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Nutrition for Increased Adaptive Capacity, Better Sports Performance and Improved Quality of Life

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Abstract: The present study discusses foods for professional athletes since sports nutrition is the foundation of effective performance. A dietary supplement complex designed for ski orienteers, swimmers, road cyclists, and biathletes is described. The composition of the dietary supplement complex with directed influence on metabolic processes, intensity, and training load is given. All the ingredients for this complex are selected, taking into account their synergistic effect and safety. The manufacturing process, with its gentle process conditions like granulation at 40 °C, drying at 60 °C, and a relatively short manufacturing time, ensures the safety of biologically active ingredients and their functional properties. The manufacturing company is the International Organization for Standardization (ISO) certified and meets the General Manufacturing Practice (GMP) requirements. The clinical trials were undertaken to evaluate the efficacy of the dietary supplement complex. The findings indicate increased adaptation to training, enhanced recovery, and balanced emotional state. The benefits of adding the dietary supplement complex to eating plans of sportsmen are listed.

Keywords: sports nutrition; dietary supplement; efficacy; functional properties; safety

1. Introduction

Sports nutrition is considered to be the foundation of the effective performance for mass sport, recreational sport, and high-performance sport, and thus, the market share for sports nutrition supplements is constantly increasing. Recent research findings [1–5] support the theoretical framework for sports nutrition developed by A.A. Pokrovskii, a prominent Russian academician, who highlighted the following important points:

1. Sportsmen need to have their energy supplies replenished.
2. General guidelines for well-balanced nutrition are to be followed, i.e., a nutrition plan has to be built up taking into account the type of sport and exercise intensity, as well as the macronutrient distribution. Therefore, the following variables should be considered: main competition phases (preparatory, pre-competition, competition, and transition); amino acid composition of protein foods consumed; fatty acid balance for proper lipid metabolism; optimal intake of micronutrients.

3. Foods and food combinations should be selected with extra care for periods of more intensive activity such as pre-competition, competition, and transition phases.
4. Nutrients are used to induce aerobic oxidation, along with the phosphorylation, coenzyme biosynthesis, accumulation of myoglobin, and other metabolic processes vital for successful performance in sport.
5. A favourable metabolic background for the biosynthesis of humoral regulators (catechins, prostaglandins, corticosteroids, etc.) should be created.
6. Nutritional factors can be used to stimulate muscle growth and increase strength.
7. Nutritional factors can help lose weight to classify for a particular weight category.
8. Meal plans should match the training plan.
9. When designing diet plans, several individual characteristics have to be considered: the type of sport, training load, physique, metabolism, lifestyles, vitamin and mineral needs, personal taste preferences and allergies, to ensure good health and excellent performance.

Functional foods included in nutrition plans of professional athletes have a positive effect on health, enhance performance, reduce the risk of injuries, and enhance recovery. A contemporary sports nutrition supplement is an outcome of extensive research in genomics, metabolomics, bionanotechnology, and medicine, along with the thoughtful application of science-intensive technologies [2,5–14].

Nutrition is crucial for successful sports performance since it enables directed influence on metabolic processes, taking into account differences in intensity levels of physical activities, as well as age, gender, and skills of amateur and professional athletes. Balanced nutrition is particularly important for competitive athletes as it helps to deal with long-duration training sessions and combat nerves before and during competitions [12,15–19].

For the present study, we focused on examining raw materials and manufacturing samples of the dietary supplement complex for ski orienteers, swimmers, road cyclists, and biathletes.

2. Materials and Methods

2.1. Dietary Supplement for Ski Orienteers

Formula 1

The ingredients for the dietary supplement were selected for their synergistic effect and safety to ensure increased endurance in cyclic sports. The ingredients of formula 1 were chosen to ensure the desired amount of ascorbic acid, retinol, and iron. The list of Formula 1 ingredients is presented in Table 1.

Formula 2

Formula 2 was designed to increase the efficiency and strengthen the functional properties of Formula 1. This supplement is a purified granular concentrate of lecithin, which is produced from soybean oil and contains at least 93.4% of such biologically active components as polyunsaturated fatty acids and phospholipids.

