A FOUR-YEAR CYCLE COMPARISON OF THE NUTRITIONAL AND CARDIOVASCULAR HEALTH STATUS OF AN ELITE-LEVEL FEMALE ARTISTIC GYMNAST: CASE STUDY REPORT FROM SLOVENIA

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Abstract

Regular monitoring of body composition, nutrition, health, and motor skills are crucial for further training process planning and performance progress. With the same protocol and methods, we evaluated a four-year change (2018 vs. 2022) in the nutritional and cardiovascular health status of the currently most successful elite-level adult female artistic gymnast in Slovenia. Detailed body composition and dietary intake were assessed using dual-energy X-ray absorptiometry and a standardized food questionnaire FFQ. The blood lipids and safety factors, blood pressure, and serum micronutrients (e.g., B_{12}, 25-hydroxyvitamin D (25(OH)D), potassium, calcium, phosphorus, magnesium, and iron) status were measured. The four-year comparison showed an improved body composition status: decreased body fat mass/percentage, android fat percentage, and android/gynoid ratio, while other anthropometrical and body composition parameters remained essentially unchanged. We also measured an improvement of some and worsening of other cardiovascular health serum variables (i.e., decreased total cholesterol but increased low-density lipoprotein cholesterol and S-glucose), most likely due to the differences in assessed dietary intake (i.e., lower total fat, mono- and polyunsaturated fatty acid intake but higher cholesterol intake and still high free sugar and saturated fat intake, despite higher fiber). Notably, nutrient intakes that are generally of concern (fiber (borderline low intake), eicosapentaenoic omega-3 fatty acids and docosahexaenoic omega-3 fatty acids, vitamin B_{12} and D, calcium (borderline low intake), iron, and zinc) were within recommended ranges. However, the athlete's vitamin E and potassium intakes were not adequate. Furthermore, in 2018, the athlete did not consume dietary supplements, while she now regularly uses several dietary supplements, including enriched plant-based protein powder, isolated vitamin B_{12}, C, D, and iron. Moreover, the athlete had significantly lower than recommended serum levels of 25(OH)D, probably due to insufficient regular intake of vitamin D in the form of a dietary supplement (1000 IU/d). Moreover, from the micronutrient serum, phosphorus, and iron levels that deviated from the reference values in the 2018 study, in the current study, they were found to be within referenced ranges (i.e., iron status was markedly improved). This kind of screening toolbox, using valid, sensitive, and affordable methods and with rapid organizational implementation, may be a viable format for regular monitoring.

Keywords: *elite-level athlete, female, artistic gymnast, body composition, bone mineral density, nutrition, micronutrients, 25-hydroxyvitamin D, cardiovascular health.*

INTRODUCTION

Tracking changes in athletes' training, health, nutrition, performance, and recovery enables coaches, athletes, and the scientific community to understand better how a specific sports strategy affects athletes (Lee et al., 2017; Thomas et al., 2016). Body composition and nutrition status play vital roles in monitoring the efficiency of physical adaptation to the training process and athletic performance, aimed at optimizing competitive performance potential (Ackland et al., 2012; Bacciotti et al., 2017; Dallas et al., 2017). Furthermore, nutrition is a key determinant of the effectiveness of adaptive responses to a training process, recovery, and sports performance. Moreover, it has an important, if not crucial, role in health status (Malsagova et al., 2021; Thomas et al., 2016).

Although there is not yet sufficient recent data to provide robust profiles of optimal elite-level female artistic gymnasts' body composition features (Bacciotti et al., 2017; Visscher et al., 2012), it is known that success in high-level gymnastics compared with lower competitive levels is associated on average with smaller size, lower body mass (BM) and body fat percentage (BF %) (Bacciotti et al., 2017). Part of the reason that there is not yet a consensus regarding the desired ranges of anthropometric variables and body composition components are (i) outdated data for elite-level female artistic gymnasts, (ii) limitation in comparing body composition with different assessment technologies, (iii) the problem of proper interpretation of the measured body composition status in connection with the (sub)optimal energy and general nutritional deficiency among female artistic gymnasts, (iv) the problem with uncritical use of the terms "elite-level" and "high-performance level" (i.e., there is no consensus on who belongs to which category or the use is arbitrarily, even uncritically, left to researchers), and finally, (v) various recent changes in sport gymnastics (e.g., safer apparatus, changes in Code of Points in 2006, the individual decision to compete on only one or two apparatus) (Anderson & Petrie, 2012; Bacciotti et al., 2017; Dallas et al., 2017; Jakše, Jakše, Fidler Mis, et al., 2021; Visscher et al., 2012). Consequently, physical and motor requirements and dietary requirements for elite-level female artistic gymnasts depend on these modified factors and changed circumstances, for which more current data is required.

In addition, at the elite-level, the International Olympic Committee and National Olympic Committees/National Federations are also performing, requiring, or recommending careful cardiovascular (CV) screening to avoid silent fatal abnormalities not being detected (Ljungqvist et al., 2009). Regardless, experts recommend healthy/balanced nutrition (i.e., high intake of fruits, vegetables, whole grains, and legumes, and limited quantities of lean meat (including poultry and seafood), low-fat dairy products, and liquid vegetable oils) for CV disease prevention and treatment to all populations. These recommended dietary patterns are all low in trans-fatty acids and saturated fat (SFA), sodium, free sugars, and ultra-processed foods, including refined grains (Freeman et al., 2017; Tobias & Hall, 2021).

The present case study aims to compare the investigated nutritional (i.e., anthropometric and body composition, dietary intake, and serum micronutrients measures) and CV health and safety status of an elite-level adult female artistic gymnast (very experienced in terms of competitive sports) from Slovenia with her data from the study published in 2018 (four-year period) (Jakse et al., 2019; Jakše, Jakše, Čuk, et al., 2021; Jakše, Jakše, Fidler Mis, et al., 2021). We chose the case study because only one truly elite-level female artistic gymnast from Slovenia is currently competing; therefore, the resulting changes will not be masked by the majority of female artistic gymnasts competing at a lower (e.g., high-performance) level.

METHODS

The study design, the protocol, the methods, and the ethical aspect of the 2018 study were reviewed and approved by the Slovenian Medical Ethics Committee (approval document no. 0120-177/2018). Therefore, another ethical evaluation for an identical study was not necessary. Regardless, the athlete re-signed an informed consent form for inclusion in the study before the current study was conducted. In addition, the athlete was not remunerated financially for participation in the study. However, we promised her feedback on the obtained comparative results. All the assessments in the study were funded by the authors.

