross-technologies of situational center is the most effective tool for taking managerial decisions, which is used to recreate an image of a situation in order to generate variants and find an optimal decision that is supported by the key resources of the task in question, meaning intellectual, physical, anthropometric, and psychological parameters of learners.

Perspectives of reflexive control theory development in the sphere of education: discussion

Sobolev Institute of Mathematics

From left to right: A. A. Fomenko, V. A. Lefebvre, V. A. Filimonov

Designation of project roles and service team members' functions taking into account socionic personality types

Socionic personality type	**Service team members' functions and ways of presenting information**
	Chart operator
Experts	**Ways of presenting information** – in the form of charts, diagrams, tables, and matrices. 1) Video clips are presented as documentaries full of historical facts. 2) Texts are narrated without intonation or tone change, the narrative is complete. 3) The essence of tasks is shown in details through interaction with the partners.
Researchers	**Ways of presenting information** – in the form of cognitive graphics. 1) Video clips are full of scientific ideas, scenarios include alternative variants of events progression. 2) Texts are based on modern scientific theories and narrated using rich intonation patterns. 3) Tasks are demonstrated with different variations.

Designation of project roles and service team members' functions taking into account socionic personality types

Socionic personality type	**Service team members' functions and ways of presenting information**
Chart operator	
Socials	**Ways of presenting information** – in the form of cognitive graphics (the same as with researchers). 1) Video clips show representatives of different national and ethnic groups. 2) Texts are voiced-over by people of different age groups, taking into consideration the gender criteria. 3) Tasks are shown in the groups of learners.
Humanitarians	**Ways of presenting information** – in the form of stylistic images, bright conceptual and mythological images. 1) Video clips are characterized by incompleteness of thought and usually provide the possibility of alternative interpretation. 2) Texts are narrated as the "stream of information" with necessity to highlight the key details. 3) Tasks are shown with one of perception channels switched off.

Designation of project roles and service team members' functions taking into account socionic personality types

Socionic personality type	**Service team members' functions and ways of presenting information**
Methodologist	
Experts	**Organize** performance tasks of the activity. **Comment** on and specify the views of strategic activities on the basis of historical facts. **Assign** functions of an "actor" and select simple creative tasks.
Researchers	**Organize** research tasks of the activity. **Comment** on the basis of interpretation of the modern research theories. **Assign** functions of a "director" and select simple communicative tasks.
Socials	**Organize** communicative tasks of the activity. **Comment** specify the views of cultural and ethnic interactions. **Assign** functions of the "screenwriter", select simple research tasks.
Humanitarians	**Organize** creative tasks of the activity. **Comment** on the basis of fiction and artistic works. **Assign** functions of a "spectator" and select simple performing tasks.

Designation of project roles and service team members' functions taking into account socionic personality types

Socionic personality type	**Service team members' functions and ways of presenting information**
Playing technique specialist	
Experts	**Define the roles** of "objective observers". **Stimulate** to follow a standard technique of performing the exercises. **In case of substandard situations** suggest to change the order of exercises.
Researchers	**Define the roles of** "independent artists". **Stimulate** to search for alternative variants of performing the exercises. **In case of substandard situations** suggest to maintain a strict order of exercises.
Socials	**Define the roles of** "emotional background creators". **Stimulates** to adjust relationships inside the group. **In case of substandard situations** suggest to take a part of a methodologist.
Humanitarians	**Define the roles of** "extra interpreters". **Stimulate** to apply creativity during performance of the exercises. **In case of substandard situations** suggest to take a part of a playing technique specialist.

Rules of splitting people into health-improving pairs and groups:

1. **<u>The Judge, a learner with the third degree of myopia</u>** (-6.25 и > diopters), is in charge of continuous watching the shuttlecock, when the tasks are performed by learners with the same or lower level of emotional stability. It means that sanguine person can watch the partners with different temperament types, though melancholic person can watch only melancholic and choleric persons, because physical load of sanguine and phlegmatic persons is more intense, and his or her eye-muscles may become overstrained.

2. ***People with the first*** (up to -3.00 diopters) ***and the second*** (from -3.25 to -6.00 diopters) ***degrees of myopia*** are arranged into pairs according to their emotional stability and interrelation of extroversive - introversive criteria. In other words, phlegmatic person can't interact with choleric person, because they do not match according to two parameters; the other impossible pair is sanguine person vs melancholic person.

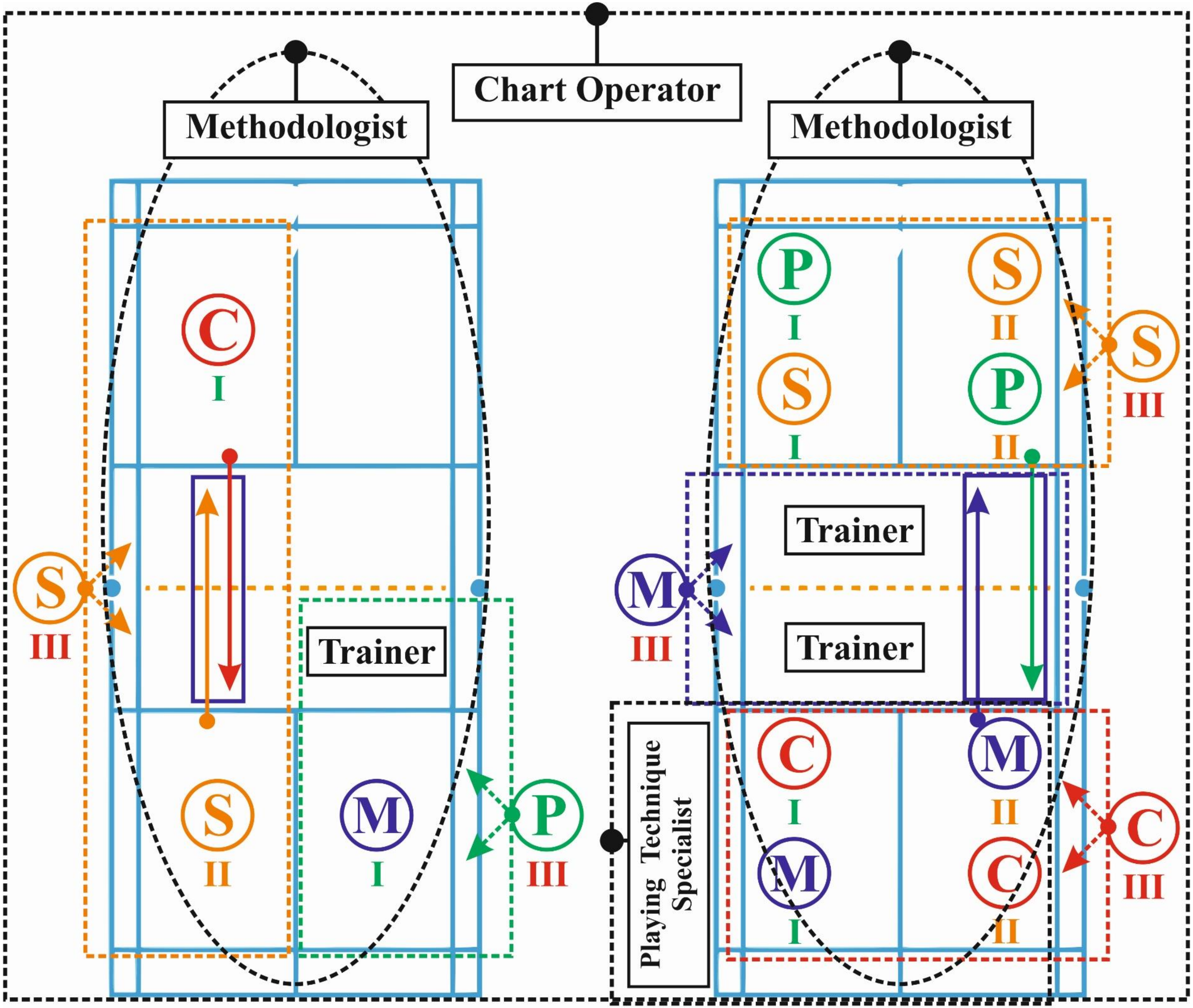


Chart Operator
Methodologist
Methodologist
C
I
S
III
Trainer
S
II
M
I
P
III
P
I
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S
III
S
I
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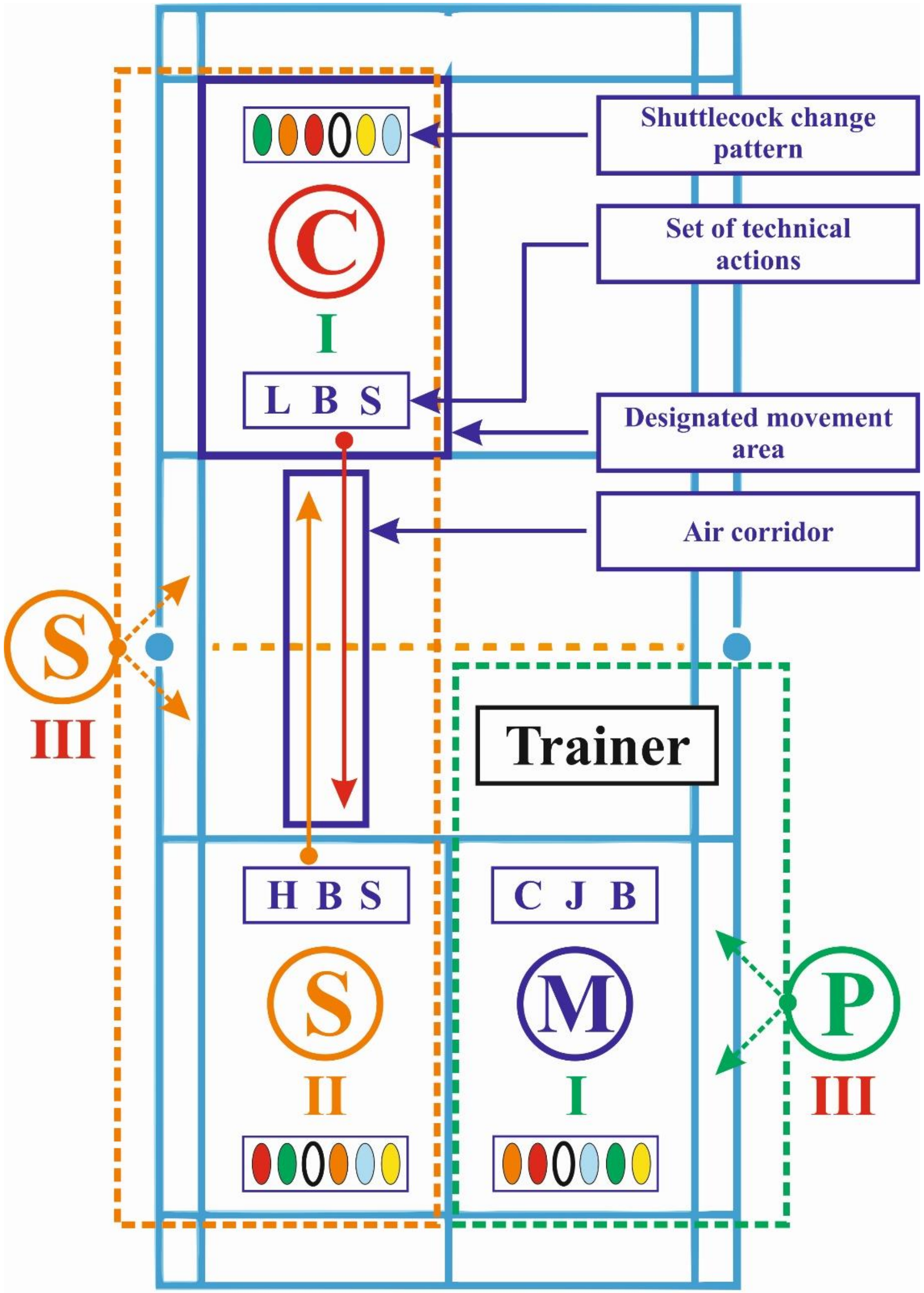
II
Trainer
M
III
Trainer
C
I
M
II
C
III
M
I
C
II
Playing Technique Specialist



Performance algorithm of a sanguine person (II degree of myopia)

General exercises

1st – 5th min. –performing individual tasks with elements of badminton;

5th – 20th min. – performing elements of badminton with the partner;

20th – 30th min. – taking the playing technique specialist's part (situations modelling and correction of technique);

30th – 40th min. – performing elements of badminton in a group;

40th – 45th min. – performing tasks according to M.S. Norbekov's method.

Rehabilitative measures

Performance algorithm of phlegmatic person (I degree of myopia)

General exercises

1st – 10th min. – performing performing individual tasks with elements of badminton;

10th – 20th min. – taking the methodologist's part (analyzing performance of the others);

20th – 35th min. – performing elements of badminton in a group;

35th – 40th min. – performing elements of badminton in pairs;

40th – 45th min. – performing tasks according to M.S. Norbekov's method.

Rehabilitative measures

Performance algorithm of a choleric person (II degree of myopia)

General exercises

1st – 10th min. – taking the chart operator's part (demonstrating of exercises' performance technique);

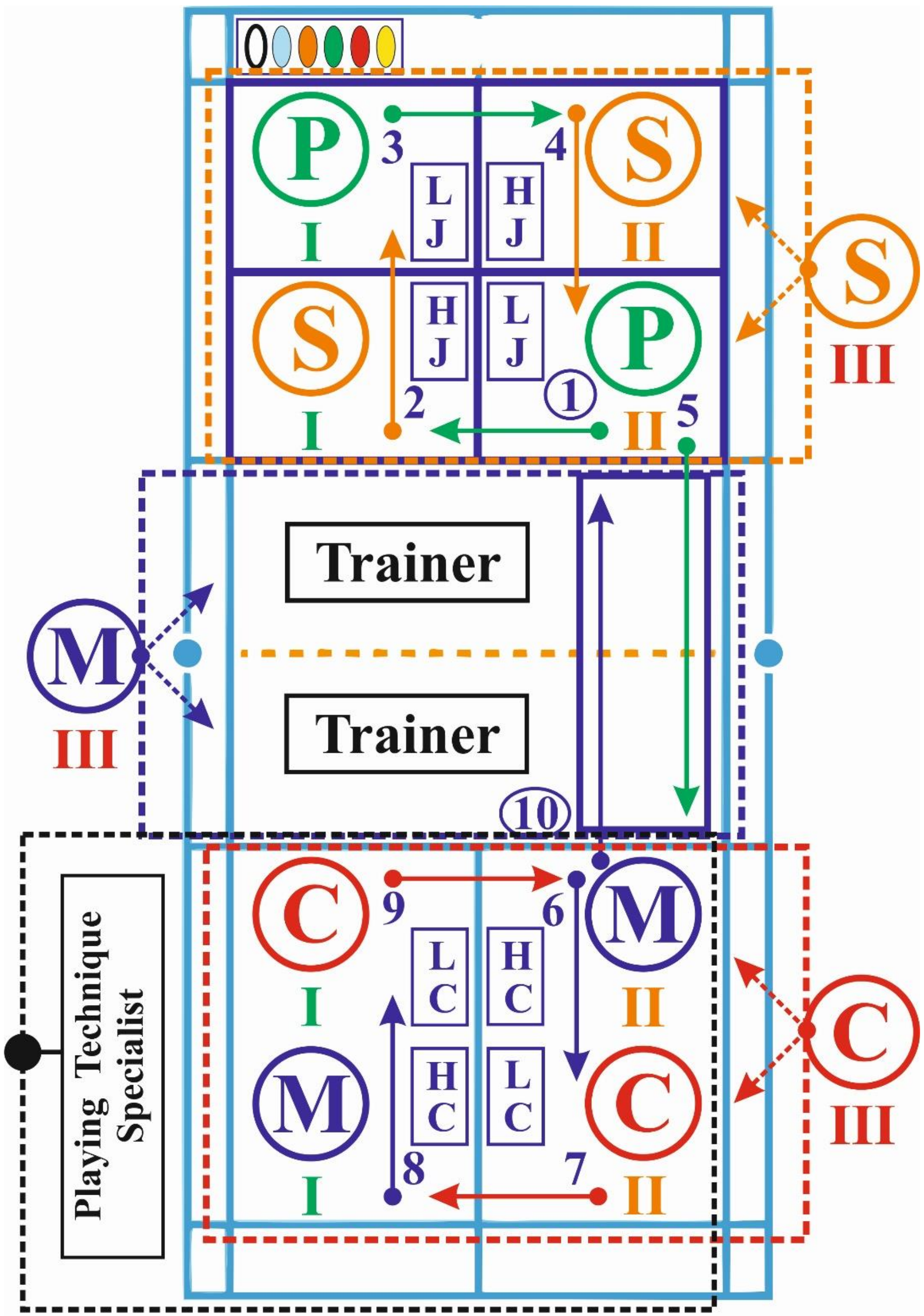
10th – 20th min. – performing elements of badminton in pairs;

20th – 25th min. – performing tasks according to Bates Method;

25th – 40th min. – performing elements of badminton in a group;

40th – 45th min. – performing tasks according to M.S. Norbekov's method.