Formula 3

The ingredients used for this formula were selected for their functional characteristics. They assist in reducing fatigue and tackling the recovery issues since the quality and the speed of the recovery is crucial to high-performing athletes. Each tablet of this supplement includes ascorbic acid—33.3 mg; vitamin E—4.2 mg; beta-carotene—2.1 mg; dry water-soluble extract of Motherwort—25 mg; Paullinia Cupana—16.5 mg; Ginkgo Biloba—15 mg; Hawthorn—15 mg; L-carnitine—5 mg; DNase—4 mg; lecithin—25 mg, bioflavonoids in terms of luteolin-7-glucoside—150 mg; iron—5.5 mg; copper—0.38 mg; zinc—4.2 mg; manganese—1.1 mg; cobalt—3.5 mg. We employed Formula 3 as a supplementary aid to ensure the proper functioning of the nervous system.

Table 1. Formula 1 ingredients.

Ingredients	Content (mg), Per 1 Tablet
Manganese Sulphate	3
Biotin	0.025
Copper Citrate	1.4
Silver Sulphate	0.0235
Potassium Iodate	0.13
Silymarin (Milk Thistle Extract)	19
Ammonium Vanadate	0.045
Iron Pyrophosphate	35
Sodium Ascorbate	40
Sodium Molybdate	0.057
Coenzyme Q10	0.8
Sodium Metasilicate (Sodium Silicate Meta)	19
Bromelain	75
Quercetin	15
Beta-Carotene 20%	4.5
Calcium Pantothenate	2.5
Solyanka Hill (Dry Extract)	19.341
Cholecalciferol (100 IU/Mg)	1
Ginkgo Biloba (Dry Extract)	10
Cyanocobalamin	0.0015
Dihydroquercetin	2.5
Thiamine Mononitrate	0.75
Zinc Citrate Trihydrate	24
Papain	25
Chromium Picolinate	0.2
Hesperedin	10
Retinol Acetate (500 IU/Mg)	2.9
Sodium Selenite	0.077
Tocopherol Acetate	10
Rutin	15
Riboflavin	0.8
Nicotinamide	10
Pyridoxine Hydrochloride	1
Folic Acid	0.1

2.2. Dietary Supplement for Swimmers, Road Cyclists, and Biathletes

Formula 4

Each capsule of Formula 4 contains Yohimbe (bark extract)—5 mg, Ginger (root)—25 mg, ginseng (root)—18 mg, calamus (root)—18 mg, ginkgo biloba extract—15 mg, starch—15 mg, maral root (leuzea)—18 mg, zinc oxide—2.5 mg, tocopherol acetate 50% (vitamin E)—10 mg, and pantohematogen preparation—0.02 mg.

The ingredients were selected for their biochemical properties, pharmacological activity, and synergistic effect.

Formula 5

Formula 5 was aimed at improving metabolic processes. Therefore, the ingredients were selected to provide the given content of magnesium, zinc, and ascorbic acid (Table 2).

Table 2. Formula 5 ingredients.

Ingredients	Content (mg), Per 1 Tablet
Magnesium Oxide	331.7
Parsley Leaf	50
Reishi Mushroom	50
Hedysarum Extract	50
Kuril Tea Extract	25
Damiana Leaf	25
Lemongrass Extract	12.5
Zinc Citrate	8.05
L-Methionine	8
Sodium Ascorbate	14
Lycopene 10%	2.5

2.3. The Manufacturing Process

It is well-known that high-tech equipment and innovative technology are crucial for producing high-quality products. It is particularly true for dietary supplement manufacturing when the producers must ensure their products are safe, effective, and stable. The main stages of the manufacturing process of Formula 1 are presented in Figure 1.