Furthermore, the current study was conducted on 14 April 2022 and executed at the same location (Medical Centre Dravlje d.o.o., Ljubljana, Slovenia), using the same protocol and methods (and carried out by the same experienced physician) as the study completed in April 2018, the published data of which we used for our comparison (Jakse et al., 2019; Jakše, Jakše, Čuk, et al., 2021; Jakše, Jakše, Fidler Mis, et al., 2021). The athlete completed an online questionnaire sent to her one day before other measurements were taken (i.e., blood sample draw (i.e., 15 mL of blood for a complete biochemical assays); anthropometric and body composition measures). A blood assay was collected, and measurements were assessed after an overnight fast.

The athlete was repeatedly recruited through personal contacts. The artistic gymnast has recently made significant progress in terms of results, so we agreed to repeat the study due to our mutual interests. The studied elite-level adult athlete (age 28.9 years) was a member of the Slovenian female national artistic gymnast team and was competing in the international quality class (i.e., World Cups, European Championship, and World Championship). At the time of the study, the gymnast was ranked the highest among all national team members (FIG, 2022).

The main variables included detailed characteristics of the athlete's nutritional and CV health status. The results in the current study were compared with the obtained results from the study completed in 2018 and published (Jakse et al., 2019; Jakše, Jakše, Čuk, et al., 2021; Jakše, Jakše, Fidler Mis, et al., 2021). In addition, we will also add the results of the best elite-level artistic gymnast (AG-2) from our first study on the same apparatus (i.e., vault) (Jakse et al., 2019; Jakše, Jakše, Čuk, et al., 2021; Jakše, Jakše, Fidler Mis, et al., 2021), which we could not analyze this time due to the subject's pregnancy. Furthermore, comparable anthropometric and body composition variables of elite-level artistic gymnasts (AG-3) published by Greek researchers will be compared with our results in the same table (Dallas et al., 2016). Where body composition variables were reported as a range of measurements one week apart (i.e., BM and BF %), we took the average of the two for clarity reasons.

The detailed characteristics of the artistic gymnast (i.e., age, education, training status, and type of dietary pattern) were evaluated with the questionnaire; however, these variables were part of a standardized food frequency questionnaire (FFQ) (De Keyzer et al., 2013). In addition, the preferred competitive discipline (obtained from the athlete) and quantitative competitive level (ranking in important international competitions) are publicly available information provided by the Federation International De Gymnastique (FIG) (FIG, 2022).

The anthropometric and body composition indices included: body height (BH); BM, body mass index (BMI); BF %, android (A) and gynoid fat (G) distribution; A/G ratio; body fat mass (BFM); fat-free mass (FFM); lean soft tissue (LST); bone mineral content total (BMC total); bone mineral density total (BMD total), and BMD segmental (i.e., left femoral neck, left femur, legs, pelvis, spine, trunk, ribs, arms, and head)). (BM is the sum of BFM, LST, and BMC, while FFM is the sum of LST and BMC.)

Body height (cm) was measured using a standardized column scale (Seca 220, Seca Gmbh & Co., Hamburg, Germany), and BM (kg) was measured using a medically approved personal floor scale (Kern, MPS 200K100HM, Kern & Sohn, Balingen, Germany), whereas body composition was assessed using dual-energy X-ray absorptiometry (DEXA) (General Electric Company, model Lunar Prodigy 5, with EnCore software, version 13.31). Body mass index (kg/m²) was calculated from BH and BM. All the assessments were performed by a well-trained and experienced physician on the same DEXA model as in our study conducted in 2018 (Jakse et al., 2019; Jakše, Jakše, Čuk et al., 2021).

To assess the dietary habits of the athlete in the previous year, we used a manual technique and double-checked it to prevent potential errors: a 52-item qualitative FFQ based on a previously substantiated 50-item FFQ (De Keyzer et al., 2013) and validated on Dutch population for assessing food consumption with seven-day estimated diet records (Clarys et al., 2014). In addition, this FFQ has been used for athletes (i.e., elite-level/high-performance female swimmers and artistic gymnasts) (Jakše, Jakše, Fidler Mis, et al., 2021) and for healthy adults (Jakše, Jakše, Godnov, et al., 2021) in the Slovene population.

To evaluate dietary intake, we used the OPEN Platform for Clinical Nutrition (Korošec et al., 2013; OPKP, 2021), which is a web-based solution developed by the Jožef Stefan Institute in Slovenia. Food intake data from the FFQ were used to assess energy and nutrient intake and the frequency of food group consumption. However, it was impossible to estimate actual sodium, chloride, or iodine intake from food preparation methods (e.g., added (non) iodized salt) based on the FFQ alone, so these minerals and trace elements were shown only from the food sources as such. Importantly, FFQ does include minimally processed, processed, or ultra-processed products that include sodium (e.g., mayonnaise, butter, lard, ketchup, confectionery, canned beans, cheese, fries, commercial bread, and pastries) (Monteiro et al., 2019); however, the intake of these foods is usually lower in athletes compared with the general population. In addition, the FFQ included dietary supplementation and sports drink, specifically the name of the manufacturer, the amount of intake, and the frequency of consumption, thus capturing the athlete's actual dietary intake. Furthermore, we could also precisely distinguish free sugars from total sugar, and plant-based and animal-based protein from total protein intake by using the unique FFQ and OPEN system. Finally, folic acid from supplementation to folate conversion factor was used: 0.5 µg of folic acid = 1 µg of folate (Institute of Medicine, 1998).

Data regarding the dietary intake of the athlete was calculated, expressed as kcal/d (energy), in units/d (i.e., in g/d (macronutrients), except for dietary cholesterol (mg/d), water intake (L/d), and micronutrients (mg/d and µg/d)) and percentage of daily energy intake (macronutrients).