Rehabilitative measures



Performance algorithm of melancholic person (III degree of myopia)

General exercises

1st – 5th min. – performing tasks according to Bates Method;

5th – 15th min. – watching the shuttlecock as the judge;

15th – 25th min. – performing individual tasks with elements of badminton;

25th – 40th min. – taking the methodologist's part (commenting and correcting performance of the others);

40th – 45th min. – performing tasks according to M.S. Norbekov's method.

Rehabilitative measures

Thank you for your attention!

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.

УДК 617.753.2

Влияние занятий бадминтоном на рефракцию, аккомодацию и гемодинамику глаз с миопией

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Аннотация

Идеальным видом спорта, в котором гармонично сочетается слежение за движущимся объектом (тренировка аккомодации), повороты головы и туловища (усиление гемодинамики), глубокое дыхание (оксигенация крови), является бадминтон.

Цель работы. Изучить состояние и динамику рефракции, аккомодации и скорости кровотока в сосудах глаза у детей с различной рефракцией на фоне занятий бадминтоном.

Материал и методы. Обследовано 40 детей (80 глаз) с аномалией рефракции от +6,63 до –6,75 дптр [в среднем –(1,28 ± 2,28) дптр] в возрасте от 7 до 11 лет [в среднем (9,24 ± 1,06) лет]. Через 6 месяцев занятий бадминтоном было обследовано 38 детей (76 глаз). Через 1 год их количество составило 27 детей (54 глаза) с различными видами рефракции [в среднем –(1,62 ± 1,81) дптр] в возрасте от 8 до 12 лет [в среднем (9,42 ± 1,10) лет]; остальные дети прекратили занятия бадминтоном. Всем пациентам проводили визометрию без коррекции зрения, с оптимальной коррекцией и в имеющихся у них корригирующих очках. Определяли запас относительной аккомодации (ЗОА), бинокулярный и монокулярный аккомодационный ответ, привычный тонус аккомодации, цветовое и энергетическое допплеровское картирование, толщину хориоидеи. Все исследования проводились до начала занятий бадминтоном, а затем через 6 месяцев и через 1 год по методике В. Г. Турманидзе.

Результаты. Острота зрения без коррекции у всех детей, участвовавших в исследовании, в целом повысилась с 0,34 до 0,42; в том числе при наличии у пациентов привычно-избыточного напряжения аккомодации (ПИНА) и спазма аккомодации (СА) – с 0,66 до 0,80. Усиление манифестной рефракции за 1 год составило 0,10 дптр, рефракции в условиях циклоплегии – 0,34 дптр, при этом у детей с СА и ПИНА через год манифестная рефракция стала слабее на 0,92 дптр, то есть спазм был полностью устранен. Об этом же говорит и снижение привычного тонуса аккомодации почти в 2 раза у всех участников исследования. Увеличение длины передне-задней оси (ПЗО) глаза за 1 год составило 0,17 мм у детей без миопии и 0,31 мм у детей с миопией, то есть с учетом поправки на естественный рост глаза увеличение длины ПЗО составило 0,14 мм, что соответствует динамике рефракции. ЗОА повысился на 30%. Скорость кровотока в глазной артерии через 6 месяцев тренировок увеличилась на 3,02 мм/с, через 1 год – на 4,06 мм/с и в среднем достигла (40,34 ± 6,26) мм/с. В центральной артерии сетчатки через 6 месяцев тренировок его скорость увеличилась на 0,88 мм/с, через 1 год – на 1,04 мм/с, составив (10,74 ± 1,71) мм/с. Толщина хориоидеи недостоверно увеличилась на 3,6 мкм. Максимальное увеличение толщины хориоидеи наблюдалось при миопии высокой степени – на 30,5 мкм.

Выводы. Проведенное исследование влияния занятий бадминтоном на функциональное состояние, кровоснабжение органа зрения и динамику рефракции позволяет дать положительную оценку данному виду физической активности как методу профилактики возникновения и прогрессирования миопии.

Ключевые слова: аккомодация, бадминтон, гемодинамика, миопия, толщина хориоидеи

Актуальность

Несмотря на широкий спектр лечебных и профилактических мероприятий, проводимых пациентам с близорукостью, количество последних во всем мире неуклонно растет. Согласно обзору Б. Холдена (B. Holden) и соавт., в 2000 году в мире было 22,9% близоруких людей (из них 2,7% имеет миопию высокой степени) и по прогнозу уже к 2050 году это число увеличится до 49,7% (≈4,8 млрд человек в целом, из которых 9,8% – с миопией высокой степени), что станет серьезной глобальной медико-социальной проблемой общественного здравоохранения [7].

В России заболеваемость детей и подростков близорукостью за последние 20 лет выросла в 1,5 раза. Близорукость занимает первое место в структуре детской глазной патологии, второе – в структуре детской инвалидности и третье – в структуре инвалидности всего населения [1].

Точные причины и механизмы развития близорукости до конца не ясны. Современные теории патогенеза миопии предполагают, что важную роль в этом процессе играет не только наследственность, но и факторы окружающей среды, такие как интенсивная работа на близком расстоянии, низкий уровень физической активности, особенно на открытом воздухе [9].

Выявлены отдельные звенья патогенеза этого заболевания, указывающие на вовлечение в развитие миопии патологии некоторых органов и систем организма. У 96% детей с близорукостью наблюдаются различные общесоматические заболевания. На первом месте по частоте встречаемости стоят заболевания соединительной ткани, сердечно-сосудистой системы и центральной нервной системы (ЦНС), среди которых наиболее часто наблюдаются перинатальные и натальные поражения ЦНС, а также цервикальная недостаточность в результате нестабильности шейных отделов позвоночника, раннего остеохондроза, родовых травм, подвывиха шейного отдела позвоночника [2, 3, 6].

Были предложены различные стратегии профилактики возникновения и прогрессирования миопии. Во многих эпидемиологических исследованиях было показано, что занятия спортом и активность на открытом воздухе приводят к сдерживанию роста миопии [8, 10–12]. Идеальным видом спорта, в котором гармонично сочетается слежение за движущимся объектом (тренировка аккомодации), повороты головы и туловища (усиление гемодинамики) и глубокое дыхание (оксигенация крови), является бадминтон.

Цель настоящей работы – изучить состояние и динамику рефракции, аккомодации и скорости кровотока в сосудах глаза у детей с различной рефракцией на фоне занятий бадминтоном.

Материал и методы

Обследовано 40 детей (80 глаз) с аномалией рефракции от +6,63 до –6,75 дптр [в среднем –(1,28 ± 2,28) дптр] в возрасте от 7 до 11 лет [в среднем (9,24 ± 1,06) лет], из них с миопией – 34 ребенка (67 глаз), в том числе слабой степени – 26 детей (51 глаз), средней – 6 детей (12 глаз), высокой – 2 ребенка (4 глаза), с гиперметропией и эмметропией – 7 детей (13 глаз). Из общего числа участников исследования была выделена группа со спазмом аккомодации (СА) и привычно-избыточным напряжением аккомодации (ПИНА): 11 детей (20 глаз), из них с миопией – 4 ребенка (7 глаз), с гиперметропией – 3 ребенка (6 глаз) и сэмметропией – 4 ребенка (7 глаз). Через 6 месяцев занятий бадминтоном было обследовано 38 детей (76 глаз). Через 1 год их количество составило 27 детей (54 глаза) с различными видами рефракции [в среднем –(1,62 ± 1,81) дптр] в возрасте от 8 до 12 лет [в среднем (9,42 ± 1,10) лет], из них с миопией – 23 ребенка (46 глаз): слабой степени – 19 детей (37 глаз), средней – 4 ребенка (7 глаз), высокой – 1 ребенок (2 глаза), а также с гиперметропией и эмметропией – 4 ребенка (8 глаз). Из общего числа обследованных на этом этапе была выделена группа пациентов (7 детей, 14 глаз) с СА и ПИНА, имеющих миопию (3 ребенка, 6 глаз), гиперметропию (2 ребенка, 4 глаза) и эмметропию (2 ребенка, 4 глаза).

Всем пациентам проводили визометрию без коррекции зрения, с оптимальной коррекцией и в имеющихся у них очках. Определяли запас относительной аккомодации (ЗОА), объективную аккомодометрию на бинокулярном авторефкератометре открытого поля Grand Seiko WR-5100K (Япония) по описанной ранее методике на расстоянии 33 см в условиях бинокулярной (бинокулярный аккомодационный ответ, БАО) и монокулярной фиксации (монокулярный аккомодационный ответ, МАО). Привычный тонус аккомодации (ПТА) определяли как разницу показаний авторефрактометра до и после циклоплегии.

Для оценки скорости кровотока в сосудах глазного яблока и ретробульбарного пространства выполняли цветовое допплеровское и энергетическое допплеровское картирование при помощи ультразвукового сканера Voluson-730 Pro (США) и линейного датчика с частотой излучения 10–16 МГц. Исследовали состояние кровотока в глазной артерии (ГА) и центральной артерии сетчатки (ЦАС).

Толщину хориоидеи измеряли на спектральном оптическом когерентном томографе RS-3000 Advance (Nidek, Япония) с использованием протокола сканирования Maculaline в режиме «Choroidal». Субфовеолярная толщина хориоидеи измерялась мануально в микрометрах как перпендикулярное расстояние между комплексом «пигментный эпителий сетчатки – мембрана Бруха» и внутренним краем склеры (хориосклеральный интерфейс).

Все исследования проводились до начала занятий бадминтоном, через 6 месяцев и через 1 год по методике В. Г. Турманидзе [5].

Результаты

Острота зрения без коррекции у всех участников исследования в среднем повысилась с 0,34 до 0,42, при этом у детей с эмметропией и гиперметропией она осталась равной 1,0, у детей с миопией не изменилась, а у детей с ПИНА и СА повысилась с 0,66 до 0,80. Максимальная корригированная острота зрения у всех детей была и осталась равной 1,0. Сила корригирующего стекла (субъективная рефракция) уменьшилась при гиперметропии и ПИНА с –0,16 до –0,07 дптр и увеличилась с –1,57 до –1,84 дптр при миопии.

Как показано в табл. 1, манифестная рефракция усилилась во всей группе школьников на 0,28 дптр через 6 месяцев занятий, а затем стала слабее на 0,18 дптр в следующие 6 месяцев. Следовательно, за год занятий бадминтоном манифестная рефракция усилилась на 0,10 дптр. Усиление циклоплегической рефракции составило 0,34 дптр, причем этот сдвиг произошел за первые полгода занятий, в последующие 6 месяцев рефракция оставалась стабильной. Таким образом, годовой градиент прогрессирования (ГГП) составил 0,34 дптр. Разница динамики манифестной и циклоплегической рефракции объяс-

Таблица 1

Показатели рефракции и тонуса аккомодации, дптр, у пациентов с различной рефракцией до и после занятий бадминтоном ($M \pm \sigma$)

Рефракция	Авторефрактометрия						ПТА		
	До занятий		Через 6 мес.		Через 1 год		До занятий	Через 6 мес.	Через 1 год
	У	Ш	У	Ш	У	Ш			
В среднем	–(2,11 ± 2,06)	–(1,62 ± 1,81)	–(2,39 ± 1,95)	–(1,96 ± 1,92)	–(2,21 ± 2,02)	–(1,96 ± 2,05)	–(0,49 ± 0,97)	–(0,43 ± 0,87)	–(0,25 ± 0,55)
Миопия:									
в среднем	–(2,54 ± 2,03)	–(2,10 ± 1,65)	–(2,74 ± 1,90)	–(2,45 ± 1,77)	–(2,71 ± 1,89)	–(2,53 ± 1,82)	–(0,44 ± 1,02)	–(0,29 ± 0,64)	–(0,18 ± 0,54)
слабой степени	–(1,66 ± 0,76)	–(1,39 ± 0,75)	–(1,94 ± 1,03)	–(1,76 ± 1,08)	–(1,91 ± 1,03)	–(1,81 ± 1,13)	–(0,27 ± 0,46)	–(0,18 ± 0,31)	–(0,10 ± 0,28)
средней степени	–(5,73 ± 1,93)	–(4,34 ± 0,76)	–(5,45 ± 1,08)	–(4,59 ± 0,69)	–(5,37 ± 0,65)	–(4,71 ± 0,68)	–(1,39 ± 2,20)	–(0,86 ± 1,41)	–(0,66 ± 1,17)
высокой степени	–(6,82 ± 0,09)	–(6,69 ± 0,08)	–(7,19 ± 0,27)	–(7,13 ± 0,18)	–(7,32 ± 0,09)	–(7,32 ± 0,09)	–(0,13 ± 0,17)	–(0,06 ± 0,13)	0,00 ± 0,00
Гиперметропия и эмметропия	0,34 ± 0,45	0,47 ± 0,32	–(0,03 ± 0,78)	0,31 ± 0,69	0,38 ± 0,65	0,66 ± 0,48	–(0,12 ± 0,31)	–(0,34 ± 0,37)	–(0,28 ± 0,21)
СА и ПИНА	–(2,36 ± 2,88)	–(0,66 ± 1,61)	–(2,04 ± 2,37)	–(0,76 ± 1,54)	–(1,44 ± 2,17)	–(0,59 ± 1,63)	–(1,70 ± 1,52)	–(1,28 ± 1,44)	–(0,85 ± 0,77)

Примечание: У и Ш – узкий и широкий зрачок соответственно.