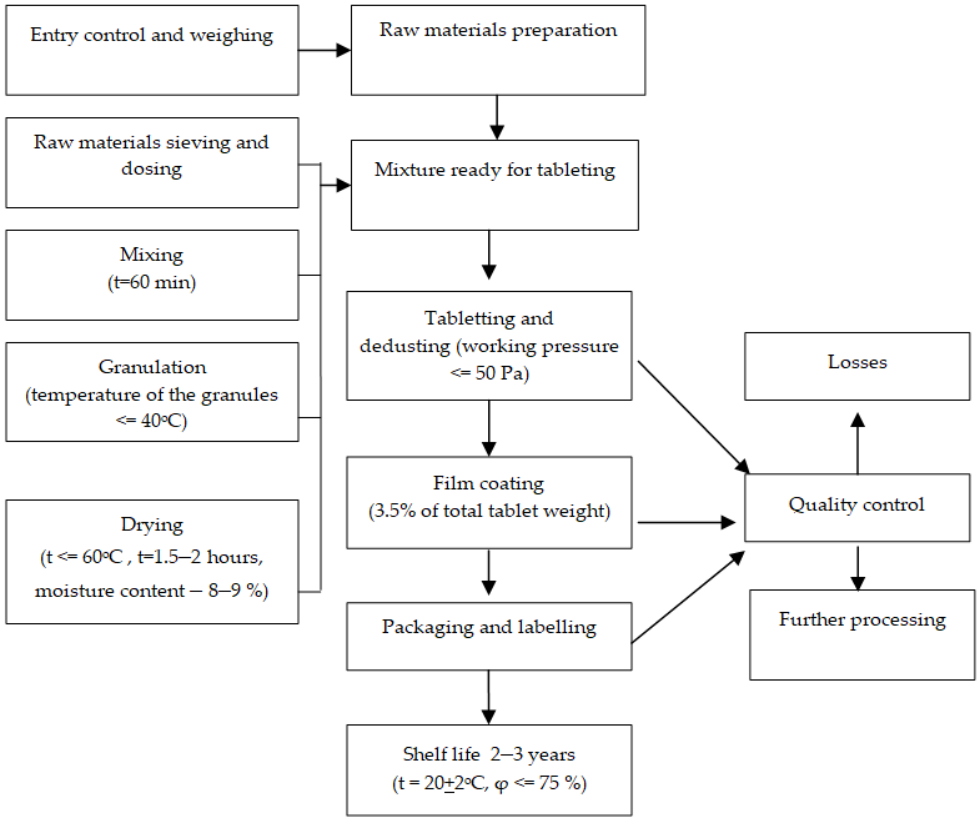

Figure 1. The manufacturing process.

2.3.1. Entry Control and Weighing

All raw materials were checked to ensure: (a) the marking on the packaging had clear and complete information on the date of manufacture and the name of the raw material; (b) the incoming quality and safety control complied with the specifications (certificates issued by an accredited laboratory); (c) the accompanying documents were marked with a green strip on the label (the statement of production admission).

2.3.2. Dosing

Before dosing, raw materials were packed and clearly labelled with the information on the expiry date, amount, and batch number.

2.3.3. Sieving and Mixing

Sieving was carried out with SGS-30 vibrating sieve. S-300 or S-50 V-shaped mixers were employed for complete and uniform blending. The mixing process lasted for 60 min with all the phases recorded. The ready mixture was put into a container, labelled, weighed, and registered. The quality of the mixture was checked by pressing the dry mixture with a pestle to ensure that the mixture was of smooth consistency and free of lumps or residues.

2.3.4. Granulation and Drying

Wet granulation was performed with MAKIZ 013-01 extruder press machine with a die hole diameter of 1 mm. To form granules, distilled water was added as the granulation fluid (25% of the weight of the dry mixture). The resulting wet granules had to be uniform, of the same colour, and the temperature of the granules did not exceed 40 °C. The drying process was carried out in S-105 drying cabinets at 60 °C and lasted for 1.5–2 h. The expected residual moisture of the granules was between 8 to 9%. Dry granulation was performed in Fitz Mill granulator; the quality control included assessing residual moisture, bulk density, fractional composition, and flow ability.