Finally, the intake of energy and nutrients intake of greater importance or concern (i.e., vitamin B_{12}, D, eicosapentaenoic omega-3 fatty acids (EPA) and docosahexaenoic omega-3 fatty acids (DHA), calcium, and iron) or nutrients that were consumed inadequately/in excess were compared with the reference values for energy and nutrient intake issued by the National Institute of Public Health of Slovenia (National institute of Public Health of Slovenia, 2020); values are summarized according to the recommendations of Central European (German (D), Austrian (A), and Swiss (CH) (D-A-CH)) reference values (DGE/ÖGE/SGE, 2018). Unfortunately, Slovenian recommendations do not mention the reference values for free sugar, saturated fatty acids (SFAs), poly- and monounsaturated fatty acids (PUFAs and MUFAs), cholesterol, EPA and DHA, and biotin intake; therefore, the athlete's free sugar intake was compared with the SACN recommendation (< 5% of daily energy intake) (Scientific Advisory Committee on Nutrition, 2015), SFA, PUFA, MUFA, cholesterol, and biotin intake was compared with the D-A-CH reference (DGE/ÖGE/SGE, 2018; Jungert et al., 2020, 2022), and EPA and DHA intake with the Dietary Reference Values of the European Food Safety Authority (EFSA, 2017). Additionally, water intake from solid foods, beverages, and supplementation (i.e., sports drinks and carbohydrate powder mixed with water) was evaluated. Total water intake was not compared with the guidelines since it depends on the sport, the type of exercise, and the environment (Thomas et al., 2016). Furthermore, the carbohydrates intake was compared with the joint position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine for nutrition and athletic performance (Thomas et al., 2016). The variable was not calculated in terms of energy availability (EA) due to our inability to estimate energy expenditure properly or obtain accurate information.

Frequently monitored serum micronutrients that are of concern among athletes were assessed and included in the analysis. The following were analyzed: vitamins B_{12} (S-vit B_{12}) and 25(OH)D), calcium (S-Ca), magnesium (S-Mg), phosphorus (S-P), and potassium (S-K), and trace element iron (S-Fe).

For the micronutrients, the abovementioned medical center used the same manufacturer and methodology as in our 2018 study (Jakse et al., 2019; Jakše, Jakše, Fidler Mis, et al., 2021). The obtained results from both studies were compared with the 2018 study and with the following references: for S-vit B_{12} with the reference value suggested to prevent neurocognitive disorders late in life (Wolters et al., 2004). For 25(OH)D status, three categories were used (i.e., sufficiency: > 75 nmol/L, insufficiency: 50 –75 nmol/L, and deficiency: < 50 nmol/L) (Holick, 2009). Reference concentrations of serum minerals and trace elements used are from the University Medical Centre Ljubljana, Slovenia, the national laboratory (University Medical Centre Ljubljana, 2018).

The assessed CV diseases risk factors, i.e., total cholesterol (S-cholesterol), high-density lipoprotein (HDL cholesterol), low-density lipoprotein (LDL cholesterol), and triglycerides were measured directly, as was blood pressure (BP). The safety markers in the blood analysis included uric acid (S-UA), fasting glucose (S-glucose), and hemoglobin. For biochemical analyses, we used the same protocol, manufacturer, and methodology as in our 2018 study (Jakše, Jakše, Fidler Mis, et al., 2021).

To assess cardiovascular health, the values obtained were compared with the recommended targets for cardiovascular disease prevention by the European Society of Cardiology (Visseren et al., 2021). For S-cholesterol and HDL cholesterol reference values, the reference values from the national laboratory, the University Medical Centre Ljubljana, Slovenia, were used (University Medical Centre Ljubljana, 2018). S-glucose recommendations from the European Diabetes Epidemiology Group for lean adults (BMI < 25 kg/m²) were used (Borch-Johnsen, 1999). For S-UA, a consensual threshold was used for all healthy subjects (Desideri et al., 2014). For hemoglobin, we used recommended cut-offs for a non-anemic state from the World Health Organization for non-pregnant females (> 120 g/L) (WHO, 2011).

The current study is a case study report of one elite-level adult athlete and compares the results obtained with the results for the same athlete from a study four years ago (Jakse et al., 2019; Jakše, Jakše, Čuk, et al., 2021; Jakše, Jakše, Fidler Mis, et al., 2021); therefore, only descriptive statistics are used to present the results.

RESULTS

The athlete started with gymnastics at the age of four and is currently competing on the vault and on the balance beam, and (if needed for the purpose of all-round competition) also on the floor and on the parallel bar. By far, she is the most successful on the vault. The ranking in important international competitions (FIG, 2022) is presented in Table 1.

Furthermore, during the studied (competitive) period, the athlete had on average 18–20 hours of training per week. In addition, the athlete reported to have regular menstrual status; however, she also reported extraordinary pain during the menstrual phase that lasted 7–10 days. However, the athlete continued the training process smoothly, even during the menstrual phase. In addition, it is essential to emphasize that the athlete maintained the same overall dietary pattern as in the 2018 study (i.e., an omnivorous diet).

Table 2 shows the changes in anthropometrical and body composition parameters. The athlete markedly changed some of her body composition variables in terms of decreased BFM (-1 kg (11%)), android fat (-3.7% (35%)), and A/G ratio (-0.12 (36%)). However, other anthropometrical and body composition parameters remained relatively unchanged

A comparison between the athlete's daily energy and nutrient intakes is presented in Table 3 and Table 4. The macronutrient composition of the food intake was 30% fat, 47% carbohydrate, 3% fiber, and 20% protein. The estimated carbohydrate intake of the athlete (4.3 g/kg BM/d) was within the recommended 3–5 g/kg BM/d guidelines for low intensity (skilled-based) physical activity (Thomas et al., 2016).

Furthermore, the obtained results showed that the athlete in this study, compared with the 2018 study, increased their carbohydrate intake and decreased the fat intake (i.e., total fat, SFA (% E), MUFA, and PUFA), increased EPA and DHA, cholesterol, and protein intake (i.e., from plant proteins (e.g., mostly due to plant-based protein dietary supplement) and also animal proteins (e.g., from milk, fish, chicken, and eggs)). In addition, the fiber intake markedly increased but was still not adequate (27 g/d vs. 30 g/d, as recommended). Significantly, in the current study, the athlete consumed adequate EPA and DHA (442 mg/d vs. 250 mg/d, set as reference) (EFSA, 2017), where the athlete’s EPA and DHA intake were all from food sources.

Micronutrients that are often of concern in the general population and among athletes, such as vitamin B_{12} (58 μg/d, the reference is set to 4 μg/d), D (26 μg/d, the reference is set to 20 μg/d), calcium (938 mg/d, the reference is set to 1000 mg/d) and iron (37 mg/d, the reference is set to 10–15 mg/d) were all adequate (except borderline low intake of calcium). However, the athlete’s vitamin E and potassium intake were not adequate. In addition, sodium, chloride, and iodine intake were from food only (i.e., without meal preparation included); therefore, all were underreported.

Furthermore, in 2018, the athlete did not consume dietary supplements, while she now regularly uses several dietary supplements, including plant-based protein powder (i.e., hemp, peas, and coconut protein enriched with calcium, iron, potassium, and sodium), vitamin B_{12}, vitamin C, vitamin D daily during the autumn-winter period, iron, and tonic drink with iron together with vitamin C (again), and some B vitamins.