Таблица 2

Объективные и субъективные показатели аккомодации, дптр, у пациентов с различной рефракцией до и после занятий бадминтоном ($M \pm \sigma$)

Рефракция	БАО			МАО			ЗОА		
	До занятий	Через 6 мес.	Через 1 год	До занятий	Через 6 мес.	Через 1 год	До занятий	Через 6 мес.	Через 1 год
В среднем	–(1,99 ± 0,38)	–(2,04 ± 0,44)	–(2,09 ± 0,38)	–(1,78 ± 0,46)	–(1,84 ± 0,05)	–(1,89 ± 0,57)	1,80 ± 1,51	2,22 ± 1,31	2,35 ± 1,05
Миопия:									
в среднем	–(1,97 ± 0,40)	–(2,00 ± 0,44)	–(2,06 ± 0,40)	–(1,72 ± 0,48)	–(1,78 ± 0,60)	–(1,81 ± 0,56)	1,32 ± 1,13	1,96 ± 1,15	2,23 ± 1,08
слабой степени	–(2,03 ± 0,34)	–(2,03 ± 0,35)	–(2,05 ± 0,39)	–(1,78 ± 0,39)	–(1,82 ± 0,52)	–(1,86 ± 0,47)	1,46 ± 1,19	1,76 ± 1,14	2,07 ± 1,02
средней степени	–(1,69 ± 0,60)	–(1,77 ± 0,77)	–(2,04 ± 0,48)	–(1,32 ± 0,71)	–(1,33 ± 0,74)	–(1,47 ± 0,86)	1,00 ± 0,50	2,79 ± 0,99	3,36 ± 0,56
высокой степени	–(2,00 ± 0,17)	–(2,22 ± 0,13)	–(2,37 ± 0,00)	–(2,19 ± 0,18)	–(2,53 ± 0,23)	–(2,25 ± 0,26)	0,00 ± 0,00	2,50 ± 0,00	1,00 ± 0,00
Гиперметропия и эмметропия	–(2,12 ± 0,27)	–(2,47 ± 0,44)	–(2,34 ± 0,33)	–(2,04 ± 0,28)	–(2,27 ± 0,21)	–(2,39 ± 0,27)	3,00 ± 1,44	3,00 ± 0,58	3,00 ± 0,29
СА и ПИНА	–(2,14 ± 0,33)	–(2,00 ± 0,33)	–(2,20 ± 0,28)	–(1,91 ± 0,39)	–(1,88 ± 0,52)	–(2,13 ± 0,47)	3,00 ± 1,53	2,62 ± 1,28	2,96 ± 0,85

Таблица 3

Толщина хориоидеи (ТХ), длина передне-задней оси глаза (ПЗО), глубина передней камеры (ГПК), с различной рефракцией до и после занятий бадминтоном ($M \pm \sigma$)

Рефракция	ТХ, мкм			ПЗО, мм			
	До занятий	Через 6 мес.	Через 1 год	До занятий	Через 6 мес.	Через 1 год	До занятий
В среднем	303,00 ± 68,59	306,80 ± 60,39	306,6 ± 73,17	23,89 ± 1,00	24,12 ± 1,04	24,15 ± 1,06	3,64 ± 0,27
Миопия:							
в среднем	301,30 ± 65,36	303,98 ± 37,15	302,07 ± 69,91	24,08 ± 0,95	24,38 ± 0,96	24,39 ± 0,97	3,70 ± 0,25
слабой степени	307,29 ± 71,40	309,09 ± 61,79	303,40 ± 76,91	23,88 ± 0,80	24,16 ± 0,85	24,21 ± 0,87	3,71 ± 0,27
средней степени	273,86 ± 23,14	279,86 ± 28,87	289,43 ± 33,25	24,31 ± 0,51	24,49 ± 0,49	24,52 ± 0,46	3,68 ± 0,14
высокой степени	292,50 ± 21,92	299,00 ± 24,04	323,00 ± 18,38	26,72 ± 0,05	26,84 ± 0,07	26,88 ± 0,05	3,49 ± 0,02
Гиперметропия и эмметропия	294,75 ± 59,97	312,25 ± 54,09	313,75 ± 52,03	23,34 ± 0,20	23,48 ± 0,23	23,51 ± 0,21	3,52 ± 0,07
СА и ПИНА	342,92 ± 94,29	332,46 ± 75,74	347,77 ± 97,30	23,02 ± 0,93	23,12 ± 0,98	23,12 ± 0,99	3,43 ± 0,26

няется снижением тонуса аккомодации: ПТА снизился за год на 0,24 дптр, то есть практически вдвое. Результаты предыдущих исследований показали, что снижение тонуса аккомодации является благоприятным признаком и ассоциируется с замедлением темпа прогрессирования миопии [4].

При миопии ГГП составил в среднем 0,43 дптр: при слабой ее степени – 0,42 дптр, средней – 0,37 дптр, высокой (1 ребенок, 2 глаза) – 0,63 дптр. У пациентов с СА и ПИНА манифестная рефракция через год стала слабее в среднем на 0,92 дптр, циклоплегическая – на 0,07 дптр (см. табл. 1).

Бинокулярный аккомодационный ответ до начала занятий бадминтоном составил в среднем –(1,99 ± 0,38) дптр. Через 6 месяцев тренировок БАО не изменился, через 1 год – увеличился на 0,10 дптр. Максимальное увеличение БАО наблюдалось при миопии высокой степени (на 0,37 дптр) и средней степени (на 0,35 дптр; табл. 2).

Монокулярный аккомодационный ответ до занятий бадминтоном в среднем составил –(1,78 ± 0,46) дптр. Через 6 месяцев тренировок МАО увеличился на 0,06 дптр, через 1 год – на 0,11 дптр. Максимальное увеличение МАО наблюдалось при гиперметропии и эмметропии (на 0,35 дптр) и при СА и ПИНА с миопией (на 0,37 дптр). Таким образом, аккомодационный ответ имел тенденцию к повышению после занятий бадминтоном, игра в который требует слежения за быстро движущимся воланом (см. табл. 2).

ЗОА через 6 месяцев тренировок в среднем увеличился по сравнению с исходными значениями на 0,42 дптр (23,3 %), а через год – на 0,55 дптр (30,5 %) и составил в среднем (2,35 ± 1,05) дптр. Максимальное увеличение ЗОА (на 2,00 дптр) наблюдалось при миопии средней степени. Причем у детей с миопией данной степени, а также у пациентов с миопией и наличием у них СА и ПИНА величина ЗОА достигла почти нормальных значений. При СА и ПИНА у детей с эмметропией и гиперметропией ЗОА соответствовал норме и не изменился (см. табл. 2).

Длина ПЗО у детей до занятий бадминтоном в среднем составляла (23,89 ± 1,00) мм, была минимальной при гиперметропии (22,5 мм), а максимальной – при миопии высокой степени (26,72 мм). Через 6 месяцев тренировок средняя длина ПЗО составила (24,12 ± 1,04) мм, через 1 год – (24,15 ± 1,06) мм, то есть за год она увеличилась на 0,26 мм. По данным М. М. Ситка, естественный рост ПЗО происходит и у пациентов со стабильной эмметропией в возрасте 8–9 лет – в среднем на (0,132 ± 0,020) мм в год. Автор предложила делать соответствующие поправки на естественный рост глаза. В нашем случае у пациентов с гиперметропией и эмметропией длина ПЗО увеличилась за год на 0,17 мм, при этом максимальный ее прирост произошел в первые 6 месяцев наблюдения. В группе детей-гиперметропов с СА и ПИНА длина ПЗО не изменилась. В группе пациентов с миопией длина ПЗО увеличилась в среднем на 0,31 мм

скорость кровотока в глазной артерии (ГА) и центральной артерии сетчатки (ЦАС) у пациентов

ГПК, мм		Скорость кровотока, мм/с					
		ГА			ЦАС		
Через 6 мес.	Через 1 год	До занятий	Через 6 мес.	Через 1 год	До занятий	Через 6 мес.	Через 1 год
3,67 ± 0,28	3,69 ± 0,29	36,28 ± 6,88	39,30 ± 6,63	40,34 ± 6,26	9,70 ± 1,18	10,58 ± 1,28	10,74 ± 1,71
3,73 ± 0,25	3,76 ± 0,25	36,04 ± 7,04	39,28 ± 6,92	40,22 ± 6,22	9,62 ± 1,12	10,71 ± 1,27	10,77 ± 1,76
3,75 ± 0,27	3,77 ± 0,27	36,79 ± 6,94	39,63 ± 6,54	40,68 ± 5,56	9,67 ± 1,07	10,97 ± 1,04	10,92 ± 1,86
3,68 ± 0,11	3,72 ± 0,10	29,72 ± 2,16	34,71 ± 6,63	35,32 ± 6,69	9,93 ± 1,00	10,26 ± 1,28	10,63 ± 0,99
3,49 ± 0,05	3,53 ± 0,05	45,01 ± 0,00	49,1 ± 0,00	49,32 ± 0,00	7,60 ± 0,00	7,67 ± 0,00	8,70 ± 0,00
3,51 ± 0,04	3,57 ± 0,09	32,86 ± 3,95	35,44 ± 2,33	36,73 ± 3,05	10,03 ± 0,37	10,14 ± 0,34	10,47 ± 0,64
3,45 ± 0,28	3,45 ± 0,29	40,07 ± 5,77	42,85 ± 4,35	43,7 ± 5,33	9,75 ± 1,56	10,53 ± 1,32	11,04 ± 1,37

за первые 6 месяцев наблюдения и в дальнейшем уже практически не менялась. С учетом поправки на естественный рост глаза, равной 0,17 мм, увеличение длины ПЗО составило 0,14 мм, что соответствует динамике рефракции.

Глубина передней камеры (ГПК) до занятий бадминтоном в среднем составляла (3,64 ± 0,27) мм, через 6 месяцев она увеличилась на 0,03 мм, через 1 год – на 0,05 мм. ГПК была максимальной при миопии слабой степени [(3,71 ± 0,27) мм]. При миопии средней и высокой степени ГПК снизилась, составив соответственно (3,68 ± 0,14) и (3,49 ± 0,02) мм. При миопии слабой степени отмечено наибольшее углубление передней камеры – на 0,06 мм за год. Углубление передней камеры является эмметропизирующим фактором, поскольку приближает фокусную точку к сетчатке.

Скорость кровотока в ГА у всех участников исследования до занятий бадминтоном в среднем составляла (36,28 ± 6,88) мм/с. Через 6 месяцев тренировок этот показатель увеличился на 3,02 мм/с, до (39,30 ± 6,63) мм/с, через 1 год – на 4,06 мм/с, до (40,34 ± 6,26) мм/с. В ЦАС до занятий бадминтоном скорость кровотока в среднем была (9,70 ± 1,18) мм/с, через 6 месяцев тренировок она увеличилась на 0,88 мм/с, через 1 год – на 1,04 мм/с и составила (10,74 ± 1,71) мм/с. Наименьшая скорость кровотока в ГА наблюдалась у пациентов с миопией средней степени, а в ЦАС – с миопией высокой степени; наибольшей в ЦАС она была при гиперметропии и эмметропии. Прирост скорости кровотока за год отмечался во всех группах; максимальным в ГА он был при миопии высокой степени (5,5 мм/с), максимальным в ЦАС – при ПИНА с миопией (1,8 мм/с).

Что касается толщины хориоидеи (ТХ), то до занятий бадминтоном она в среднем составила (303,00 ± 68,59) мкм, через 6 месяцев тренировок – (306,80 ± 60,39) мкм, через 1 год – (306,60 ± 73,17) мкм. Максимальное увеличение ТХ наблюдалось при миопии высокой степени (на 30,50 мкм). В группе пациентов с СА и ПИНА толщина хориоидеи не изменилась, а в группе пациентов с миопией слабой степени и с СА и ПИНА с эмметропией она уменьшилась. В целом до занятий бадминтоном ТХ коррелировала с длиной ПЗО и снижалась от (342,92 ± 94,29) мкм при СА и ПИНА до (292,50 ± 21,92) мкм при миопии высокой степени. Выделяется группа с миопией средней степени, при которой ТХ была наименьшей: (273,86 ± 23,14) мкм; при миопии слабой степени она составила (307,29 ± 71,40) мкм, высокой – (292,50 ± 21,92) мкм (!) (табл. 3).

Обсуждение

В патогенезе приобретенной прогрессирующей миопии на ранних стадиях выделяют снижение аккомодационной способности, местной и церебральной гемодинамики. Предрасполагающими к этому снижению факторами являются гиподинамия, вынужденная ученическая поза с антефлексией головы, частые и длительные заболевания. Занятия спортом, особенно связанным с поворотами головы и шеи, глубоким дыханием и слежением за движущимся объектом, способствуют устранению или минимизации влияния перечисленных патогенных факторов.

Проведенные исследования показывают благотворное влияние занятий бадминтоном на функциональное состояние и гемодинамику глаз с близорукостью. Эти занятия следует рекомендовать для профилактики возникновения и прогрессирования миопии.

Заключение

Таким образом, на фоне регулярных занятий бадминтоном в течение 1 года отмечены следующие изменения:

■ Острота зрения без коррекции в целом у всех участников исследования повысилась с 0,34 до 0,42; при этом у детей с эмметропией и гиперметропией она осталась равной 1,0, у детей с миопией не изменилась, а у пациентов с ПИНА и спазмом аккомодации повысилась с 0,66 до 0,8. Максимальная корригированная острота зрения у всех детей была и осталась равной 1,0. Сила корригирующего стекла (субъективная рефракция) при гиперметропии и ПИНА уменьшилась с –0,16 до –0,07 дптр, а при миопии увеличилась с –1,57 до –1,84 дптр.

■ Усиление манифестной рефракции за 1 год составило 0,10 дптр, циклоплегической – 0,34 дптр. Среди всех школьников наилучший эффект отмечен у детей с СА и ПИНА: у них через год манифестная рефракция стала слабее на 0,92 дптр, то есть спазм аккомодации был полностью устранен. Об этом же говорит и снижение величины привычного тонуса аккомодации почти в 2 раза в целом по всем группам.

■ Увеличение длины глаза за год составило 0,17 мм у детей без миопии и 0,31 мм у детей с миопией. Таким образом, с учетом поправки на естественный рост глаза удлинение ПЗО составило 0,14 мм, что соответствует динамике рефракции.

■ ЗОА повысился на 30 %.

■ На фоне занятий бадминтоном отмечено усиление кровотока в глазной артерии и центральной артерии сетчатки во всех группах детей.

■ Отмечено незначительное увеличение толщины хориоидеи (то есть увеличение ее кровенаполнения), особенно при миопии высокой степени.

■ Проведенное исследование влияния занятий бадминтоном на функциональное состояние, кровоснабжение органа зрения и динамику рефракции позволяет дать положительную оценку данному виду физической активности как методу профилактики возникновения и прогрессирования миопии.

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Influence of badminton on refraction, accommodation and hemodynamics of myopia eyes

Ideal sport, which blends the tracking of moving object (training accommodation), turns head and trunk (increased hemodynamic), deep breathing (oxygenation of blood), is badminton.

Purpose. To study the state and dynamics of refraction, accommodation, and blood flow rate in the vessels of the eye in children with different refraction on the background of badminton.

Material and methods. 40 children (80 eyes) with refraction anomaly from +6,63 to –6,75 D [on average – (1.28 ± 2.28) D] at the age from 7 to 11 years [on average (9.24 ± 1.06) years]. After 6 months of training badminton was surveyed 38 children (how many 76 eyes). 27 children (54 eyes) with different refraction [average –(1.62 ± 1.81) D] aged 8 to 12 years [average (9.42 ± 1.10) years] were examined. All patients underwent visual acuity testing without correction and with optimal correction in their glasses. The reserves of relative accommodation, binocular and monocular accommodation response, habitual tone of accommodation, color and energy Doppler mapping, choroid thickness were determined. All studies were carried out before, 6 months and a year after the start of badminton classes by the method of Turmanidze V. G.

Results. Visual acuity without correction in the whole group of children increased from 0.34 to 0.42; including the usual excess voltage of accommodation (PINA) and spasm of accommodation increased from 0.66 to 0.8. Increased refraction over 1 year amounted to 0.1 diopters in a narrow pupil and 0.34 D wide, including in children with spasm and PINA in a year overt refraction decreased by 0.92 D, i. e., the spasm was completely resolved. This is also evidenced by the decrease in the usual tone of accommodation almost 2 times in General for all groups. The increase in the length of the eye for the year was 0.17 mm in children without myopia and 0.31 mm in children with myopia, that is, taking into account the correction for the natural growth of the eye, the increase in PZO was 0.14 mm, which corresponds to the dynamics of refraction. Zoe's up 30 %. Blood flow rate in the eye artery increased by 3.02 mm/sec after 6 months of training, by 4.06 mm/sec after 1 year and amounted to (40.34 ± 6.26) mm/sec. In the Central retinal artery after 6 months of training – increased by 0.88 mm/sec, after 1 year – by 1.04 mm/sec and amounted to (10.74 ± 1.71) mm/sec. The thickness of the choroidal unreliable increased by 3.6 microns. The maximum increase in choroidal thickness was observed in high-grade myopia at 30.5 μm.

Conclusion. The study of the influence of badminton on the functional state, blood supply to the organ of vision and the dynamics of refraction allows us to give a positive assessment of this type of physical activity as a method of prevention of myopia and its progression.

Keywords: accommodation, badminton, choroid thickness, hemodynamics, myopia

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ENGLISH VERSION

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

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Summary

Badminton is an ideal sport that harmoniously combines tracing a moving object (accommodation training), head and torso turns (hemodynamics strengthening), deep breathing (blood oxygenation).

Purpose: to investigate the state of refraction, accommodation and blood flow in eye vessels of children with various refractions who are engaged in regular badminton playing.

Material and methods. 27 children (54 eyes) with various refractive errors (averagely, -1.62±1.81 D) aged 8 to 12 years (average 9.42±1.1 years) were examined. All patients were measured for uncorrected visual acuity, optimal visual acuity, and visual acuity when wearing their own spectacles. Relative accommodation reserve (RAR), binocular and monocular accommodation response, the habitual accommodation tone (HAT), colour and power Doppler imaging (CDI and PDI) and choroid thickness were determined. 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 Valery Turmanidze.