2.3.5. Tabletting and Dedusting

Tabletting was implemented in Kilian E 150 tablet press with the compression force of $\leq$50 kN. Every thirty minutes a weight uniformity test was performed, with the weight of twenty tablets compared. As tablets had to be strong enough for coating and transportation, the tensile strength was also essential. After pressing, random ten tablets were chosen for a detailed examination. Tablet appearance was checked for chips, discolouration, and smoothness. After checks, tablets were dedusted to prepare them for coating and stored in clearly labelled containers with information about the product name, quantity, batch number, production date, and the operator's signature.

2.3.6. Film Coating

Enteric coating, applied by Accelocota-150 or Accelocota-350 coating systems, was used to prevent the tablets from dissolving and target the action. Enteric coating accounted for 3.5% of the total tablet weight.

2.3.7. Quality Control

To meet the strict guidelines and deliver the best possible product, tablets were thoroughly examined before packaging. Any batch which did not possess the desired characteristics was withdrawn and stored for further processing in accordance with the guidelines on 'Managing manufacturing defects'.

2.3.8. Packaging and Labelling

At this stage, tablets were packed into plastic jars of various volumes by an automatic filler machine and labelled.

Samples of finished products were examined for quality and compliance with the requirements following 42 month-long storage at relative humidity of 75% and temperature of 20 $\pm$ 2 °C. Organoleptic, physical, chemical, and microbiological parameters of the product meet the stated requirements. The nutritional value of the dietary supplement is presented in Table 3.

The manufacturing of Formulas 2–5 was similar to the manufacturing process of Formula 1. The manufacturing process and the ingredients were tested to guarantee the product quality and competitiveness in accordance with ISO 9001:2015, which provides the Quality Management Requirements (QMS) and concentrates on procedures essential for improving customer satisfaction and meeting regulatory needs, and ISO 22000:2018, which sets the requirements for organizations involved in food production, and provides details on maintaining the hygienic environment, planning operations, and withdrawal criteria to enforce food safety.

2.4. Effectiveness

Empirical testing was employed to evaluate the developed formulas, with the study conducted during training sessions.

Resting heart rate, maximum heart rate, heart rate reserve, and heart rate variability were recorded and analysed to measure training intensity and exercise tolerance. The Schiller Cardiovit AT-2 Plus was used for electrocardiography. The step-wise incremental

load test was performed using a Monark bicycle ergometer. To register the effectiveness of the adaptation processes, we applied Effex-2 computer method while monitoring training loads. Psychomotor activity was examined with the help of the tests, registering accuracy and stability of movements, time, and effort. The Spielberg and Khanin Anxiety Inventory, as well as Sopov Motivational State Scale, were performed to analyse individual characteristics. The Luscher Colour Scale was used to obtain additional data. Methods of variation statistics were applied to study quantitative characteristics, with Student's t-test used to obtain the statistical significance.

Table 3. The nutritional value of the dietary supplement.

Components	Content (mg), Per 1 Tablet
Folic Acid (B9)	0.1 (0.08–0.12)
Niacin (B3)	10 (8.5–11.5)
Riboflavin (B2)	0.9 (0.76–1.04)
Thiamine (B1)	0.75 (0.64–0.86)
Pyridoxine (B6)	1 (0.85–1.15)
Ascorbic Acid (C)	40 (35–45)
Cholecalciferol (D3)	0.0025 (0.0021–0.0028)
Tocopherol (E)	5 (4.2–5.7)
Pantothenic Acid (B5)	2.5 (2.1–2.8)
Retinol s(A)	0.53 (0.51–0.55)
Beta Carotene	0.87 (0.74–1.0)
Molybdenum, Mcg	22 (18–33)
Silicon	2.5 (2.1–2.8)
Silver, Mcg	15 (10–20)
Boron	1 (0.85–1.15)
Vanadium, Mcg	20 (15–25)
Iodine	0.075 (0.064–0.086)
Zinc	7.5 (6.4–8.6)
Iron	7.2 (6.8–7.6)
Manganese	1 (0.85–1.15)
Copper	0.5 (0.42–0.57)
Selenium	0.035 (0.029–0.04)
Chromium	0.025 (0.021–0.028)
Coenzyme Q10	0.8 (0.5–1)
Flavonolignans, in terms of Silibinin	5.0 (4.2–5.7)
Flavonol Glycosides	2.4 (2.1–2.8)
Hesperidin	10 (8.5–11.5)
Rutin	15 (12–17.5)
Quercetin	15 (12–17.5)
Proteolytic Activity, (FIP/G)	$\geq$3.0