In line with dietary intake, the analysis showed that the athlete rarely consumed legumes and nuts/seeds (both groups 1–3 times per month); however, milk (daily), salmon fish (3 times per week), eggs, fruits, and oat flakes (all 5–6 times per week) were consumed as were meat (mostly chicken), other whole grain products (e.g., whole grain bread, whole grain pasta, rice), other dairy products (e.g., cheese or yogurt), and cooked vegetables 2–4 times per week. Raw vegetables were rarely consumed. On most days, the athlete avoided unhealthy and ultra-processed foods (e.g., white flour products, sweets, mayonnaise) or unhealthy food preparation methods (e.g., frying). In addition, the athlete prepared most of her meals at home. Finally, the athlete regularly consumed all three meals: breakfast, lunch, and dinner (of note, the athlete reported that lunch was skipped once per week; we assume that on the day off training).

Table 1:
Ranking in important international competitions.

Parameter	Year 2018	Year 2022
Age (years)	24.9	28.9
High-profile ranking (place)		
World championship	-	
European championship (vault, 2017)	9th	
World cup overall (vault, 2016)	1rd	
World cup (vault, 2018)	1rd	
World cup (vault, 2015)	2nd	
World cup (vault, 2016)	2nd	
World championship (vault, 2021)		14th
European championship (vault, 2017)		4th
World cup (vault, 2021)		1rd
World cup (vault, 2022, 2022)		1rd
World cup (vault, 2021, 2021)		2nd

Table 2.
Anthropometrics and body composition changes.

Parameter	Year 2018	Year 2022	AG-2†	AG-3††
BH (cm)	151	151	157	154
BM (kg)	48.7	48.0	49.0	45.8
BMI (kg/m2)	21.4	21.1	19.9	19.3
BF (%)	20.8	19.9	16.3	11.7
Android (%)	14.2	**10.5**	13.2	-
Gynoid (%)	31.6	32.2	27.4	-
A/G	0.45	**0.33**	0.48	-
BFM (kg)	9.7	**8.7**	7.6	-
FFM (kg)	39.0	39.3	41.3	40.5
LST (kg)	36.7	37.0	38.8	-
BMC total (kg)	2.26	2.26	2.65	-
BMD total (g/cm^2)	1.24	1.25	1.32	-
BMD left femoral neck	1.35	1.31	1.27	-
BMD left femur	1.40	1.37	1.28	-
BMD legs	1.36	1.39	1.42	-
BMD pelvis	1.35	1.31	1.38	-
BMD spine	1.12	1.12	1.25	-
BMD trunk	0.99	0.98	1.06	-
BMD ribs	0.68	0.65	0.73	-
BMD arms	1.14	1.14	1.17	-
BMD head	2.08	2.12	2.22	-

Significant change in value is shown in bold (i.e., ≥ 9% of relative change). BH: body height, BM: body mass, BMI: body mass index, BF: body fat, FFM: fat-free mass, BFM: fat mass, A/G: android/gynoid ratio, LST: lean soft tissue, BMC: bone mineral content, BMD: bone mineral density (i.e., all variables in g/cm^2 units). †AG-2: elite-level artistic gymnast from our first study (i.e., best performer on the same apparatus (i.e., vault)) (Jakše, Jakše, Čuk, et al., 2021). ††AG-3: elite-level artistic gymnast from the study of other researchers (Dallas et al., 2016). Body composition of the AG-3 was estimated from skinfold thickness using a Lange skinfold caliper.

Table 3.
Intake of energy and macronutrients.

Macronutrients (per day)	Year 2018	Year 2022	AG-2†	AG-3††
Energy intake (kcal)	1476	1765	1759	1712
Carbohydrates (g)	150	**208**	165	-
(% E)	41	**47**	37	52
Carbohydrates (g/kg BM)	3.1	**4.3**	3.4	4.8
Total sugars[TS] (g)	69	**100**	123	-
(% E)	19	**23**	28	-
Free sugars[FS] (g)	48	**42**	75	-
(% E)	13	**9**	17	-
Starches (g)	57	69	45	-
(% E)	15	16	10	-
Dietary fiber (g)	17	**27**	11	15
(% E)	2.3	**3**	1.3	-
Soluble fiber (g)	4.1	**6.5**	4.1	-
Insoluble fiber	11	**14**	7	-
Fat (g)	70	**59**	93	-
(% E)	43	**30**	48	33
SFAs (g)	21	21	42	-
(% E)	13	**11**	21	-
MUFAs (g)	30	**20**	31	-
(% E)	18	**10**	16	-
PUFAs (g)	14	**9**	8	-
(% E)	8.5	**4.6**	4.1	-
EPA + DHA (mg)	100	**442**	98	-
Cholesterol (mg)	193	**376**	128	-
Protein (g)	53	**87**	60	-
(% E)	14	**20**	14	15
(g/BM)	1.1	**1.8**	1.2	1.4
Plant protein (g)	16	**35**	12	-
(% E)	4.3	**8**	2.7	-
Animal protein (g)	37	**52**	48	-
(% E)	10	**12**	11	-
Alcohol (g)	0.1	0	0	-
Total water[TW] (l)	1.6	**2.1**	1.3	2.9

Significant changes in value (i.e., 15% of relative change) are shown in bold. % E = percentage of total energy intake (general Atwater energy conversion factors were used (kcal/g): carbohydrates and protein = 4, dietary fiber = 2, fat = 9, alcohol = 7) (Food and Agriculture Organization of the United Nations, 2003). TS = total sugars: all monosaccharides and disaccharides: free sugars plus sugars naturally present in foods (e.g., lactose in milk, fructose in fruits) (WHO, 2015). FS = free sugar: all monosaccharides and disaccharides added to foods and beverages by the manufacturer, cook, or consumer (i.e., added sugars) plus sugars naturally present in honey, syrups, fruit juices, fruit juice concentrates, and sports drinks (defined by the World Health Organization (WHO, 2015) and adapted by the Scientific Advisory Committee on Nutrition (Scientific Advisory Committee on Nutrition, 2015)). SFAs = saturated fatty acids; MUFAs = monounsaturated fatty acids; PUFAs = polyunsaturated fatty acids; EPA = eicosatetraenoic acid; DHA = docosahexaenoic acid. TW = total water: from beverages, solid foods, and supplementation. †AG-2: elite-level artistic gymnast from our first study (i.e., best performer on the same apparatus (i.e., vault)) (Jakše, Jakše, Fidler Mis, et al., 2021). ††AG-3: elite-level artistic gymnast from the study of other researchers (Dallas et al., 2016). Dietary intake of the AG-3 was assessed using three different methods: a) an arbitration history (emphasis on basic and customary intake) via personal interviews; b) a 7-day record of weighed food and drink consumption; and c) a FFQ with emphasis on foods rich in calcium and vitamin D.