Results. Uncorrected visual acuity of the whole group rose from 0.34 to 0.42. In the subgroup of habitually excessive accommodation strain (HEAS) and accommodation spasm it rose from 0.66 to 0.8. Over a year, refraction increased by 0.1 D for the narrow pupil and by 0.34 D for the dilated pupil. In children with spasm or HEAS, manifest refraction sank by 0.92 D, which means that the spasm was completely eliminated. This is supported by the evidence that the habitual accommodation tone sank almost 2 times for all groups as a whole. Over the year, the eye length increased by 0.17 mm in children with no myopia and by 0.31 mm in myopic children. 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. Relative accommodation reserve showed a 30% increase. The blood flow rate in the ophthalmic artery increased by 3.02 mm/sec after 6 months of workout by 3.02 mm/sec and after a year, it increased by 4.06 mm/sec and reached 40.34±6.26 mm/sec. In the central retinal artery, it increased by 0.88 mm/sec after 6 months of workout and by 1.04 mm/sec after a year of workout and reached 10.74±1.71 mm/sec. The thickness of the choroid showed a statistically unreliable increase of 3.6 microns. The maximum increase of the choroid thickness was observed in high myopia, where it rose by 30.5 microns. **Conclusion.** The study of badminton playing impact on the functional state, blood supply, and refraction change enables us to assess positively this type of physical activity as a means of prevention of myopia onset and progression.

Key words: badminton, myopia, accommodation, choroid thickness, hemodynamics.

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Relevance. Despite the wide range of therapeutic and preventive measures taken to oppose myopia, the number of myopic patients is steadily growing around the world. According to a review by B.Holden et al, in 2000, the share of myopic people in the world was 22.9 %. Of these, 2.7% had high myopia. A forecast says that by the year 2050 these figures will grow to reach, respectively, 49.7% (≈ 4,8 billion people) and 9.8%, which will become a serious global medical and social problem of public health care [1].

In Russia, the incidence of myopia in children and adolescents has increased 1.5 times over the past 20 years. Myopia claims the first place in the structure of children's eye pathology, the second place in the structure of children's disability and the third place in the structure of disability of the whole population [2].

The exact causes of myopia and mechanisms underlying its development are not entirely clear. Present-day theories of myopia pathogenesis assume that even though hereditary factors play a decisive role in the onset and progression of myopia, they are not alone: very important are environment factors such as intensive near visual work, insufficient physical activity (especially outdoor).

Individual pathogenetic links have been identified, indicating the involvement of the pathology of certain organs and body systems into myopia development. 96% of children with myopia are found to have various general somatic diseases.

The most common are diseases of the connective tissue, cardiovascular and central nervous systems, among which perinatal and natal lesions of the central nervous system, cervical insufficiency resulting from instability of the cervical spine, early osteochondrosis, birth injuries, and subluxations of cervical spine occur the most frequently [4-6].

A variety of preventive strategies for the onset and progression of myopia have been proposed. Many epidemiological studies show that sports and outdoor activities have a deterrent effect on myopia growth [7-10].

Badminton is an ideal sport that harmoniously combines tracing a moving object (accommodation training), head and torso turns (hemodynamics strengthening), deep breathing (blood oxygenation).

Purpose: to investigate the state of refraction, accommodation and blood flow in eye vessels of children with various refractions who are engaged in regular badminton playing.

Material and methods. 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. Again, in the total cohort of patients, a group with spasm and HEAS was identified.

All patients were measured for uncorrected visual acuity, optimal visual acuity, and visual acuity when wearing their own spectacles. Relative accommodation reserve (RAR) was determined using a Grand Seiko Binocular Open Field Autorefkeratometer WR-5100K device (Japan). The same device was used to perform objective measurements of accommodation. Both types of measurements were made according to the technique described earlier at a distance of 33 cm under the conditions of binocular fixation (binocular accommodation response, BAR) and monocular fixation (monocular accommodation response, MAR).

The habitual accommodation tone (HAT) was determined as a difference between the readings of the autorefractometer before and after cycloplegia.

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 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 Valery Turmanidze [11].

Results. 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.

As shown in Table 1, manifest refraction increased by 0.28 D in the whole group of children after 6 months of practice and sank again by 0.18 over the next six months. Consequently, over a year, manifest refraction increased by 0.1 D. Cycloplegic refraction increased by 0.34 D; it should be noted that the shift took place in the first 6 months of practice whilst in the next 6 months the refraction remained stable. Thus, the yearly progression rate amounted to 0.34 D. The difference between the change patterns of manifest and cycloplegic refraction is explained by a reduction in the accommodation tone: the habitual tone of accommodation sank by 0.24 D in a year, which implies a nearly double reduction. The results of previous studies showed that a reduction of accommodation tone is a favorable sign, associated with reduced myopia progression rate [12].

In myopia, 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 (Table 1).

Table 1

Refraction and accommodation tone indicators (diopters) in patients with various refractions before and after badminton practice (M±σ)

Refraction	Autorefractometry						HAT		
	before badminton practice		After 6 months		After 1 year		before badminton practice	After 6 months	After 1 year
	narrow pupil	wide pupil	narrow pupil	шир	narrow pupil	wide pupil			
Average	-2.11± 2.06	-1.62± 1.81	-2.39± 1.95	-1.96± 1.92	-2.21± 2.02	-1.96± 2.05	-0.49± 0.97	-0.43± 0.87	-0.25± 0.55
Myopia, average	-2.54± 2.03	-2.1± 1.65	-2.74± 1.9	-2.45± 1.77	-2.71± 1.89	-2.53± 1.82	-0.44± 1.02	-0.29± 0.64	-0.18± 0.54
Myopia, low	-1.66± 0.76	-1.39± 0.75	-1.94± 1.03	-1.76± 1.08	-1.91± 1.03	-1.81± 1.13	-0.27± 0.46	-0.18± 0.31	-0.1± 0.28
Myopia, moderate	-5.73± 1.93	-4.34± 0.76	-5.45± 1.08	-4.59± 0.69	-5.37± 0.65	-4.71± 0.68	-1.39± 2.2	-0.86± 1.41	-0.66± 1.17
Myopia, high	-6.82± 0.09	-6.69± 0.08	-7.19± 0.27	-7.13± 0.18	-7.32± 0.09	-7.32± 0.09	-0.13± 0.17	-0.06± 0.13	0±0
Hyperopia/Emme-tropia	0.345± 0.45	0.47± 0.32	-0.03± 0.78	0.31± 0.69	0.38± 0.65	0.66± 0.48	-0.12± 0.31	-0.34± 0.37	-0.28± 0.21
Spasm and HEAS	-2.36± 2.88	-0.66± 1.61	-2.04± 2.37	-0.76± 1.54	-1.44± 2.17	-0.59± 1.63	-1.7± 1.52	-1.28± 1.44	-0.85± 0.77

Binocular accommodation response before badminton practice showed an average of –1.99 D. After 6 months of workouts BAR was the same whilst after 1 year it grew 0.1 D. The maximum BAR increase was observed in high myopia, where it grew by 0.37 D, and in moderate myopia (by 0.35 D); see Table 2.

Table 2

Objective and subjective accommodation parameters (diopters) in in patients with various refractions before and after badminton practice (M±σ)

Refraction	BAR			MAR			RAR		
	before badminton practice	after 6 months	After 1 year	before badminton practice	After 6 months	After 1 year	before badminton practice	After 6 months	After 1 year
Average	-1.99± 0.38	-2.04± 0.44	-2.09± 0.38	-1.78± 0.46	-1.84± 0.05	-1.89± 0.57	1.8± 1.51	2.22± 1.31	2.35± 1.05
Myopia. average	-1.97± 0.4	-2.0± 0.44	-2.06± 0.4	-1.72± 0.48	-1.78± 0.6	-1.81± 0.56	1.32± 1.13	1.96± 1.15	2.23± 1.08
Myopia, low	-2.03± 0.34	-2.03± 0.35	-2.05± 0.39	-1.78± 0.39	-1.82± 0.52	-1.86± 0.47	1.46± 1.19	1.76± 1.14	2.07± 1.02
Myopia, moderate	-1.69± 0.6	-1.77± 0.77	-2.04± 0.48	-1.32± 0.71	-1.33± 0.74	-1.47± 0.86	1±0.5	2.79± 0.99	3.36± 0.56
Myopia, high	-2.0± 0.17	-2.22± 0.13	-2.37± 0	-2.19± 0.18	-2.53± 0.23	-2.25± 0.26	0±0	2.5±0	1±0
Hyperopia/Emme-tropia	-2.12± 0.27	-2.47± 0.44	-2.34± 0.33	-2.04± 0.28	-2.27± 0.21	-2.39± 0.27	3± 1.44	3± 0.58	3± 0.29
Spasm and HEAS	-2.14± 0.33	-2.0± 0.33	-2.2± 0.28	-1.91± 0.39	-1.88± 0.52	-2.13± 0.47	3± 1.53	2.62± 1.28	2.96± 0.85

Monocular accommodation response before badminton practice was –1.78 D on average. After 6 months of workouts MAR it grew by 0.06 D and after 1 year it grew, in total, by 0.11 D. The maximum MAR 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 (Table 2).

After 6 months of workouts, RAR showed an average increase of 0.42 D (23.3%)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±1.05 D. The maximum RAR increase of 2.0 D was observed in moderate 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 (Table 2).

The AP axis, before badminton activities, averaged 23.89±1.0 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±1.04 mm, and after a year, 24.15±1.06 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. In our group of patients with hyperopia and emmetropia, AP axis increased by 0.17 mm in a year; 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±0.27 mm. After 6 months, ACD increased by 0.03 mm and after a year by 0.05 mm in total. ACD was minimal in hyperopia with spasm (3.1 mm±), and maximal in low myopia (3.71±0.27 mm). In myopia, ACD is decreasing from 3.71±0.27 mm in low myopia to 3.68±0.14 mm in moderate myopia and 3.49±0.02 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. 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±6.88 mm/sec. After 6 months of workouts the parameter grew by 3.02 mm/sec to achieve 39.3±6.63 mm/sec and after a year it grew by 4/06 mm/sec and achieved 40.34±6.26 mm/sec. In CRA, before badminton activities, the blood flow rate showed an average of 9.7±1.18 mm/sec, whilst after 6 months of workouts it rose by 0.88 mm/sec and after a year it grew by 1.04 mm/sec to achieve 10.74±1,71 mm/sec. The lowest blood flow rate in OA was observed in the group of moderate 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 mm/sec), and the CRA maximum addition was in HEAS with myopia (1.8) mm/sec).

Choroid thickness (CT) was, before badminton activities, 303±68.59 microns on average. After 6 months of workouts, CT dropped to 306.8±60.39 microns and in another 6 months it was 306.6±73,17 microns. The maximum CT increase (by 30.5 microns) was observed in high myopia. In the group of patients with spasm and HEAS, CT remained the same. In the groups of patients with low myopia and those with emmetropia with spasm or HEAS, the choroid thickness decreased. On the whole, CT correlated before badminton activities with the anteroposterior (AP) axis, varying from 342,92±94.29 microns in spasm to 292±21.92 microns in high myopia. A group of moderate myopia could be isolated: it had the least CT, which was 273.86±23.14 microns (whilst low myopia revealed 307.29±71.4 microns and high myopia, 292.5±21.92 мкм microns!). (Table 3).

Table 3

Choroid thickness (microns), AP length (mm), anterior chamber depth (mm), blood flow rate in the ophthalmic and central retinal arteries in patients with various refraction, before and after badminton workouts (M± σ)

Refraction	CT			APA			Anterior chamber depth			Blood flow rate					
										Ophthalmic artery			Central retinal artery		
	Before practice start	After 6 months	After 1 year	Before practice start	After 6 months	After 1 year	Before practice start	After 6 months	After 1 year	Before practice start	After 6 months	After 1 year	Before practice start	After 6 months	After 1 year
Average	303± 68.59	306.8± 60.39	306.6± 73.17	23.89±1 .0	24.12± 1.04	24.15± 1.06	303± 68.59	3.67± 0.28	3.69± 0.29	303± 68.59	39.3± 6.63	40.34± 6.26	9.7± 1.18	10.58± 1.28	10.74± 1.71
Myopia, average.	301.3± 65.36	303.98± 37.15	302.07± 69.91	24.08±0 .95	24.38± 0.96	24.39± 0.97	3.7± 0.25	3.73± 0.25	3.76± 0.25	36.04± 7.04	39.28± 6.92	40.22± 6.22	9.62± 1.12	10.71± 1.27	10.77± 1.76
Myopia, low	307.29± 71.4	309.09± 61.79	303.4± 76.91	23.88±0 .8	24.16± 0.85	24.21± 0.87	3.71± 0.27	3.75± 0.27	3.77± 0.27	36.79± 6.94	39.63± 6.54	40.68± 5.56	9.67± 1.07	10.97± 1.04	10.92± 1.86
Myopia, moderate	273.86± 23.14	279.86± 28.87	289.43± 33.25	24.31±0 .51	24.49± 0.49	24.52± 0.46	3.68± 0.14	3.68± 0.11	3.72± 0.1	29.72± 2.16	34.71± 6.63	35.32± 6.69	9.93± 1	10.26± 1.28	10.63± 0.99
Myopia. high	292.5± 21.92	299± 24.04	323± 18.38	26.72±0 .05	26.84± 0.07	26.88± 0.05	3.49± 0.02	3.49± 0.05	3.53± 0.05	45.01± 0	49.1± 0	49.32± 0	7.6±0	7.67±0	8.7±0
Hyperopia and emmetropia	294.75± 59.97	312.25± 54.09	313.75± 52.03	23.34±0 .2	23.48± 0.23	23.51± 0.21	3.52± 0.07	3.51± 0.04	3.57± 0.09	32.86± 3.95	35.44± 2.33	36.73± 3.05	10.03± 0.37	10.14± 0.34	10.47± 0.64
Spasm and HEAS	342.92± 94.29	332.46± 75.74	347.77± 97.3	23.02±0 .93	23.12± 0.98	23.12± 0.99	3.43± 0.26	3.45± 0.28	3.45± 0.29	40.07± 5.77	42.85± 4.35	43.7± 5.33	9.75± 1.56	10.53± 1.32	11.04± 1.37

Discussion. In the pathogenesis of acquired progressive myopia at early stages, the reduction of accommodation ability, as well as local and cerebral hemodynamics are isolated. In their turn, factors that predispose this reduction are hypodynamia, forced pupil postures with head anteflexion, frequent and prolonged illnesses. Athletics and sport exercises, especially those presupposing head and neck turns, deep breathing, tracing a moving object are instrumental in the elimination or minimization of the impact of the mentioned pathogenetic factors.

Our studies confirm a favorable impact of badminton playing on the functional state and hemodynamics of myopic eyes. Badminton should be recommended for the prevention of myopia onset and progression.

Conclusions. 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 all groups.
3. Over the year, the length of the eye increased by 0.17 mm in children without myopia and by 0.31 mm in children with myopia. Thus, considering the adjustment for natural eye growth), the anterio-posterior axis of the eye grew by 0.14 mm, which corresponds with refraction dynamics.
4. RAR (relative accommodation reserve) increased by 30%.
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 slight choroid thickness increase (i.e. blood supply increase in the choroid) was noted, especially for high myopia.
7. Our studies of the impact badminton playing on the functional state, blood supply, and refraction dynamics hemodynamics of myopic eyes show that this type of physical activity may be given a positive assessment as a prevention of myopia onset and progression.