2.4.1. Dietary Supplement for Ski Orienteers

A representative sample of ten professional ski orienteers included five nationally ranked sportsmen and five national champions. The nutrition plan with the dietary supplement was designed to assist the sportsmen in reaching their peak athletic potential as well as maintain it until the end of the season. The dosage of the dietary supplement was calculated according to medical history and training load. The effectiveness of the dietary supplement was evaluated by comparison with the loads performed by the athletes in the control group.

2.4.2. Dietary Supplement for Swimmers

A representative sample of eighteen professional swimmers was chosen to evaluate the functional properties and effectiveness of Formulas 4 and 5. The experimental group included ten sportsmen, while the control group consisted of eight sportsmen. The age range was 18.8 $\pm$ 1.6 years, weight—74.6 $\pm$ 5.7 kg; height—1.86 $\pm$ 0.08 m, total sports experience—10.8 $\pm$ 1.7 years. For a period of twenty days, the participants of the first

(main) group received Formula 4 and Formula 5 twice daily with breakfast and lunch, while the participants of the second (control) group did not. All the swimmers had similar nutrition plans and living conditions.

To assess the performance, the diagnostic computer complex 'ART-2' was used with breathing studied using cardiac monitors (Polar Accurex Plus, Beckman and Cortex).

Pulmonary ventilation, oxygen consumption, and heart rate were examined. The sportsmen performed rowing movements in the recorded tests: with increasing power (step test for 1 min 10 times); with competitive activity (1 min, T-1); with the maximum activity (10 strokes, T-10).

2.4.3. Dietary Supplement for Road Cyclists

Road cyclists engaged in the study were divided into two groups of eight. The first (main) group included sportsmen aged 16.4 ± 0.4 with total sports experience of 4.6 ± 0.3 years. The weight range was 66.3 ± 5.1 kg and height—1.78 ± 0.63 m. The second (control) group included eight sportsmen aged 15.5 ± 0.7, and their total sports experience amounted to 3.8 ± 1.1 years. The weight and the height were 55.7 ± 9.5 kg and 1.67 ± 0.11 m, respectively.

The participants of the first (main) group were administered 1 capsule of Formula 5 twice daily with breakfast and lunch for the twenty-day period. Both groups had similar eating plans, living conditions, and training loads and intensity.

2.4.4. Dietary Supplement for Biathletes

To assess the effectiveness of Formulas 3 and 5, two groups of biathletes were selected to participate in the trial. The first (main) group included ten biathletes with 10.2 ± 1.3 years of total sports experience. The age range was 22.4 ± 3.1 years, weight—69.3 ± 5.4 kg, and height—1.78 ± 0.03 m. The second (control) group included 8 participants with sports experience of 9.4 ± 1.7 years, aged 21.8 ± 3.2 years, 1.78 ± 0.05 m tall, and within the weight range of 69.8 ± 7.1 kg.

The participants of the first (main) group were administered 1 capsule of Formula 3 and 1 capsule of Formula 5 twice daily with breakfast and lunch for the twenty-day period. Both groups had similar eating plans, living conditions, and training loads and intensity.

3. Results

3.1. Ski Orienteers

As ski orienteering competitions are held on rugged terrain, sportsmen are required to have high physical endurance and strength. Professional ski orienteers usually demonstrate increased muscle metabolism, with highly oxidative fibres in their leg muscles and the deltoid muscle, and thus possess a better developed network of capillaries. This contributes to more active gas exchange and the transfer of nutrients from the blood to muscle cells, which ensures the efficiency of aerobic metabolism.

The findings of our study indicate that the use of the dietary supplement complex assisted in more than 30% cyclic load rise, since the average distance that ski orienteers covered during training sessions in January amounted to 478 km, and for the same period in February, the average distance increased and totalled at 623 km ($p < 0.05$). At the same time, an increase in high-intensity training with heart rate of more than 170 beats per minute was registered, from 16% in January to 33% in February (Figure 2).