Table 4.
Intake of selected vitamins, minerals, and trace elements.

Micronutrients (per day)	Year 2018	Year 2022	AG-2	AG-3
Vitamins				-
Thiamine (mg)	1.2	1.4	0.8	-
Riboflavin (mg)	1.6	2.7	2.0	-
Niacin (mg)	16	21	11	-
Pantothenic acid (mg)	6.4	9.0	4.1	-
Vitamin B6 (mg)	1.6	2.1	0.9	2.2
Biotin (µg)	78	97	76	-
Folate/folic acid[FA] (µg)	283	468	340	-
Vitamin B_{12} (µg)	4.3	58	10.2	1.9
Retinol equ.[RE] (mg)	1.4	2.1	2.5	-
Vitamin C (mg)	34	**302**	28	152
Vitamin D (µg)	5.4	**26**	3.8	-
Vitamin E (mg)	9.0	7.1	9.2	12.8
Vitamin K (µg)	75	**286**	55	-
Minerals				-
Calcium (mg)	410	**938**	696	878
Magnesium (mg)	261	**479**	291	287
Phosphorus (mg)	1219	**1656**	1091	994
Potassium (mg)	2235	**3342**	1510	-
Sodium (mg)[†]	966	**1358**	1696	-
Chloride (mg)[†]	1411	**1679**	1291	-
Trace elements				-
Iron (mg)	11	**37**	12	11.6
Iodine (µg)[†]	42	**56**	102	-
Zinc (mg)	8	**10**	10	9.4
Selenium (µg)	93	**171**	21	-

Significant changes in value (i.e., 15% of relative change) are shown in bold. FA = folic acid (of note, the athlete did not consume folic acid in dietary supplement form; therefore, the folic acid from supplementation to folate conversion was not used). RE = retinol equivalents: vitamin A + α-carotene (1 mg retinol equivalent = 12 mg α-carotene) + β-carotene (1 mg retinol equivalent = 6 mg β-carotene) + γ-carotene (1 mg retinol equivalent = 12 mg γ-carotene). [†]Sodium, chloride, and iodine intake are from food and supplements only (i.e., without iodized salt from meal preparation). The athlete did not consume many minimally processed, processed, or ultra-processed products or canned products that are included in the FFQ (e.g., mayonnaise, butter, lard, ketchup, confectionery, canned beans, cheese, fries, commercial bread, and pastries) and that include sodium; therefore, the recorded intake of sodium and chloride from food only may be lower than actual intake. [†]AG-2: elite-level artistic gymnast from our first study (i.e., best performer on the same apparatus (i.e., vault)) (Jakše, Jakše, Fidler Mis, et al., 2021). [††]AG-3: elite-level artistic gymnast from the study of other researchers (Dallas et al., 2016). Dietary intake of the AG-3 was assessed using three different methods: a) an arbitration history (emphasis on basic and customary intake) via personal interviews, b) a 7-day record of weighed food and drink consumption, and c) a FFQ with emphasis on foods rich in calcium and vitamin D.

Table 5.
Serum micronutrient status.

Parameter	Reference†	Year 2018	Year 2022	AG-2†
Vitamins				
S-vit B_{12} (pmol/L)	≥ 258	284	**598**	224
25(OH)D (nmol/L)	≥ 75	55	**47**	89
Minerals				
S-Ca (mmol/L)	2.10–2.60	2.46	2.34	2.43
S-Mg mmol/L)	0.60–1.10	0.95	**0.79**	0.8
S-P (mmol/L)	0.84–1.45	1.75	1.29	1.09
S-K (mmol/L)	3.8–5.5	4.5	4.4	5.0
Trace element				
S-Fe (µmol/L)	10.7–28.6	10.4	**25.1**	17.9

Significant changes (i.e., 10% of relative change) in value are shown in bold. †Serum vitamin B_{12} (S-vit B_{12}) reference value is suggested to prevent neurocognitive disorders late in life (Wolters et al., 2004). For 25(OH)D status, we used three categories (i.e., sufficiency: > 75 nmol/L, insufficiency: 50–75 nmol/L, and deficiency: < 50 nmol/L) (Holick, 2009). Concentrations of serum minerals and trace elements used are from the national laboratory, the University Medical Centre Ljubljana, Slovenia (University Medical Centre Ljubljana, 2018). †AG-2: elite-level artistic gymnast from our first study (i.e., best performer on the same apparatus (i.e., vault)) (Jakše, Jakše, Fidler Mis, et al., 2021).

Table 6.
Cardiovascular (CV) health and safety factors.

Parameter	Recomm./Refer.†	2018	2022	AG-2†
S-cholesterol (mmol/L)	< 5.2	5.3	**4.7**	5.1
LDL cholesterol (mmol/L)	< 3.4	3.0	3.1	3.2
HDL cholesterol (mmol/L)	> 1.3	1.6	1.7	1.2
Triglycerides (mmol/L)	< 1.7	1.0	**0.6**	1.0
Blood pressure (mmHg)				
Systolic	120–129	111	115	99
Diastolic	80–84	78	79	66
S-glucose (mmol/L)	< 5.8	3.7	**4.4**	4.5
S-UA (µmol/L)	< 360	249	**293**	178
Hemoglobin (g/L)	≥ 120	149	**137**	137

Significant changes in value (i.e., 10%) are shown in bold. †Recommendations or reference values: S-cholesterol and HDL cholesterol reference values were from the national laboratory, the University Medical Centre Ljubljana, Slovenia (University Medical Centre Ljubljana, 2018). Low-density lipoprotein cholesterol (LDL cholesterol), triglycerides, and BP recommendations used were from the European Society of Cardiology (Visseren et al., 2021). S-glucose recommendations were used from the European Diabetes Epidemiology Group for lean adults (BMI < 25 kg/m²) (Borch-Johnsen, 1999). Serum uric acid (S-UA) consensual threshold is used for all healthy subjects (Desideri et al., 2014). For hemoglobin, we used recommended cut-offs for a non-anemic state from the World Health Organization for non-pregnant females (> 120 g/L) (WHO, 2011). †AG-2: elite-level artistic gymnast from our first study (i.e., best performer on the same apparatus (i.e., vault)) (Jakše, Jakše, Fidler Mis, et al., 2021).