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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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Состояние и динамика волнового фронта глаза у детей с различной рефракцией на фоне регулярных занятий спортом (бадминтоном)

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Целью *настоящей работы явился сравнительный анализ уровня аберраций, структуры волнового фронта, его реакции на циклоплегию у детей с различной рефракцией до и через год после регулярных занятий спортом (бадминтоном).* ***Материал и методы.*** *Обследовано 40 детей (80 глаз) с аномалиями рефракции от +6,63 до -6,75 дптр (в среднем -1,28 ± 2,28 дптр) в возрасте от 7 до 11 лет (в среднем 9,24 ± 1,06 года) до, через 6 мес (38 детей, 72 глаза) и 1 год (27 детей, 54 глаза) занятий бадминтоном. Всем пациентам проводили аберрометрию волнового фронта до и после циклоплегии на аберрометре OPD-Scan III (Nidek). Анализировали коэффициенты Цернике до 12-го порядка включительно: вертикальный и горизонтальный наклон (tilt 1, tilt 2), вертикальный и горизонтальный трефойл (trefoil 6, trefoil 9), вертикальную и горизонтальную кому (coma 7, coma 8), сферическую аберрацию (СА), среднеквадратичное отклонение от идеального волнового фронта (RMS).* ***Результаты.*** *Установлено, что СА при миопии отрицательная, при гиперметропии положительная; tilt 1, tilt 2, trefoil 9, coma 7 при миопии достоверно выше, а coma 8 достоверно ниже, чем при гиперметропии. Наклон волнового фронта (tilt 1, tilt 2) в условиях циклоплегии достоверно снижается в гиперметропических глазах и не изменяется в миопических. Последнее свидетельствует о недостаточном натяжении цинновых связок миопического глаза. На фоне регулярных занятий бадминтоном отмечаются достоверные изменения аберраций волнового фронта, свидетельствующие об укреплении связочного аппарата хрусталика и нормализации тонуса цилиарной мышцы.* ***Заключение.*** *Структура волнового фронта у детей с различной рефракцией достоверно различается. Занятия бадминтоном способствуют укреплению связочного аппарата хрусталика.*

Ключевые слова: миопия, гиперметропия, аберрации, бадминтон

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The state and dynamics of the wavefront of the eye in children with different refractions engaged in regular sport activities (badminton)

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*The paper is **aimed** at comparing the level of aberrations, structure of the wavefront, and its response to cycloplegia in children with different refractions before they started practicing badminton regularly and after a year's duration of this practice. **Material and methods.** 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 before the practice, 6 months after practice start (38 children, 72 eyes) and after 1 year of badminton playing (27 children, 54 eyes). All patients underwent wavefront aberrometry before and after cycloplegia on an OPD-Scan III (Nidek) aberrometer. 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). **Results.** SA in myopia was found to be negative, in hyperopia positive; tilt 1, tilt 2, trefoil 9, coma 7 in myopia were significantly higher, and coma 8 significantly lower than in hyperopia. The slope of the wavefront (tilt 1, tilt 2) in cycloplegia falls significantly in hyperopic eyes and does not change in myopic ones. The latter fact points to insufficient tension of Zinn ligaments in the myopic eye. Regular badminton practice results in significant changes in wavefront aberrations, indicating a strengthening of the ligaments of the lens and the normalization of the ciliary muscle tone. **Conclusions.** The structure of the wavefront in children with different refractions shows significant differences. Badminton helps strengthen the ligaments of the lens.*

Keywords: myopia, aberrations, badminton

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Частота миопии в последние десятилетия неуклонно увеличивается и составляет 30–40 % среди лиц молодого возраста в нашей стране, в США и европейских странах и 70–96 % в регионе Юго-Восточной Азии [1–5].

По данным А.И. Дашевского [6], дети 4–7 лет в норме должны иметь гиперметропическую рефракцию (порядка 1,0 дптр). К сожалению, повышение зрительных нагрузок, компьютеризация всех аспектов жизни современных детей, увеличение требований к новым программам в школе, снижение физической нагрузки и гиподинамия привели к ранней эмметропизации (в возрасте 4–6 лет) и возникновению близорукости в школьном возрасте [7]. В последние годы в развитии приобретенной миопии все большую роль отводят снижению физической активности, особенно на открытом пространстве, и для минимизации патогенного действия неблагоприятных факторов окружающей среды рекомендуют занятия спортом. В этом отношении идеальным видом спорта, в котором гармонично сочетаются слежение за движущимся объектом (тренировка аккомодации), повороты головы и туловища (активизация гемодинамики), глубокое дыхание (оксигенация крови), является бадминтон.

Согласно современным воззрениям, в развитии приобретенной близорукости, помимо наследственной обусловленности, значительную роль играют факторы внешней среды и прежде всего — оптические погрешности формирования ретинального изображения. В экспериментах показано, что как центральная, так и периферическая гиперметропическая дефокусировка изображения стимулирует рост глаза и миопизацию рефракции. В свою очередь, фокусировка изображения на сетчатке определяется точностью (адекватностью) и устойчивостью аккомодационного ответа, а также аберрациями волнового фронта глаза. Последние тесно взаимосвязаны с аккомодацией и периферической рефракцией. С одной стороны, аберрации определяют качество ретинального изображения и являются стимулом к его фокусировке. Известно, что отрицательная сферическая аберрация (СА) и кома стимулируют аккомодационный ответ; напряжение аккомодации, в свою очередь, усиливает отрицательную СА [8, 9]. С другой стороны, высокий уровень аберраций, в частности положительной СА, увеличивает глубину фокусной области, облегчает зрительную работу вблизи без участия аккомодации (так называемая псевдоаккомодация) и может снижать аккомодационный ответ, что приводит к отставанию аккомодации (accommodation lag) и формированию гиперметропического дефокуса на сетчатке.

По предположению M. Collins и C. Wildsoet, индивидуальные аберрации, такие как СА, могут нарушить процесс эмметропизации. По мнению авторов, отрицательная СА индуцирует миопический рост глаза, а положительная, наоборот, замедляет [10]. В ряде работ сообщается о высоких значениях аберраций 4-го, 5-го и более высоких порядков у лиц с миопией по сравнению с эмметропами [11]. В глазах с быстрым прогрессированием миопии наблюдался более высокий уровень как общих аберраций (total HOAs) и среднеквадратичного отклонения от идеального волнового фронта (RMS), так и аберраций 3-го порядка и комы, чем в глазах с медленным прогрессированием миопии [12–15]. Изменение СА при близорукости связывают с изменением хрусталика во время роста глаза [16, 17]. Более высокий уровень аберраций, снижающих качество ретинального изображения, может играть роль в развитии миопии [13, 18, 19].

В то же время в некоторых исследованиях в миопических глазах зарегистрирован, наоборот, более низкий, чем в эмметропических, уровень аберраций 4-го порядка [10], СА [20–22], аберраций 3-го и высших порядков [20, 23, 24]. В других работах не обнаружено различий в параметрах волнового фронта в разных рефракционных группах [25–28].

В естественных условиях существует физиологический тонус аккомодации, обеспечивающийся балансом между симпатической и парасимпатической иннервацией [29]. Благодаря этому тонусу (в основном) внутренняя оптика глаза стремится компенсировать роговичные аберрации, что приводит к снижению общих (глазных) HOAs и улучшению ретинального образа. У детей и молодых лиц с миопией и гиперметропией общие HOAs ниже роговичных [30, 31].

Изменения волнового фронта выявляются и при циклоплегии в сравнении с нециклоплегическими условиями [32].

Представляет особый интерес сравнение аберраций волнового фронта и их изменений под действием циклоплегии в глазах с миопией и гиперметропией. Согласно полученным нами ранее данным, в естественных условиях при ширине зрачка 3 мм уровень аберраций tilt 1, горизонтальный трефойл и вертикальная кома достоверно выше при миопии, чем при гиперметропии, а их изменения в ответ на циклоплегию существенно ниже или отсутствуют. Нам представляется, что эти особенности можно связать с состоянием связочного аппарата хрусталика и цилиарной мышцы. Повышенный уровень аберраций, связанных с наклоном хрусталика, его смещением, децентрацией оптических элементов глаза, может свидетельствовать о слабом натяжении связок (возможно, связанном с избыточным тонусом цилиарной мышцы). Это подтверждается и при циклоплегии: изменение тонуса цилиарной мышцы, натяжения цинновых связок и положения хрусталика при миопии недостаточны для существенных изменений волнового фронта [33].

Помимо аккомодации и центрального дефокуса, роль аберраций велика и в формировании периферического ретинального дефокуса. По ряду сообщений, положительная СА способствует формированию относительной периферической миопии, а отрицательная — гиперметропии. Не только экспериментальные, но и клинические наблюдения убедительно показывают тормозящее влияние миопического дефокуса на процесс прогрессирования близорукости [34].

Перечисленные факты объясняют повышенный интерес к изучению волнового фронта глаза, отмечаемый в научной литературе последних лет. Роль аберраций в постнатальном рефрактогенезе представляется несомненной, однако результаты многочисленных исследований неоднозначны. Связь общего уровня аберраций с рефракцией, прогрессированием близорукости, отставанием аккомодации подтверждается в одних работах и не находит подтверждения в других.

ЦЕЛЬЮ настоящей работы явился сравнительный анализ уровня аберраций, структуры волнового фронта, его реакции на циклоплегию у детей с различной рефракцией до и через год после регулярных занятий спортом (бадминтоном).

МАТЕРИАЛ И МЕТОДЫ

Обследовано 40 детей (80 глаз) в возрасте от 7 до 11 лет (в среднем 9,24 ± 1,06 года) с аномалией рефракции от +6,63 до -6,75 дптр (в среднем -1,28 ± 2,28 дптр), из них с миопией 34 ребенка (67 глаз), в том числе слабой степени — 26 детей (51 глаз), средней — 6 детей (12 глаз), высокой — 2 ребенка (4 глаза), с гиперметропией и эмметропией — 7 детей (13 глаз) соответственно. Из общего числа участников исследования была выделена группа со спазмом аккомодации (СпА) и привычно-избыточным напряжением аккомодации (ПИНА): 11 детей (20 глаз), из них с миопией 4 ребенка (7 глаз), с гиперметропией — 3 ребенка (6 глаз) и эмметропией — 4 ребенка (7 глаз). Через 6 мес занятий бадминтоном обследовано 38 детей (76 глаз). Через год обследовано 27 детей (54 глаза) в возрасте от 8 до 12 лет (в среднем 9,42 ± 1,10 года) с различной рефракцией (в среднем -1,62 ± 1,81 дптр), из них с миопией — 23 ребенка (46 глаз): слабой степени — 19 детей (37 глаз), средней — 4 ребенка (7 глаз), высокой — 1 ребенок (2 глаза), а также с гиперметропией и эмметропией — 4 ребенка (8 глаз), и выделена группа пациентов (7 детей, 14 глаз) со СпА и ПИНА, имеющих миопию (3 ребенка, 6 глаз), гиперметропию (2 ребенка, 4 глаза) и эмметропию (2 ребенка, 4 глаза). Всем пациентам проводили аберрометрию волнового фронта в затемненной комнате до и после медикаментозной циклоплегии (применяли 1 % циклопентолат дегидрохлорид дважды, с интервалом 10 мин, аберрометрию проводили через 40 мин после первого закапывания) на аберрометре OPD-Scan III (Nidek). Поскольку действие циклоплегиков сопровождается и мидриазом, увеличивающим уровень многих аберраций, мы проводили анализ волнового фронта до и после инстилляции циклопентолата при фиксированной ширине зрачка, чтобы оценить влияние на него только циклоплегии, а не мидриаза. Аберрации анализировали при ширине зрачка 3 мм как без циклоплегии, так и в условиях циклоплегии (в последнем случае — с помощью выбора 3-мм зоны). Анализировали коэффициенты Цернике до 12-го порядка включительно: вертикальный и горизонтальный наклон (tilt 1, tilt 2), вертикальный и горизонтальный трефойл (trefoil 6, trefoil 9), вертикальную и горизонтальную кому (coma 7, coma 8), СА и RMS.

Занятия бадминтоном проводились по методике В.И. Турманидзе [35].

РЕЗУЛЬТАТЫ И ОБСУЖДЕНИЕ

Как показывает анализ таблиц 1—4, при миопии и гиперметропии выявляются достоверные различия следующих аберраций: СА, tilt 1, tilt 2, trefoil 9, coma 7 при миопии достоверно выше, а coma 8 — достоверно (в 10 раз) ниже, чем при гиперметропии. СА при миопии имеет отрицательные значения, а при гиперметропии — положительные.

Реакция на циклоплегию также весьма характерна. СА и при миопии, и при гиперметропии показывала сдвиг в сторону положительных значений: в первом случае в 2 раза уменьшалась отрицательная СА, во втором — увеличивалась положительная. При спазме и ПИНА положительная СА увеличивалась в 5 раз! Эти изменения укладываются в изменения формы хрусталика под циклоплегией — его уплощение со снижением преломляющей силы центральных отделов (см. табл. 2).

Наклон волнового фронта (tilt 1, tilt 2) в глазах с гиперметропией под циклоплегией снижался (tilt 2 в 25 раз!), а при миопии уменьшался недостоверно (в 1,5 раза) или даже увеличивался. Trefoil 9 при гиперметропии под циклоплегией увеличивался в 5 раз, а при миопии не изменялся (см. табл. 1—3).

Указанные изменения в ответ на циклоплегию перечисленных аберраций, связанных с наклоном волнового фронта, согласуются с описанными нами ранее и укладываются в предложенное объяснение [33]. Натяжение цинновых связок под действием циклоплегика в глазах с гиперметропией достаточно для изменения формы и положения хрусталика, а при миопии — недостаточно, что, очевидно, вызвано слабостью связочного аппарата и/или привычным гипертонусом цилиарной мышцы.

Изменения волнового фронта в ответ на циклоплегию в глазах с ПИНА и спазмом аккомодации были неоднозначны. Сферическая аберрация и tilt 1 вели себя так же, как в глазах с гиперметропией (каковыми они в среднем и являлись): т. е. первая увеличивалась в 5 раз в сторону положительных значений (в соответствии с уплощением хрусталика),а второй снижался (см. табл. 1, 2).

Таблица 1. Структура волнового фронта у детей с различной рефракцией до и после занятий бадминтоном: RMS и tilt 1 ($M \pm \sigma$)
Table 1. Wavefront structure in children with different refraction before and after badminton classes: RMS and tilt 1 ($M \pm \sigma$)

Рефракция Refraction	RMS						Tilt 1					
	до before		через 6 мес after 6 months		через 1 год after 1 year		до before		через 6 мес after 6 months		через 1 год after 1 year	
	до циклоплегии before cycloplegia	после циклоплегии after cycloplegia	до циклоплегии before cycloplegia	после циклоплегии after cycloplegia	до циклоплегии before cycloplegia	после циклоплегии after cycloplegia	до циклоплегии before cycloplegia	после циклоплегии after cycloplegia	до циклоплегии before cycloplegia	после циклоплегии after cycloplegia	до циклоплегии before cycloplegia	после циклоплегии after cycloplegia
В среднем по группе Averaging over the group n = 54	0,1788 ± 0,1000	0,19833 ± 0,10000	0,23178 ± 0,15000	0,19167 ± 0,09000	0,08621 ± 0,03000	0,08164 ± 0,03000	0,00839 ± 0,03000	0,0091 ± 0,0600	0,0125 ± 0,0600	0,0096 ± 0,0600	0,0146 ± 0,0600	0,0184 ± 0,0600
Миопия Myopia n = 46	0,1822 ± 0,1000	0,19545 ± 0,11000	0,22764 ± 0,15000	0,195 ± 0,090	0,08187 ± 0,03000	0,081 ± 0,030	0,011834± 0,060000*	0,0149 ± 0,0600*	0,0182 ± 0,0600*	0,0202 ± 0,0600*	0,0219 ± 0,0500*	0,0167 ± 0,0600*
Миопия слабой степени Low myopia n = 37	0,1631 ± 0,0800	0,18343 ± 0,08000	0,22389 ± 0,17000	0,18257 ± 0,08000	0,08187 ± 0,03000	0,081 ± 0,020	0,0186 ± 0,0600*	0,0134 ± 0,0600*	0,015 ± 0,060*	0,0189 ± 0,0500*	0,0219 ± 0,0600*	0,0167 ± 0,0500*
Миопия средней степени Moderate myopia n = 7	0,2943 ± 0,1500	0,28857 ± 0,16000	0,25143 ± 0,08000	0,27143 ± 0,13000	0,079 ± 0,030	0,08333 ± 0,03000	0,03486 ± 0,05000*	0,0247 ± 0,0700*	0,0304 ± 0,0900*	0,0264 ± 0,0800*	0,0062 ± 0,0600*	0,0033 ± 0,0600*
Миопия высокой степени High myopia n = 2	0,125 ± 0,050	0,08 ± 0,03	0,21 ± 0,10	0,145 ± 0,060	0,0465 ± 0,0100	0,066 ± 0,000	-0,044 ± 0,030	0,007 ± 0,010	0,032 ± 0,010*	0,021 ± 0,100*	0,015 ± 0,010*	0,0135 ± 0,0700*
Гиперметропия и эмметропия Hyperopia and emmetropia n = 8	0,20 ± 0,08	0,25 ± 0,05	0,22 ± 0,03	0,23 ± 0,10	0,068 ± 0,020	0,0735 ± 0,0200	-0,0528 ± 0,0400	-0,0423 ± 0,0600	-0,0383 ± 0,0400	-0,049 ± 0,060	-0,059 ± 0,040	-0,0428 ± 0,0700
Спазм и ПИНА Spasm and seudomyopia n = 14	0,1613 ± 0,0900	0,18615 ± 0,0500	0,23 ± 0,14	0,14923 ± 0,05000	0,13 ± 0,04	0,08767 ± 0,02000	-0,0134 ± 0,0300	0,005 ± 0,040	-0,0069 ± 0,0500	-0,0169 ± 0,0300	0,019 ± 0,040	0,0427 ± 0,0600

Примечание. n — количество глаз; * — $p < 0,05$ — достоверно относительно показателей пациентов с гиперметропией и эмметропией.
Note. n — number of eyes; * — $p < 0.05$ — significant with respect to patients with hyperopia and emmetropia.