Therefore, nutrition plans with the dietary supplement complex contribute to increased load and intensity training.

Based on the study, the recommended dosage was determined to be 1 tablet of Formula 1 daily and 1 teaspoon of Formula 2 twice daily for the period of twenty-five days.

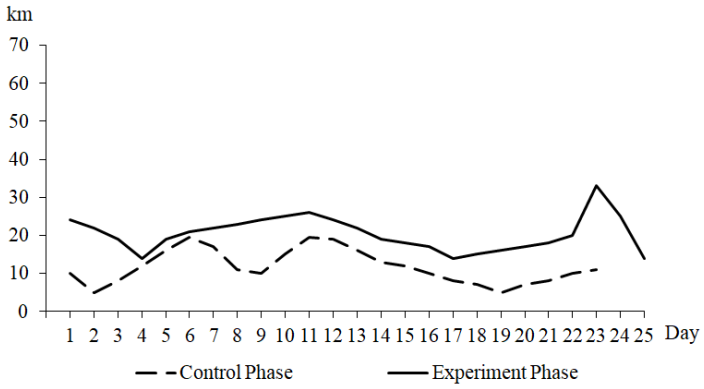

Figure 2. The dynamics of skiing load intensity.

3.2. Swimmers and Road Cyclists

All the participants underwent the same three-step stages: (a) thorough study of eating plans, (b) extensive testing before taking the dietary supplement complex, and (c) repeated testing after taking the dietary supplement complex.

The study of the eating plans revealed the imbalance, with animal proteins and fast digestible carbohydrates prevailing. The lack of starch (polysaccharide), animal-derived lipids, and vegetable oils, as well as an insufficient consumption of essential micronutrients, was recorded. During the winter season, Vitamin C intake amounted to 55% of the recommended dose, with 69% in spring. The deficiency of Vitamins A and D was also present, which is known to have an adverse effect on health and sports performance when training intensively.

The difference between competitive activity (T-1) and maximum activity (T-10) was tested. Having completed the course of diet therapy, the participants of the first (main) group demonstrated an increase in power from 171 $\pm$ 26.8 to 180.0 $\pm$ 31.9 W ($p < 0.05$). The power output for the participants of the second (the control) group changed from 148.3 $\pm$ 40.6 to 146.2 $\pm$ 28.1 W ($p > 0.05$).

The average cycle power (T-1) of the participants of the first group constituted to 134.8 $\pm$ 20.2 W before dietary supplement consumption and rose to 139.5 $\pm$ 23.3 W after ($p < 0.05$). In the control group, these indicators were 125.9 $\pm$ 17.7 and 127.2 $\pm$ 17.3 W, respectively ($p > 0.05$).

The biochemical changes are explained by the participation of methionine (which is a component of Formula 5) in the biosynthesis of creatine and protein in muscle tissue. It should be noted that the resynthesis of ATP by creatine phosphokinase plays a key role in the processes of energy supply of short-term muscle work during its maximum intensity. Moreover, no additional vitamin and mineral complexes are necessary, since the dietary supplement provides all the essential nutrients.

According to the step protocol of the stepwise incremental load test, the initial load was 75 W, with 6 increments of 37.5 W at intervals of 3 min. The load was further increased with the maximum pedalling frequency set for an increment every minute. A telemetric heart rate monitor (Polar Electro Accurex Plus) was used to obtain data on energy supply, while Beckman instrument system was applied to track external respiration. Besides, aerobic and anaerobic metabolic thresholds, as well as critical power and maximum oxygen consumption, were calculated. The participants of the first group demonstrated higher power of physical activity with an 8% rise of the anaerobic metabolic threshold ($p < 0.05$), and a consistent increase in heart rate to 170, 180, and 185 bpm.

3.3. Biathletes

The stepwise incremental load test was performed by increasing the treadmill incline every three minutes, from 72 $\pm$ 9 W to 402 $\pm$ 5.6 W.