Serum micronutrients are presented in Table 5. All vitamins and minerals were within reference ranges, except for 25(OH)D, in the deficiency category. Furthermore, S-P was increased in the 2018 study, while the value was now within the reference range. Moreover, a four-year comparison has shown that the athlete markedly improved the S-Fe status that was below the reference range in the 2018 study.

The significant observation in comparing the measured results of a blood test is that all blood variables and BP (i.e., CV health and safety factors) obtained were within reference values. However, a four-year comparison has shown that the athlete lowered S-cholesterol, triglycerides, and hemoglobin while increasing LDL cholesterol, HDL cholesterol, S-glucose, and S-UA (Table 6).

DISCUSSION

To our knowledge, this kind of repeated (i.e., period of a four-year cycle) screening of the same elite-level adult female artistic gymnast with the same protocol and methods is rarely seen in the scientific literature. With our study, we highlighted five critical findings. First, our results confirmed the importance of monitoring and analyzing athletes with the same study protocol and methods. The benefits of regular monitoring of elite-level artistic gymnasts are primarily for the athlete and coach, followed by gymnasts competing at lower-level competitions (i.e., high-performance level and younger gymnasts) and the scientific and artistic gymnastic community. Second, a four-year comparison has shown that the gymnast markedly improved her body composition status (i.e., decreased BFM, android fat, and A/G ratio). Third, dietary intake analysis showed that nutrients that are generally of concern among (female) athletes (specifically, female gymnasts), such as fiber (borderline low intake), EPA and DHA, vitamin B_{12} and D, calcium (borderline low intake), iron, and zinc, were adequate. However, the athlete's vitamin E and potassium intake were not adequate. Furthermore, in 2018, the athlete did not consume dietary supplements, while she now regularly uses several dietary supplements, including enriched plant-based protein powder, isolated vitamin B_{12}, C, D, and iron. Fourth, in regard to the serum micronutrient status, all measured vitamins and minerals were within the reference ranges, except vitamin 25(OH)D, which was deficient, and S-Fe, which markedly improved, compared with the 2018 study. Finally, markers of CV health status were all within the reference values; however, LDL cholesterol status could improve.

A four-year comparison (2018 vs. 2022) in body composition indices measured in the same competitive phase and calendar period showed a noticeable improvement in terms of decreased BFM, android fat, and A/G ratio. Although our athlete was an adult gymnast, we emphasize that she maintained her BH in both studies (i.e., 151 cm) and had similar BM (48.7 kg and 48.0 kg) and BMI (21.4 kg/m^2 and 21.1 kg/m^2). The variables that were relatively unchanged were LST, BMC total, BMD total, and BMD segmental. These results are interesting in the sense that the athlete probably maintained, in addition to the overall dietary pattern, the pattern of training, and in terms of the selection of apparatus for which she prepared and competed and avoided major injuries. We assumed that the lower android fat (i.e., trunk and upper body) and consequently lower A/G ratio might also result from changed dietary intake (e.g., lower free sugar and total fat intake and higher protein intake) (Cava et al., 2017; Manore, 2015).

Compared with older data on 31 elite-level artistic gymnasts from the United States of America (i.e., US national team, measured by DEXA), our elite-level artistic gymnast was the same size (151 cm vs. 151 cm) but had higher BM (48.0 kg vs. 46.5 kg) and BF % (19.9 % vs. 12.4 %). However, our artistic gymnast was, at the time of the study, an experienced elite-level athlete, aged 28.9 years, compared to the mean age of only 15.2 years (Deutz et al., 2000) in the mentioned study. Furthermore, when comparing our results with another US study on 48 elite-level female gymnasts (there is no data on whether the sample included exclusively artistic gymnasts), in which the researchers also used DEXA, these gymnasts were, on average, also significantly younger (15.8 years, the oldest was 19.2 years), but of similar size than our gymnast (152.2 cm), and BM (47.7 kg), with lower BF % (14.3%) and higher relative FFM (85% vs. 82% of BM). However, the US gymnasts had, on average, lower BMD total (1.06 g/cm^2 vs. 1.25 g/cm^2) (Bauer et al., 2005). The most relevant comparison of our gymnast may be with the most successful gymnast from the 2018 study (i.e., also a participant in the Olympic Games); her parade apparatus was also the vault. The compared gymnast was 6 cm taller (157 cm), with similar BM (49 kg), but consequently with a lower BMI (19.9 kg/m^2), lower BF % (16.3%), higher BMC total (2.65 kg vs. 1.25 kg), higher LST (38.8 kg vs. 37.0 kg), higher BMD total (1.32 g/cm^2 vs. 1.25 g/m^2), but not BMD left femoral neck (1.27 g/cm^2 vs. 1.31 g/cm^2) and left femur (1.28 g/cm^2 vs. 1.37 g/cm^2). The higher BMD total of the previously most successful gymnast was at the expense of higher BMD legs (1.42 g/cm^2), BMD pelvis (1.38 g/cm^2), BMD spine (1.25 g/cm^2), BMD trunk (1.06 g/cm^2), BMD ribs (0.73 g/cm^2), BMD arms (1.17 g/cm^2), and BMD head (2.22 g/cm^2) (Jakse et al., 2019; Jakše, Jakše, Čuk, et al., 2021). In addition, Greek researchers, although using a different method to assess the body composition status, measured lower BMI (19.3 kg/m^2) and BF % (11.7%) in an 18.5-year-old elite-level artistic gymnast (Dallas et al., 2016). Importantly, the available data in recent systematic reviews of elite-level female gymnasts used mostly outdated studies, and recent data are still not sufficient for providing robust conclusions about whether body composition features explain competitive performance (Bacciotti et al., 2017). We emphasize that there is a need for a more transparent use of the terms “elite-level” and “high-performance level” to avoid inappropriate comparisons. In addition, body composition is assessed with numerous methods (i.e., bioimpedance, DEXA, skinfold measurement), so direct comparisons are oftentimes limited.

The athlete, in terms of dietary intake, relied to a great extent on dietary supplements (i.e., four years ago, the athlete did not use them at all) with which she covered the nutritional sufficiency of certain nutrients (i.e., with enriched plant-based protein powder, vitamin B_{12}, C, D, and iron).