Таблица 2. Структура волнового фронта у детей с различной рефракцией до и после занятий бадминтоном: tilt 2 и сферические аберрации (M ± σ)
Table 2. Wavefront structure in children with different refraction before and after badminton classes: tilt 2 and spherical aberrations (M ± σ)

Рефракция Refraction	Tilt 2						CA Sph					
	до before		через 6 мес after 6 months		через 1 год after 1 year		до before		через 6 мес after 6 months		через 1 год after 1 year	
	до циклоплегии before cycloplegia	после циклоплегии after cycloplegia	до циклоплегии before cycloplegia	после циклоплегии after cycloplegia	до циклоплегии before cycloplegia	после циклоплегии after cycloplegia	до иклоплегии before cycloplegia	после циклоплегии after cycloplegia	до циклоплегии before cycloplegia	после циклоплегии after cycloplegia	до циклоплегии before cycloplegia	после циклоплегии after cycloplegia
В среднем по группе Averaging over the group n = 54	0,0306 ± 0,2900	0,0217 ± 0,2900	-0,0157 ± 0,0400	-0,0139 ± 0,0400	-0,015 ± 0,050	-0,0269 ± 0,0400	-0,0198 ± 0,1400	-0,00926 ± 0,15000	0,003019 ± 0,010000	0,021981 ± 0,050000	0,002458 ± 0,040000	0,001071 ± 0,050000
Миопия Myopia n = 46	0,0383 ± 0,3200*	0,0263 ± 0,3200*	-0,0174 ± 0,0400	-0,0185 ± 0,0400*	-0,0209 ± 0,0500	-0,0172 ± 0,0400	-0,02545 ± 0,16000*	-0,01405 ± 0,16000*	0,00175 ± 0,01000	0,013977 ± 0,040000	-0,00253 ± 0,04000*	0,001333 ± 0,05000
Миопия слабой степени Low myopia n = 37	-0,0031 ± 0,0400	-0,0169 ± 0,0400*	-0,0139 ± 0,0400	-0,0096 ± 0,0400	-0,0209 ± 0,0500	-0,0172 ± 0,0300	-0,0022 ± 0,0100*	0,0122 ± 0,0400	0,001857 ± 0,010000	0,013971 ± 0,050000	-0,00253 ± 0,04000*	0,001333 ± 0,050000
Миопия средней степени Moderate myopia n = 7	0,2703 ± 0,800*	0,242 ± 0,820*	-0,0247 ± 0,0300	-0,0554 ± 0,0600	-0,0072 ± 0,0700	-0,0703 ± 0,0600	-0,14814 ± 0,40000*	-0,14914 ± 0,40000*	0,001571 ± 0,010000	0,018143 ± 0,020000	0,0182 ± 0,0400	-0,004 ± 0,040
Миопия высокой степени High myopia n = 2	-0,0495 ± 0,0100	-0,0525 ± 0,0100	-0,0085 ± 0,0900	0,027 ± 0,020	-0,0465 ± 0,0400	-0,032 ± 0,030	-0,003 ± 0,010*	-0,0005 ± 0,0100*	0,0005 ± 0,0100	-0,0005 ± 0,0100	-0,0155 ± 0,0100	-0,037 ± 0,030
Гиперметропия и эмметропия Hyperopia and emmetropia n = 8	-0,002 ± 0,030	-0,0008 ± 0,0500**	-0,0028 ± 0,0200	-0,0002 ± 0,0400**	0,0115 ± 0,0400	0,0073 ± 0,0300**	0,00725 ± 0,01000	0,025 ± 0,020**	0,0075 ± 0,0100	0,0445 ± 0,0400**	0,0035 ± 0,0100	0,01075 ± 0,01000**
Спазм и ПИНА Spasm and pseudomyopia n = 14	0,0049 ± 0,0400	0,0022 ± 0,0400	-0,0045 ± 0,0300	0,0067 ± 0,0300	-0,0003 ± 0,0500	-0,0110 ± 0,0300	0,004 ± 0,010	0,023077 ± 0,050000**	0,006385 ± 0,010000	0,060923 ± 0,090000**	0,0596 ± 0,0700	0,003333 ± 0,08000**

Примечание. n — количество глаз; * — p < 0,05 — достоверно относительно показателей у пациентов с гиперметропией и эмметропией; ** — p < 0,05 — достоверно относительно показателей до циклоплегии.
Note. n — number of eyes; * — p < 0.05 — significant with respect to patients with hyperopia and emmetropia; ** — p < 0.05 — significant with respect to parameters before cycloplegia.

Таблица 3. Структура волнового фронта у детей с различной рефракцией до и после занятий бадминтоном: trefoil 6 и trefoil 9 (M ± σ)
Table 3. Wavefront structure in children with different refraction before and after badminton classes: trefoil 6 and trefoil 9 (M ± σ)

Рефракция Refraction	Trefoil 6						Trefoil 9					
	до before		через 6 мес after 6 months		через 1 год after 1 year		до before		через 6 мес after 6 months		через 1 год after 1 year	
	до циклоплегии before cycloplegia	после циклоплегии after cycloplegia	до циклоплегии before cycloplegia	после циклоплегии after cycloplegia	до циклоплегии before cycloplegia	после циклоплегии after cycloplegia	до циклоплегии before cycloplegia	после циклоплегии after cycloplegia	до циклоплегии before cycloplegia	после циклоплегии after cycloplegia	до циклоплегии before cycloplegia	после циклоплегии after cycloplegia
В среднем по группе Averaging over the group n = 54	-0,0274 ± 0,0500	-0,02376 ± 0,04000	-0,031 ± 0,060	-0,0118 ± 0,0400	-0,01813 ± 0,04000	-0,02093 ± 0,04000	0,023593 ± 0,260000	0,027963 ± 0,260000	-0,00407 ± 0,03000	-0,00419 ± 0,03000	-0,01167 ± 0,03000	0,002571 ± 0,030000
Миопия Myopia n = 46	-0,0259 ± 0,0500	-0,0208 ± 0,0400	-0,02607 ± 0,05000	-0,01075 ± 0,04000	-0,01753 ± 0,04000	-0,023 ± 0,040	0,034205 ± 0,280000	0,038909 ± 0,280000	0,000864 ± 0,030000	-0,00132 ± 0,03000	-0,00187 ± 0,03000	0,005333 ± 0,030000
Миопия слабой степени Low myopia n = 37	-0,0323 ± 0,0500	-0,02437 ± 0,04000	-0,03071 ± 0,05000	-0,01651 ± 0,04000	-0,01753 ± 0,04000	-0,023 ± 0,040	-0,01023 ± 0,03000	-0,00083 ± 0,03000*	-0,00177 ± 0,03000	-0,00077 ± 0,020000*	-0,00187 ± 0,03000	0,005333 ± 0,030000*
Миопия средней степени Moderate myopia n = 7	-0,0039 ± 0,0500	-0,00957 ± 0,06000	-0,00814 ± 0,05000	0,022143 ± 0,030000	-0,0086 ± 0,0500	0,000333 ± 0,040000	0,258571 ± 0,700000	0,251143 ± 0,710000*	-0,00014 ± 0,020000	0,000714 ± 0,060000*	-0,0256 ± 0,0400	0,006667 ± 0,050000*
Миопия высокой степени High myopia n = 2	0,0085 ± 0,0100	0,0025 ± 0,0100*	-0,0075 ± 0,0400	-0,025 ± 0,010	-0,009 ± 0,020	0,0015 ± 0,0600	0,0265 ± 0,0400	-0,0085 ± 0,0100	0,0505 ± 0,0200*	-0,018 ± 0,020	-0,0065 ± 0,0100	-0,0055 ± 0,0300
Гиперметропия и эмметропия Hyperopia and emmetropia n = 8	-0,0353 ± 0,0100	-0,04025 ± 0,04000	-0,03725 ± 0,02000	-0,0345 ± 0,0200	-0,036 ± 0,030	-0,04675 ± 0,02000	-0,00875 ± 0,04000	-0,04025 ± 0,05000	-0,0175 ± 0,0300	-0,01275 ± 0,01000	-0,0145 ± 0,0300	-0,0145 ± 0,0400
Спазм и ПИНА Spasm and pseudomyopia n = 14	-0,0236 ± 0,0400	-0,03154 ± 0,04000	-0,03469 ± 0,07000	-0,00538 ± 0,03000	-0,00467 ± 0,04000	-0,003 ± 0,050	-0,01769 ± 0,04000	-0,00292 ± 0,04000	-0,01646 ± 0,04000	-0,00492 ± 0,03000	-0,0347 ± 0,0400	0,002667 ± 0,030000

Примечание. n — количество глаз; * — p < 0,05 — достоверно относительно показателей у пациентов с гиперметропией и эмметропией.
Note. n — number of eyes; * — p < 0.05 — significant with respect to patients with hyperopia and emmetropia.

Таблица 4. Структура волнового фронта у детей с различной рефракцией до и после занятий бадминтоном: coma 7 и coma 8 (M ± σ)
Table 4. Wavefront structure in children with different refraction before and after badminton classes: coma 7 and coma 8 (M ± σ)

Рефракция Refraction	Coma 7						Coma 8					
	до before		через 6 мес after 6 months		через 1 год after 1 year		до before		через 6 мес after 6 months		через 1 год after 1 year	
	до циклоплегии before cycloplegia	после циклоплегии after cycloplegia	до циклоплегии before cycloplegia	после циклоплегии after cycloplegia	до циклоплегии before cycloplegia	после циклоплегии after cycloplegia	до циклоплегии before cycloplegia	после циклоплегии after cycloplegia	до циклоплегии before cycloplegia	после циклоплегии after cycloplegia	до циклоплегии before cycloplegia	после циклоплегии after cycloplegia
В среднем по группе Averaging over the group n = 54	0,001407 ± 0,020000	0,002963 ± 0,020000	0,005481 ± 0,020000	0,006389 ± 0,030000	0,005792 ± 0,020000	0,008214 ± 0,020000	-0,00015 ± 0,02000	-0,0022 ± 0,0300	-0,00481 ± 0,01000	-0,00256 ± 0,01000	-0,00329 ± 0,02000	-0,00793 ± 0,01000
Миопия Myopia n = 46	0,004023 ± 0,020000*	0,004545 ± 0,020000*	0,006977 ± 0,020000*	0,009795 ± 0,030000*	0,008533 ± 0,020000*	0,007556 ± 0,020000*	0,000205 ± 0,030000	-0,00236 ± 0,03000	-0,0052 ± 0,0100	-0,00348 ± 0,01000*	-0,005 ± 0,020	-0,005 ± 0,010
Миопия слабой степени Low myopia n = 37	0,004343 ± 0,010000*	0,004457 ± 0,020000*	0,006657 ± 0,010000*	0,0064 ± 0,0200*	0,008533 ± 0,020000*	0,007556 ± 0,0200000*	-0,0018 ± 0,0100	-0,00509 ± 0,01000	-0,00429 ± 0,01000	-0,00197 ± 0,01000	-0,005 ± 0,010	-0,005 ± 0,010
Миопия средней степени Moderate myopia n = 7	0,007714 ± 0,020000*	0,004857 ± 0,020000*	0,007571 ± 0,030000*	0,027143 ± 0,070000*	0,0018 ± 0,0100*	0,001 ± 0,020*	0,014714 ± 0,060000*	0,008714 ± 0,070000*	-0,00714 ± 0,01000	-0,00843 ± 0,01000	-0,0004 ± 0,0200	-0,02133 ± 0,03000
Миопия высокой степени High myopia n = 2	-0,0145 ± 0,0100	0,005 ± 0,000*	0,0105 ± 0,0100*	0,0085 ± 0,0300*	0,007 ± 0,000*	0,007 ± 0,020*	-0,0155 ± 0,0100	0,0065 ± 0,0100	-0,0145 ± 0,0300	-0,0125 ± 0,0100	-0,0035 ± 0,0200	-0,008 ± 0,010
Гиперметропия и эмметропия Hyperopia and emmetropia n = 8	-0,0185 ± 0,0100	-0,0145 ± 0,0200	-0,01325 ± 0,02000	-0,014 ± 0,020	-0,02 ± 0,02	-0,01025 ± 0,02000	-0,00225 ± 0,01000	-0,00375 ± 0,02000	-0,0015 ± 0,0100	0,00025 ± 0,01000	0,0045 ± 0,0100	0,00125 ± 0,01000
Спазм и ПИНА Spasm and pseudomyopia n = 14	-0,00369 ± 0,01000	0,002385 ± 0,010000	0,000308 ± 0,020000	-0,00185 ± 0,01000	0,008667 ± 0,010000	0,015 ± 0,020	0,001154 ± 0,010000	0,000231 ± 0,010000	-0,00108 ± 0,01000	0,001538 ± 0,010000	-0,00207 ± 0,02000	-0,00333 ± 0,01000

Примечание. n — количество глаз; * — $p < 0,05$ — достоверно относительно показателей у пациентов с гиперметропией и эмметропией.
Note. n — number of eyes; * — $p < 0.05$ — significant with respect to patients with hyperopia and emmetropia.

Tilt 2, trefoil 6, trefoil 9 достоверно не изменялись в ответ на циклоплегию (табл. 1–3).

Coma 7 у пациентов с ПИНА и спазмом, как и при гиперметропии, имела отрицательные значения (при миопии — положительные), а после циклоплегии увеличивалась в 8 раз с переходом в положительные значения (во всех остальных группах — не изменялась) (см. табл. 4).

Значения coma 8 при ПИНА также соответствовали таковым при гиперметропии, а после циклоплегии снижались более значительно, чем в других группах, — в 4,5 раза (при гиперметропии — в 1,5 раза, при миопии — в 3,5 раза) (см. табл. 4).

В целом можно сказать, что структура волнового фронта глаза при ПИНА и спазме аккомодации соответствовала истинной рефракции этих глаз, т. е. гиперметропии. В то же время реакция волнового фронта на циклоплегию в этих глазах отличалась от реакции и миопических, и гиперметропических глаз.

После регулярных занятий бадминтоном произошли достоверные изменения значений ряда аберраций волнового фронта глаза. Так, суммарные аберрации (RMS) через 6 мес занятий достоверно не изменились, а через год снизились во всех группах, что позволяет говорить об улучшении качества зрения. СА при миопии через 6 мес снизилась в 20 раз и перешла в положительные значения, т. е. приблизилась к состоянию глаз с гиперметропией. Через год сохранялось уменьшение уровня СА в 10 раз по сравнению с исходным (см. табл. 1).