The findings of the testing indicated that the intake of the dietary supplement complex led to an increase in oxygen consumption ($p < 0.05$), increasing training intensity with

the heart rates of 120, 170, 180, and 185 bpm. The findings of psychomotor tests revealed improved stability and accuracy by 3% and 9%, respectively, with an 8% enhancement of eye-hand coordination. At the same time, the data for the second (control) group demonstrated a 2% decrease in the accuracy of power regulation along with a 3.5% decline of eye-hand coordination, whereas the spatial parameters increased by 4%. Therefore, Formula 3 demonstrated antioxidant activity and helped ensure the proper functioning of the nervous system.

4. Discussion

Our research revealed positive changes in energy levels, performance, and recovery after exercise. Considering the study findings, we identified the following benefits of adding dietary supplements to eating plans (Figure 3).

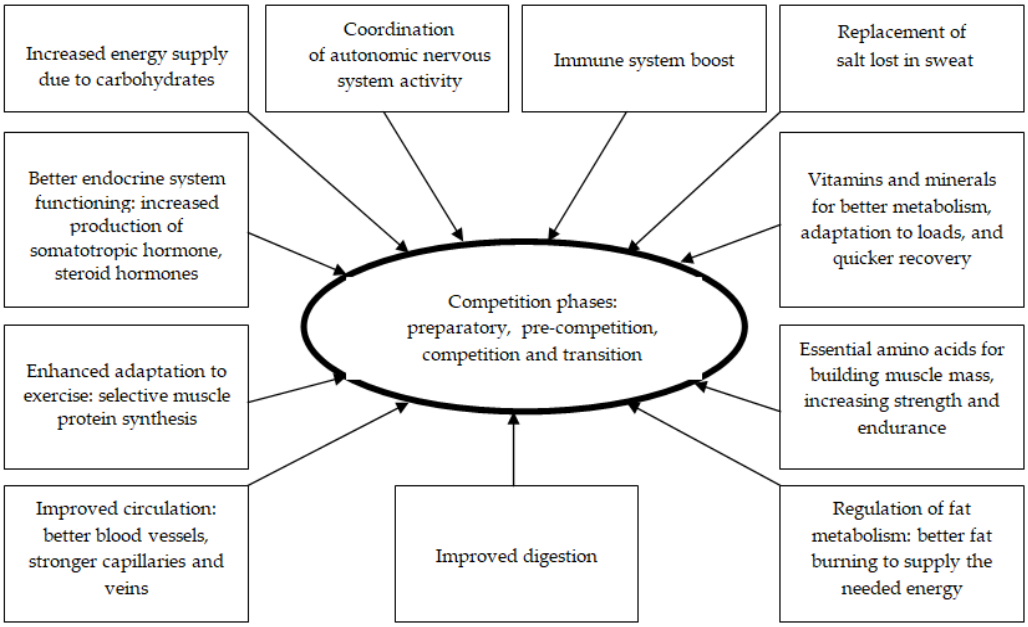

Figure 3. The benefits of adding dietary supplements to the eating plans of sportsmen.

Numerous chemical reactions that occur in protein, carbohydrate, lipid, energy, and electrolyte metabolism stimulate body's functional reserves and adaptive capacity, therefore nutritional support and individually designed eating plans are crucial for enhanced sporting performance. Dietary supplements assist in ensuring efficient metabolic processes and replenishment, with antioxidant qualities of Vitamin C, E, and Selenium being important for the improvement of metabolic processes.

5. Conclusions

The available research evidence, as well as our own studies, prove the importance of nutrition in enhancing sports performance and maintaining health. The formulas developed in the present study can be included in eating plans to provide additional nutritional support, which is necessary for sportsmen engaged in cyclic sports during their final stages of training. As the pre-competition stage involves mainly glycolytic and mixed loads, sportsmen experience the need for legal performance-enhancing substances to sustain their nervous, immune, and cardiovascular systems.

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Conflicts of Interest: The authors declare no conflict of interest.

Sample Availability: Samples of the compounds are not available from the authors.

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