Furthermore, the estimated average carbohydrate intake of the athlete in the previous and current study (2018 vs. 2022) (3.1 g/kg BM/d vs. 4.3 g/kg BM/d) (Jakše, Jakše, Fidler Mis, et al., 2021) would be barely suitable for skilled-based intensity exercise (Thomas et al., 2016). Significantly, while the athlete in the current study markedly increased the energy intake (1476 kcal/d vs. 1765 kcal/d), carbohydrate (41% vs. 47 % of energy), and protein intake (14% vs. 20% of energy) and decreased total fat (43% vs. 30% of energy) and SFA intake (13% vs. 8% of energy), and unfavorable increased cholesterol intake (193 mg/d vs. 376 mg/d). However, although it may be different for other athletes with higher energy needs, the athlete’s free sugar, SFA, and cholesterol intake were higher than recommended (DGE/ÖGE/SGE, 2018; Scientific Advisory Committee on Nutrition, 2015). Moreover, the athlete greatly increased fiber intake (17 g/d vs. 27 g/d), which represents borderline low intake compared with the reference intake (30 g/d) and EPA and DHA intake (100 mg/d vs. 442 mg/d) that were adequate (250 mg/d) (EFSA, 2017) at the time. However, the athlete had inadequate intake of vitamin E (7.1 mg/d, the reference is set to 12 mg/d) and potassium (3342 mg/d, the reference is set to 4000 mg/d) (National institute of Public Health of Slovenia, 2020). Micronutrients that are often of concern in the general population and among athletes (e.g., vitamin B_{12}, D, calcium (borderline low intake), and iron) were adequate. In addition, sodium, chloride, and iodine intake were from food only (i.e., without meal preparation included); therefore, all were underreported; however, according to FFQ (i.e., dietary intake from foods and dietary supplements), we estimate that iodine intake is probably inadequate (National institute of Public Health of Slovenia, 2020).

In addition, in a rare recent investigation, its authors reported a case study of AG-3, members of the Greek National Team. Using an arbitration history of food intake via personal interview, 7-day weighed food record protocol and the FFQ, the researchers found that from assessed nutrients only vitamin C, vitamin B_6 and zinc exceeded daily recommended amounts, whereas fiber (14.7 g/d), vitamin B_{12} (1.2 µg/d) and calcium intake (878 mg/d) were insufficient and had the highest deviation from the recommended dietary intake (Dallas et al., 2016). Despite the fact that our results are hardly comparable to the values reported in this case study due to the use of a different method for assessing dietary intake, the database used, and the different nutrients that were included in the analysis, we can clearly see a similar trend of unbalanced nutrition in certain segments when compared with dietary intake recommendations.

In line with dietary intake, our analysis showed that the athlete severely limited her intake of raw vegetables, nuts/seeds, and legumes. However, the athlete consumed dairy products daily and whole grains, eggs, and fish on most days. The athlete regularly consumed all three main meals, prepared most of the meals at home and avoided unhealthy or ultra-processed food. Hence, the differences assessed in the dietary intake were consistent with the obtained differences in the S-vit B_{12} (improved), 25(OH)D (below the reference values), and S-Fe (improved), and CV health status (i.e., some variables increased, others (un)favorable decreased, and others remained at a similar level, and within recommendation). We emphasize three things in regard to obtained serum values of micronutrients. Firstly, the athlete's 25 (OH)D status was in the deficient category despite regular intake of vitamin D from a dietary supplement source. Significantly, the athlete consumed 1000 IU/d of vitamin D in the form of dietary supplements for the whole autumn and winter period. The current Slovenian recommendation, especially in periods of respiratory infections and covid-19 and due to the latitude of Slovenia (46 °N), advise taking daily up to 4000 IU, especially when tests show low concentrations of 25(OH)D (Pfeifer et al., 2020). In regard to (in)adequate vitamin D status, several studies have confirmed the existence of a problem of serum deficiencies in 25(OH)D) among female athletes in general and artistic gymnasts specifically (Lovell, 2008; Quadri et al., 2016), which may increase the risk of stress fractures and illness, increase muscle weakness, and delay muscle recovery (Sikora-Klak et al., 2018). Secondly, the athlete regularly consumed animal-based food sources (e.g., salmon, fish, milk, and eggs) and vitamin B_{12} dietary supplements; therefore, based on her current S-vit B_{12} status (598 pmol/L), she may decrease the amount or the frequency of vitamin B_{12} intake from dietary supplement sources. Thirdly, high intake of iron from dietary supplements resulted in an improvement in S-Fe status in comparison with the 2018 study (10.4 µmol/L vs. 25.1 µmol/L).

In both studies, all CV health markers were within the reference values. Furthermore, the four-year comparison has shown that the athlete lowered S-cholesterol, triglycerides, and hemoglobin (as a safety marker) but increased the LDL cholesterol, HDL cholesterol, and S-UA as a safety marker. However, some noteworthy differences merit further examination, with several possible explanations for these observed differences. Furthermore, our athlete currently experiences increased LDL cholesterol (from 3.0 mmol/L in 2018 to 3.1 mmol/L in 2022) that might be explained by increased SFA, dietary cholesterol, and free sugar intake, which are associated with an increased risk of CV diseases (Bergeron et al., 2019; Freeman et al., 2017; Sacks et al., 2017; Zhong et al., 2019), whereas dietary fiber (the athlete's fiber intake was borderline low) yields a reduction in LDL cholesterol (via reduced gastrointestinal absorption) (Veronese et al., 2018). The athlete regularly consumed oats and other whole grains that are known to have a favorable impact on LDL cholesterol (Cicero et al., 2020); however, in terms of the overall diet pattern, the athlete has reserves for more frequent intake of foods that are mostly absent from her diet and are also known to control LDL cholesterol (e.g., soy and other legumes, tomato, flaxseeds, walnuts, and green tea (Schoeneck & Iggman, 2021)). In addition, several studies suggest that LDL cholesterol levels greater than or equal to 2.6 mmol/L may be associated with preclinical atherosclerosis despite the absence of other risk factors. Moreover, this threshold may become a serious health concern or even fatal for athletes later in life (Abdullah et al., 2018; Fernández-Friera et al., 2017; O'Keefe et al., 2004). However, because the studied athlete was considered to have normal BM and BF %, as an athlete, she is regularly physically active, had regulated blood pressure (115/79 mmHg), normal levels of triglycerides (0.6 mmol/L), HDL cholesterol (1.7 mmol/L), non-HDL cholesterol (3.0 mmol/L) and she is non-smoker, according to SCORE2 risk prediction algorithms (Hageman et al., 2021) we believe that LDL cholesterol of 3.1 mmol/L is unlikely to pose a significant risk of cardiovascular disease. The athlete's higher HDL cholesterol was probably due to regular physical activity (Palazón-Bru et al., 2021) and coconut fat intake (Teng et al., 2020). However, while seminal observational studies have shown an inverse relationship between HDL-cholesterol and atherosclerotic risk, recent evidence suggests that high and extremely high HDL-cholesterol may not reduce the risk of CV disease events or may even be associated with increased all-cause mortality. The lowest risk was seen for HDL cholesterol to be between 1.4 mmol/L to 1.5 mmol/L (Zhong et al., 2020). Regulated blood pressure in both studies, although with insufficient potassium intake, is most likely due to lower salt intake (food preparation at home) and daily whole grains and fruit intake (Stamler et al., 2018).