Изменения tilt 1 носили непостоянный характер, и к году занятий значения вернулись к исходному уровню. Tilt 2 через 6 мес при миопии уменьшился в 2,5 раза с сохранением этих значений через год. При гиперметропии tilt 2 через 6 мес не изменился, а через год резко увеличился с переходом в положительные значения. При ПИНА и спазме tilt 2 уменьшился в течение года, однако реакция на циклоплегию была парадоксальной: он увеличивался в 25 раз (см. табл. 1, 2).

Trefoil 6 не изменился в течение года при гиперметропии и снизился в 1,7 раза при миопии с появлением реакции на циклоплегию (показатель после циклоплегии снижался в 2 раза). Еще более выраженная реакция на циклоплегию появилась через 6 мес в группе с ПИНА и спазмом: trefoil 6 снизился в 5 раз. Через год в этой группе уровень этой аберрации снизился в 4,5 раза по сравнению с исходным (см. табл. 3).

Trefoil 9 в глазах с миопией через полгода занятий снизился в 12 раз с появлением отсутствовавшей ранее реакции на циклоплегию. Эти изменения сохранились и через год. При спазме и ПИНА данные аберрации в течение года увеличились, однако появилась реакция на циклоплегию, аналогичная таковой при миопии: отмечено увеличение в 5 раз с переходом из отрицательных в положительные значения (см. табл. 3).

Достоверных изменений coma 7 в естественных условиях через 6 мес не отмечено ни в одной группе. Только при ПИНА и спазме появилась реакция на циклоплегию в виде увеличения coma 7 в 6 раз с переходом из положительных значений в отрицательные. Через год в этой группе значения coma 7 повысились в 3 раза по отношению к исходным. При гиперметропии изменений не отмечено ни до, ни после циклоплегии (см. табл. 4).

Значения coma 8 в течение года у пациентов с миопией, ПИНА и спазмом еще больше снизились с переходом в отрицательные; реакция на циклоплегию при этом отсутствовала. В глазах с гиперметропией динамика аберраций coma 8 была противоположной: их уровень еще повысился с переходом в положительные значения; реакция на циклоплегию была выраженной: снижение в 3,5 раза (см. табл. 4).

Таким образом, на фоне регулярных занятий бадминтоном в глазах с миопией, ПИНА и спазмом произошли достоверные изменения аберраций волнового фронта, которые можно связать с укреплением связочного аппарата хрусталика и нормализацией тонуса цилиарной мышцы. Это прежде всего сдвиг сферических аберраций из отрицательных (когда центр оптической системы преломляет сильнее, чем периферия) в положительные значения (периферия преломляет сильнее центра). Такой эффект однозначно свидетельствует об уплощении хрусталика, что, в свою очередь, связано с устранением гипертонуса цилиарной мышцы и повышением натяжения цинновых связок.

Уменьшение наклона волнового фронта (tilt 2), вертикального и горизонтального трефойла и горизонтальной комы (coma 8), т. е. аберраций, связанных с рассогласованием и иррегулярностью элементов оптической системы, также можно отнести на счет укрепления связочного аппарата хрусталика. Еще в большей мере об этом свидетельствует появление отсутствовавшей ранее реакции на циклоплегию, а именно изменений волнового фронта при натяжении цинновых связок под действием циклоплегических средств (см. табл. 2–4).

ВЫВОДЫ

1. Структура волнового фронта у детей с различной рефракцией достоверно различается: СА при миопии отрицательная, при гиперметропии положительная; tilt 1, tilt 2, trefoil 9, coma 7 при миопии достоверно выше, а coma 8 — достоверно ниже, чем при гиперметропии.

2. Наклон волнового фронта (tilt 1, tilt 2) в условиях циклоплегии достоверно снижается в гиперметропических глазах и не изменяется в миопических. Последнее свидетельствует о недостаточном натяжении цинновых связок.

3. На фоне регулярных занятий бадминтоном выявлены достоверные изменения аберраций волнового фронта, свидетельствующие об укреплении связочного аппарата хрусталика и нормализации тонуса цилиарной мышцы.

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The state and dynamics of the wavefront of the eye in children with different refractions engaged in regular sport activities (badminton)

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*The paper is **aimed** at comparing the level of aberrations, structure of the wavefront, and its response to cycloplegia in children with different refractions before they started practicing badminton regularly and after a year's duration of this practice. **Material and methods.** 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 before the practice, 6 months after practice start (38 children, 72 eyes) and after 1 year of badminton playing (27 children, 54 eyes). All patients underwent wavefront aberrometry before and after cycloplegia on an OPD-Scan III (Nidek) aberrometer. 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). **Results.** SA in myopia was found to be negative, in hyperopia positive; Tilt 1, Tilt 2, Trefoil 9, Coma 7 in myopia were significantly higher, and Coma 8 significantly lower than in hyperopia. The slope of the wavefront (Tilt 1, Tilt 2) in cycloplegia falls significantly in hyperopic eyes and does not change in myopic ones. The latter fact points to insufficient tension of Zinn ligaments in the myopic eye. Regular badminton practice results in significant changes in wavefront aberrations, indicating a strengthening of the ligaments of the lens and the normalization of the ciliary muscle tone. **Conclusions.** The structure of the wavefront in children with different refractions shows significant differences. Badminton helps strengthen the ligaments of the lens.*

Keywords: myopia, aberrations, badminton.

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In recent decades, the incidence of myopia is steadily growing, claiming 30 to 40% of young people in Russia, USA, and Europe, and 70 to 96% in South-East Asia [1–5].

According to the data of Aron Dashevsky, children aged 4 to 7 years must normally have hyperopic refraction (ca 1.0 D) [6]. Regretfully, increasing visual work, the computerization of all life aspects of modern children, increasing requirements of new programs at school, reduction of physical exercise and physical inactivity bring about early emmetropization occurring at the age of 4–6 ears and the onset of myopia of schoolchildren. In recent years, the development of acquired myopia tends to be explained, more and more often, by insufficient physical activity, especially open air activity. To minimize the pathogenic impact of adverse environmental factors, sports activities are recommended.

Badminton is an ideal sport that harmoniously combines tracing a moving object (accommodation training), head and torso turns (hemodynamics strengthening), deep breathing (blood oxygenation).

According to modern views, not only hereditary predisposition but also environmental factors, and above all, optical errors in the formation of a retinal image, play a significant role in the development of acquired myopia. It has been shown by experiments that both the central and the peripheral hyperopic defocus stimulate eye growth and myopization of refraction. In its turn, image focusing on the retina is determined by the accuracy (adequacy) and stability of the accommodation response, as well as by aberrations of the wavefront of the eye. These aberrations are closely related with the accommodation and the peripheral refraction. On the one hand, the aberrations determine the quality of the retinal image and stimulate its focusing. As is known, the negative spherical aberration (SA) and the coma stimulate the accommodation response; in its turn, the accommodation stress increases the negative SA [8, 9].

On the other hand, the high level of aberrations, in particular, of the positive Sa, increases the depth of the focus area, facilitates near visual work without accommodation participation (the so-called pseud-accommodation) and may reduce the accommodation response, which leads to an accommodation lag and the formation of hyperopic defocus on the retina.

M. Collins и C. Wildsoet [10] suggested that individual aberrations, such as SA, may violate the emmetropization process. They believed that the negative SA induces the myopic eye growth while the positive SA slows it down. A number of papers report high values of the 4th, 5th and higher order aberrations (HOA) in myopic subjects as compared to emmetropes [11]. The eyes that revealed rapid myopia progression showed a higher level of both total HOAs and root mean square of the ideal wavefront, and 3rd order aberrations and the coma than the eyes with slow myopia progression [12–15].

SA change in myopia is associated with the lens change during eye growth [16, 17]. A higher level of aberrations reducing the quality of the retinal image may play a role in myopia development [13, 18, 19].

Contrariwise, certain studies report a lower level of 4th order aberrations [10], SA [20–22], 3th and higher-order aberrations [20, 23, 24] in myopi eyes as compared to emmetropic ones. Yet other studies do not see differences in wavefront parameters in different refraction groups [25–28].

Under natural conditions, there exists a physiological tone of accommodation, which is enabled by the balance of sympathetic and parasympathetic innervation [29]. Mainly due to this tone, the internal optics of the eye tends to for corneal aberrations, which leads to a decrease in total (ophthalmic) HOAs and an improvement in the retinal image. In children and young people with myopia and hyperopia, the total HOAs are lower than the retinal ones [30, 31].

Wavefront changes are revealed under cycloplegia as compared to non-cycloplegic conditions [32].

Of special interest is the result of comparison of wavefront aberrations and their changes occurring under cycloplegia in myopic and hyperopic eyes. According to our previous data, the level of tilt1, horizontal trefoil and vertical coma aberrations under natural conditions with the pupil width of 3 mm are significantly higher in myopia than in hyperopia, whilst their changes in response to cycloplegia are substantially lower or completely absent. We believe that these features can be associated with the state of the ligamentous apparatus of the lens and the ciliary muscle. An increased level of aberrations associated with the tilt of the lens, its shift, decentration of the optical elements of the eye may be an evidence of a weak ligament tension (possibly associated with the excessive tone of the ciliary muscle). This is also confirmed in cycloplegia: changes in the tone of the ciliary muscle, the tension of the Zinn ligaments and the position of the lens in myopia are insufficient for significant changes in the wavefront [33].

In addition to the accommodation and the central defocus, aberrations play an important role in the formation of the peripheral retinal defocus. A number of studies report that the positive SA contributes to the formation of relative peripheral myopia, while the negative SA is instrumental in the onset of hyperopia. Both the experimental and the clinical observations clearly indicate the inhibitory effect of myopic defocus on the process of myopia progression [34].

The above facts explain an increasing interest to eye wavefront studies which is noted in the literature in recent years. The role of aberrations in postnatal refractogenesis appears to be indisputable but the results of numerous studies are ambiguous. The association of the total level of aberrations with the refraction, myopia progression and accommodation lag is confirmed in some papers but unconfirmed in others.

The **PURPOSE** of this work was a comparative analysis of the level of aberrations, the structure of the wavefront, its response to cycloplegia in children with various refractions before they started practicing badminton regularly and after a year's duration of this practice.

MATERIAL AND METHODS

40 children (80 eyes) aged 7 to 11 years (average 9.24 ± 1.06 years) with refractive errors from +6.63 to -6.75 D (average -1.28 ± 2.28 D) were examined. Of these, 34 chidlren (67 eyes) were myopic: 26 children (51 eyes) had low myopia, 6 children (12 eyes) with moderate myopia and 2 children (4 eyes) with high myopia. The remaining 13 eyes belonging to 7 children were hyperopic or emmetropic. From the total cohort of patients, a group with spasm and habitually excessive accommodation strain (HEAS) was isolated that counted 11 children (20 eyes), of which 7 eyes of 4 children were myopic, 6 eyes of 3 children were hyperopic and 7 eyes of 4 children were emmetropic.

6 months after badminton practice start, 38 children (76 eyes) were examined, and after 1 year of regular badminton playing 27 children (54 eyes) aged 8 to 12 (average 9.42 ± 1.10 years) with various refraction levels (averagely -1.62 ± 1.81 D) underwent through examination. Of the 54 eyes, 46 eyes belonging to 23 children were myopic: 37 eyes of 19 children had low myopia, 7 eyes of 4 children had moderate myopia, and 2 eyes of 1 child had high myopia. Again, in the total cohort of patients, a group of 7 children (14 eyes) with spasm and HEAS was identified: 3 children (6 eyes) were myopic, 2 children (4 eyes) were hyperopic and 2 children (4 eyes) were emmetropic.

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

Badminton was practiced according to the technique proposed by Valery Turmanidze [35].

RESULTS AND DISCUSSION

As is seen from the analysis of the tables 1–4, the following aberrations show statistically significant differences in myopia and hyperopia: SA, tilt 1, tilt 2, trefoil 9, and coma 7 are higher in myopia than in hyperopia, whilst coma 8 is 10 times lower. SA has negative values in myopia and positive values in hyperopia.

The response to cycloplegia is very specific, too. Both in myopia and hyperopia, SA showed a shift towards positive values: in the first case, the negative SA showed a 2-fold reduction while in the second case the positive SA increased.

In spasm and HEAS, the positive SA showed a 5-fold (!) increase. These changes fall within the changes of lens shape under cycloplegia: the lens is flattening and the refractive power of the central region is decreasing (table 2).

The waverfron slope (tilt 1, tilt 2) in hyperopic eyes under cycloplegia decreased (tilt 2 showed a 25-fold decrease!) while in myopic eyes it showed a statistically insignificant (1.5-fold) reduction or even an increase. Trefoil 9 showed a 5-fold increase in hyperopia under cycloplegia and remained unchanged in myopia (tables 1–3).

The above changes of the listed aberrations that occur in response to cycloplegia and are associated with the wavefront slope agree with those we reported earlier and are consistent with the proposed explanation [33]. The tension of the Zinn ligaments under cycloplegic in hyperopic eyes is sufficient for the change in the shape and position of the lens but it is insufficient for myopia, which is obviously caused by weak ligamentous apparatus and/or habitually excessive tone of the ciliary muscle.

The changes of the waverfront in response to cycloplegia in eyes with HEAS and accommodation spasm were ambivalent. The spherical aberration and tilt 1 behaved in the same way as in the hyperopic eyes (which they indeed were, on average): namely, the former increased 5 times toward the positive values (conforming to lens flattening) and the letter was decreasing (tables 1, 2).

Tilt 2, trefoil 6, trefoil 9 showed no significant changes in response to cycloplegia (tables 1–3).

Coma 7 in patients with HEAS and spasm had negative values as in hyperopia (in myopia the values were

Table 1. Wavefront structure in children with various refractions before and after badminton workouts: RMS and Tilt 1 ($M \pm \sigma$)

Refraction	RMS						Tilt 1					
	before		after 6 months		after 1 year		before		after 6 months		after 1 year	
	before cycloplegia	after cycloplegia	before cycloplegia	after cycloplegia	before cycloplegia	after cycloplegia	before cycloplegia	after cycloplegia	before cycloplegia	after cycloplegia	before cycloplegia	after cycloplegia
Averaging over the group n = 54	0.1788 ± 0.1000	0.19833 ± 0.10000	0.23178 ± 0.15000	0.19167 ± 0.09000	0.08621 ± 0.03000	0.08164 ± 0.03000	0.00839 ± 0.03000	0.0091 ± 0.0600	0.0125 ± 0.0600	0.0096 ± 0.0600	0.0146 ± 0.0600	0.0184 ± 0.0600
Myopia n = 46	0.1822 ± 0.1000	0.19545 ± 0.11000	0.22764 ± 0.15000	0.195 ± 0.090	0.08187 ± 0.03000	0.081 ± 0.030	0.011834 ± 0.060000*	0.0149 ± 0.0600*	0.0182 ± 0.0600*	0.0202 ± 0.0600*	0.0219 ± 0.0500*	0.0167 ± 0.0600*
Low myopia n = 37	0.1631 ± 0.0800	0.18343 ± 0.08000	0.22389 ± 0.17000	0.18257 ± 0.08000	0.08187 ± 0.03000	0.081 ± 0.020	0.0186 ± 0.0600*	0.0134 ± 0.0600*	0.015 ± 0.060*	0.0189 ± 0.0500*	0.0219 ± 0.0600*	0.0167 ± 0.0500*
Moderate myopia n = 7	0.2943 ± 0.1500	0.28857 ± 0.16000	0.25143 ± 0.08000	0.27143 ± 0.13000	0.079 ± 0.030	0.08333 ± 0.03000	0.03486 ± 0.05000*	0.0247 ± 0.0700*	0.0304 ± 0.0900*	0.0264 ± 0.0800*	0.0062 ± 0.0600*	0.0033 ± 0.0600*
High myopia n = 2	0.125 ± 0.050	0.08 ± 0.03	0.21 ± 0.10	0.145 ± 0.060	0.0465 ± 0.0100	0.066 ± 0.000	-0.044 ± 0.030	0.007 ± 0.010	0.032 ± 0.010*	0.021 ± 0.100*	0.015 ± 0.010*	0.0135 ± 0.0700*
Hyperopia and emmetropia n = 8	0.20 ± 0.08	0.25 ± 0.05	0.22 ± 0.03	0.23 ± 0.10	0.068 ± 0.020	0.0735 ± 0.0200	-0.0528 ± 0.040	-0.0423 ± 0.0600	-0.0383 ± 0.0400	-0.049 ± 0.060	-0.059 ± 0.040	-0.0428 ± 0.0700
Spasm and pseudomyopia n = 14	0.1613 ± 0.0900	0.18615 ± 0.05000	0.23 ± 0.14	0.14923 ± 0.05000	0.13 ± 0.04	0.08767 ± 0.02000	-0.0134 ± 0.0300	0.005 ± 0.040	-0.0069 ± 0.0500	-0.0169 ± 0.0300	0.019 ± 0.040	0.0427 ± 0.0600

Note. n — number of eyes; * — $p < 0.05$ — significant with respect to patients with hyperopia and emmetropia; ** — $p < 0.05$ — significant with respect to parameters before cycloplegia.

Table 2. Wavefront structure in children with various refractions before and after badminton workouts: Tilt 2 and spherical aberrations ($M \pm \sigma$)

Refraction	Tilt 2						SA					
	before		after 6 months		after 1 year		before		after 6 months		after 1 year	
	before cycloplegia	after cycloplegia	before cycloplegia	after cycloplegia	before cycloplegia	after cycloplegia	before cycloplegia	after cycloplegia	before cycloplegia	after cycloplegia	before cycloplegia	after cycloplegia
Averaging over the group n = 54	0.0306 ± 0.2900	0.0217 ± 0.2900	-0.0157 ± 0.0400	-0.0139 ± 0.0400	-0.015 ± 0.0500	-0.0269 ± 0.0400	-0.0198 ± 0.1400	-0.00926 ± 0.15000	0.003019 ± 0.010000	0.021981 ± 0.050000	0.002458 ± 0.040000	0.001071 ± 0.050000
Myopia n = 46	0.0383 ± 0.3200*	0.0263 ± 0.3200*	-0.0174 ± 0.0400	-0.0185 ± 0.0400*	-0.0209 ± 0.0500	-0.0172 ± 0.0400	-0.02545 ± 0.16000*	-0.01405 ± 0.16000*	0.00175 ± 0.01000	0.013977 ± 0.040000	-0.00253 ± 0.04000*	0.001333 ± 0.050000
Low myopia n = 37	-0.0031 ± 0.0400	-0.0169 ± 0.0400*	-0.0139 ± 0.0400	-0.0096 ± 0.0400	-0.0209 ± 0.0500	-0.0172 ± 0.0300	-0.0022 ± 0.0100*	0.0122 ± 0.0400	0.001857 ± 0.010000	0.013971 ± 0.050000	-0.00253 ± 0.04000*	0.001333 ± 0.050000
Moderate myopia n = 7	0.2703 ± 0.8000*	0.242 ± 0.820*	-0.0247 ± 0.0300	-0.0554 ± 0.0600	-0.0072 ± 0.0700	-0.0703 ± 0.0600	-0.14814 ± 0.40000*	-0.14914 ± 0.40000*	0.001571 ± 0.010000	0.018143 ± 0.020000	0.0182 ± 0.0400	-0.004 ± 0.040
High myopia n = 2	-0.0495 ± 0.0100	-0.0525 ± 0.0100	-0.0085 ± 0.0900	0.027 ± 0.020	-0.0465 ± 0.0400	-0.032 ± 0.030	-0.003 ± 0.010*	-0.0005 ± 0.0100*	0.0005 ± 0.0100	-0.0005 ± 0.0100	-0.0155 ± 0.0100	-0.037 ± 0.030
Hyperopia and emmetropia n = 8	-0.002 ±0.03	-0.0008 ±0.05**	-0.0028 ±0.02	-0.0002 ±0.04**	0.0115 ±0.04	0.0073 ±0.03**	0.00725 ±0.01	0.025 ±0.02**	0.0075 ±0.01	0.0445 ±0.04**	0.0035 ±0.01	0.01075 ±0.01**
Spasm and pseudomyopia n = 14	0.0049 ± 0.0400	0.0022 ± 0.0400	-0.0045 ± 0.0300	0.0067 ± 0.0300	-0.0003 ± 0.0500	-0.0110 ± 0.0300	0.004 ± 0.010	0.023077 ± 0.050000**	0.006385 ± 0.010000	0.060923 ± 0.090000**	0.0596 ± 0.0700	0.003333± 0.080000**

Note. n — number of eyes; * — $p < 0.05$ — significant with respect to patients with hyperopia and emmetropia; ** — $p < 0.05$ — significant with respect to parameters before cycloplegia

Table 3. Wavefront structure in children with various refractions before and after badminton workouts: Trefoil 6 and Trefoil 9 (M ± σ)

Refraction	Trefoil 6						Trefoil 9					
	before		after 6 months		after 1 year		before		after 6 months		after 1 year	
	before cycloplegia	after cycloplegia	before cycloplegia	after cycloplegia	before cycloplegia	after cycloplegia	before cycloplegia	after cycloplegia	before cycloplegia	after cycloplegia	before cycloplegia	after cycloplegia
Averaging over the group n = 54	-0.0274 ± 0.0500	-0.02376 ± 0.04000	-0.031 ± 0.060	-0.0118 ± 0.0400	-0.01813 ± 0.04000	-0.02093 ± 0.04000	0.023593 ± 0.260000	0.027963 ± 0.26000	-0.00407 ± 0.03000	-0.00419 ± 0.03000	-0.01167 ± 0.03000	0.002571 ± 0.030000
Myopia n=46	-0.0259 ± 0.0500	-0.0208 ± 0.0400	-0.02607 ± 0.05000	-0.01075 ± 0.04000	-0.01753 ± 0.04000	-0.023 ± 0.040	0.034205± 0.280000	0.038909 ± 0.280000	0.000864± 0.030000	-0.00132 ± 0.03000	-0.00187 ± 0.03000	0.005333 ± 0.030000
Low myopia n = 37	-0.0323 ± 0.0500	-0.02437 ± 0.04000	-0.03071 ± 0.05000	-0.01651 ± 0.04000	-0.01753 ± 0.04000	-0.023 ± 0.040	-0.01023 ± 0.03000	-0.00083 ± 0.03000*	-0.00177 ± 0.03000	-0.00077 ± 0.02000*	-0.00187 ± 0.03000	0.005333 ± 0.030000*
Moderate myopia n = 7	-0.0039 ±0.05	-0.00957 ±0.06	-0.00814 ±0.05	0.022143 ±0.03	-0.0086 ±0.05	0.000333 ±0.04	0.258571 ±0.7	0.251143 ±0.71*	-0.00014 ±0.02	0.000714 ±0.06*	-0.0256 ±0.04	0.006667 ±0.05*
High myopia n = 2	0.0085± 0.0100	0.0025 ± 0.0100*	-0.0075 ± 0.0400	-0.025 ± 0.0100	-0.009 ± 0.020	0.0015 ± 0.0600	0.0265 ± 0.0400	-0.0085 ± 0.0100	0.0505 ± 0.0200*	-0.018 ± 0.020	-0.0065 ± 0.0100	-0.0055 ± 0.0300
Hyperopia and Emmetropia n = 8	-0.0353 ± 0.0100	-0.04025 ± 0.04000	-0.03725 ± 0.02000	-0.0345 ± 0.0002	-0.036 ± 0.030	-0.04675 ± 0.02000	-0.00875 ± 0.04000	-0.04025 ± 0.05000	-0.0175 ± 0.0300	-0.01275 ± 0.01000	-0.0145 ± 0.0300	-0.0145 ± 0.0400
Spasm and pseudomyopia n = 14	-0.0236 ± 0.0400	-0.03154 ± 0.04000	-0.03469 ± 0.07000	-0.00538 ± 0.03000	-0.00467 ± 0.04000	-0.003 ± 0.050	-0.01769 ± 0.04000	-0.00292 ± 0.04000	-0.01646 ± 0.04000	-0.00492 ± 0.03000	-0.0347 ± 0.0400	0.002667 ± 0.030000

Note. n — number of eyes; * — $p < 0.05$ — significant with respect to patients with hyperopia and emmetropia; ** — $p < 0.05$ — significant with respect to parameters before cycloplegia.

Table 4. Wavefront structure in children with various refractions before and after badminton workouts: Coma 7 and Coma 8 (M ± σ)

Refraction	Coma 7						Coma 8					
	before		after 6 months		after 1 year		before		after 6 months		after 1 year	
	before cycloplegia	after cycloplegia	before cycloplegia	after cycloplegia	before cycloplegia	after cycloplegia	before cycloplegia	after cycloplegia	before cycloplegia	after cycloplegia	before cycloplegia	after cycloplegia
Averaging over the group n = 54	0.001407 ± 0.020000	0.002963± 0.020000	0.005481 ± 0.020000	0.006389 ± 0.030000	0.005792± 0.020000	0.008214± 0.020000	-0.00015 ± 0.02000	-0.0022 ± 0.0300	-0.00481 ± 0.01000	-0.00256 ± 0.01000	-0.00329 ± 0.02000	-0.00793 ± 0.01000
Myopia n = 46	0.004023 ± 0.020000*	0.004545± 0.020000*	0.006977 ± 0.020000*	0.009795 ± 0.030000*	0.008533± 0.020000*	0.007556 ± 0.020000*	0.000205 ± 0.030000	-0.00236 ± 0.03000	-0.0052 ± 0.0100	-0.00348 ± 0.01000*	-0.005 ± 0.020	-0.005 ± 0.010
Low myopia n = 37	0.004343 ± 0.010000*	0.004457± 0.020000*	0.006657 ± 0.010000*	0.0064 ± 0.0200*	0.008533± 0.020000*	0.007556± 0.020000*	-0.0018 ± 0.0100	-0.00509 ± 0.01000	-0.00429 ± 0.01000	-0.00197 ± 0.01000	-0.005 ± 0.010	-0.005 ± 0.010
Moderate myopia n = 7	0.007714 ± 0.020000*	0.004857± 0.020000*	0.007571 ± 0.030000*	0.027143 ± 0.070000*	0.0018 ± 0.0100*	0.001 ± 0.020*	0.014714± 0.060000*	0.008714 ± 0.070000*	-0.00714 ± 0.01000	-0.00843 ± 0.01000	-0.0004 ± 0.0200	-0.02133 ± 0.03000
High myopia n = 2	-0.0145 ± 0.0100	0.005 ± 0.000*	0.0105 ± 0.0100*	0.0085 ± 0.0300*	0.007 ± 0.000*	0.007 ± 0.020*	-0.0155 ± 0.0100	0.0065 ± 0.0100	-0.0145 ± 0.0300	-0.0125 ± 0.0100	-0.0035 ± 0.0200	-0.008 ± 0.010
Hyperopia and emmetropia n = 8	-0.0185 ± 0.0100	-0.0145 ± 0.0200	-0.01325 ± 0.02000	-0.014 ± 0.020	-0.02 ± 0.02	-0.01025 ± 0.02000	-0.00225 ± 0.01000	-0.00375 ± 0.02000	-0.0015 ± 0.0100	0.00025 ± 0.01000	0.0045 ± 0.0100	0.00125 ± 0.01000
Spasm and pseudomyopia n = 14	-0.00369 ± 0.01000	0.002385± 0.010000	0.000308 ± 0.020000	-0.00185 ± 0.01000	0.008667± 0.010000	0.015 ± 0.020	0.001154± 0.010000	0.000231 ± 0.010000	-0.00108 ± 0.01000	0.001538 ± 0.010000	-0.00207 ± 0.02000	-0.00333 ± 0.01000

Note. n — number of eyes; * — $p < 0.05$ — significant with respect to patients with hyperopia and emmetropia; ** — $p < 0.05$ — significant with respect to parameters before cycloplegia.

positive); after cycloplegia, it increased 8 times and transferred to positive values. In all other groups, it remained unchanged (see table 4).

The values of Coma 8 in patients with HEAS were conform to those in hyperopia. After cycloplegia, these aberrations showed a more significant reduction than in other groups – they sank 4.5 times (in hyperopia there was a 1.5-fold decrease and in myopia, a 3.5-fold decrease), see table 4.

On the whole, it can be concluded that the wavefront structure of the eyes in HEAS and accommodation spasm corresponded to the true refraction of these eyes, i.e. to hyperopia. At the same time, the response of the wavefront to cycloplegia in these eyes differed from the response shown both by myopic and hyperopic eyes.

After regular badminton workouts, statistically significant changes of a number of eye wavefront aberrations were observed. The total aberrations (RMS) did not show a significant change but after a year they fell in all groups, which can be assessed as an increase in vision quality. In myopia, SA showed a 20-fold decrease and transferred to positive values, which means that it approached the state of hyperopic eyes. After a year, a 10-fold reduction of SA level against the initial values was still observable (see table 1).

Changes of tilt 1 were unstable and by the end of the year of workouts its values return to the initial ones. In myopia, Tilt 2 dropped 2.5 times after 6 months, and the values remained the same after a year. In hyperopia, Tilt 2 did not change after 6 months but after a year it showed a sharp increase with a transfer to positive values. In HEAS and spasm, Tilt 2 decreased by the end of the year but the response to cycloplegia was paradoxical: it showed a 25-fold increase (see tables 1, 2).

Trefoil 6 did not change after a year of practice in hyperopia but it showed a 1.7-fold decrease in myopia, which was accompanied by the emergence of a response to cycloplegia (the indicator dropped 2 times after cycloplegia). An even more pronounced response to cycloplegia was observed after 6 months in the groups of HEAS and spasm: trefoil 6 dropped 5 times. After a year, the level of this aberration dropped 4.5 times as compared to the initial value (see table 3).

Trefoil 9 reduced 12 times in myopic patients after 6 months and developed a previously absent response to cycloplegia. The changes persisted after a year. In spasm and HEAS, these aberrations increased during the year but developed a response to cycloplegia similar to that in myopia: a 5-fold increase with the transfer from negative to positive values was observed (see table 3).

No statistically significant changes of Coma 7 under natural conditions were observed after 6 months in any group. Only in HEAS and spasm, a response to cycloplegia was observed, which consisted in a 6-fold increase of Coma 7 with positive values transferring to negative ones. After a year, Coma 7 values increased 3 times in this group with respect to the initial values. In hyperopia, no changes were observed either before or after cycloplegia (see table 4).

Coma 8 values showed an even higher reduction after a year in patients with myopia, HEAS and spasm, demonstrating the transfer to negative values; no response to cycloplegia was present. In hyperopic eyes, the changes of Coma 8 aberrations were opposite: their level showed an even higher increase, with a transfer to positive values, and the response to cycloplegia was pronounced: it showed a 3.5-fold decrease (see table 4).

It can thus be concluded that after regular badminton practice, the eyes with myopia, HEAS or spasm showed statistically significant changes of wavefront aberrations, which can be associated with the strengthening of the ligamentous apparatus of the lens and the normalization of ciliary muscle tone. First of all, the changes consisted in a shift of spherical aberrations from negative values (when the center of the optical system shows a more powerful refraction than the periphery) to positive values (the periphery refracts stronger than the center. Such an effect is an undeniable evidence of lens flattening, which, in its turn, is associated with the elimination of the hypertone of the ciliary muscle and with increased tension of Zinn ligaments.

A reduction of the wavefront slope (Tilt 2), vertical and horizontal trefoil and horizontal coma (coma 8), i.e. the aberrations associated with the mismatch and irregularity of the elements of the optical system can also be attributed to the strengthening of the ligamentous apparatus of the lens.

The appearance of a previously absent response to cycloplegia, namely wavefront changes in Zinn ligaments under the influence of cycloplegic agents is an even clearer indication of this fact (see table 2–4).

CONCLUSIONS

The structure of the wavefront in children with various refractions shows a statistically significant difference. In particular, SA is negative in myopia anf positive in hyperopia; Tilt 1, Tilt 2, Trefoil 9, Coma 7 in myopia is significantly higher and Coma 8 is significantly lower than in hyperopia.

The wavefront slope (Tilt 1, Tilt 2) under cycloplegia significantly decreases in hyperopic eyes and does not change in myopic ones. The latter indicates insufficient tension of Zinn ligaments.

After regular badminton workouts, statstically significant changes are revealed in wavefront aberrations, which is an evidence of the strengthening of the ligamentous apparatus of the lens and the normalization of the tone of the ciliary muscle.

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