The present case study report examined an elite-level adult female national team artistic gymnast, currently the most successful one representing Slovenia. Although the athlete was already considered an elite-level in the first study four years ago, she was not the best performer in the country at that time (i.e., 2018) or as successful as at present. Significantly, in the study we used the same competitive and calendar period, the same location (i.e., medical center), the same protocol, and the same wide data sets of objective methods, and compared the athlete's change/progress over the four-year range. Therefore, the novelty of our results with two screenings of the successful elite-level artistic gymnast under the same conditions enables valuable interpretations of the results obtained. In addition, this kind of screening or monitoring showed its usefulness as it is affordable, carried out using valid methods, and is not time-consuming. The study has some obvious limitations inherent to the case study design; therefore, the results should be interpreted with caution regarding application of the results to other national team members. Furthermore, when analyzing the dietary assessment we are aware of the possibility that the energy and nutrients intake were underreported or underestimated (Capling et al., 2017). This issue is especially relevant for female artistic gymnasts because of known problems with under-reporting of energy intake by elite-level female gymnasts (Jonnalagadda et al., 2000). The nature of FFQ itself (i.e., completing FFQ from memory and perception), especially for one athlete only, differs significantly from, for example, a three-day (weighted) dietary record. Notably, the athlete did not have access to the completed FFQ from 2018. Moreover, the obtained FFQ results were further considered in the context of body composition and extensive blood tests results. At the time of the study, our elite-level athlete was not using any periodized nutrition plan, as recommended by most professionals (Jeukendrup, 2017). In addition, there is a lack of follow-up scientific studies on elite-level female gymnasts that would monitor their various changes; therefore, there is a need for further studies to investigate the curve of changes in the monitored variables (also the motor skills) of the athlete that affect the sports performance and the development of her sports career.

CONCLUSION

A four-year comparison of the results of the elite-level female athlete has shown an improvement in some relevant body composition variables. Furthermore, the dietary intake of the athlete also showed several improvements regarding the adequacy of nutrients that are generally of concern among female athletes; however, most improvement was primarily achieved through several supplementations on a daily basis. In fact, the athlete did not regularly consume supplementation four years ago. Furthermore, all the measured serum micronutrients were within the reference ranges, and S-Fe was markedly improved. Finally, the CV health status was within the reference values, but the changes were polarized; S-cholesterol was favorable, while triglycerides unfavorably decreased. In the long run, LDL cholesterol should probably be lower.

The obtained results may provide helpful concrete information for a coach-athlete relationship, for an artistic gymnast at lower-level competitions, and for the development of elite-level artistic gymnasts in Slovenia.

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REFERENCES

Ackland, T. R., Lohman, T. G., Sundgot-Borgen, J., Maughan, R. J., Meyer, N. L., Stewart, A. D., & Mller, W. (2012). Current status of body composition assessment in sport: review and position statement on behalf of the ad hoc research working group on body composition health and performance, under the auspices of the I.O.C. Medical Commission. *Sports Medicine*, *42*(3), 227–249.

Anderson, C., & Petrie, T. A. (2012). Prevalence of Disordered Eating and Pathogenic Weight Control Behaviors Among NCAA Division I Female Collegiate Gymnasts and Swimmers. *Research Quarterly for Exercise and Sport*, *83*(1), 120–124.

Bacciotti, S., Baxter-Jones, A., Gaya, A., & Maia, J. (2017). The Physique of Elite Female Artistic Gymnasts: A Systematic Review. *Journal of Human Kinetics*, *58*(1), 247–259.

Bauer, P. W., Pivarnik, J. M., Fornetti, W. C., Jallo, J. J., & Nassar, L. (2005). Cross Validation of Fat-Free Mass Prediction Models for Elite Female Gymnasts. *Pediatric Exercise Science, 17*(4), 337–344.

Bergeron, N., Chiu, S., Williams, P. T., M King, S., & Krauss, R. M. (2019). Effects of red meat, white meat, and nonmeat protein sources on atherogenic lipoprotein measures in the context of low compared with high saturated fat intake: a randomized controlled trial. *The American Journal of*

Clinical Nutrition, *110*(1), 24–33.

Borch-Johnsen, K. (1999). Is fasting glucose sufficient to define diabetes? Epidemiological data from 20 European studies. *Diabetologia*, *42*(6), 647–654.

Capling, L., Beck, K. L., Gifford, J. A., Slater, G., Flood, V. M., & O'Connor, H. (2017). Validity of Dietary Assessment in Athletes: A Systematic Review. *Nutrients*, *9*(12), 1313.

Cava, E., Yeat, N. C., & Mittendorfer, B. (2017). Preserving Healthy Muscle during Weight Loss. *Advances in Nutrition: An International Review Journal*, *8*(3), 511–519.

Cicero, A. F. G., Fogacci, F., Veronesi, M., Strocchi, E., Grandi, E., Rizzoli, E., Poli, A., Marangoni, F., & Borghi, C. (2020). A randomized Placebo-Controlled Clinical Trial to Evaluate the Medium-Term Effects of Oat Fibers on Human Health: The Beta-Glucan Effects on Lipid Profile, Glycemia and inTestinal Health (BELT) Study. *Nutrients*, *12*(3), 686.

Clarys, P., Deliens, T., Huybrechts, I., Deriemaeker, P., Vanaelst, B., De Keyzer, W., Hebbelinck, M., & Mullie, P. (2014). Comparison of nutritional quality of the vegan, vegetarian, semi-vegetarian, pesco-vegetarian and omnivorous diet. *Nutrients*, *6*(3), 1318–1332.

Dallas, G. C., Dallas, C. G., Simatos, E. J., & Simatos, J. E. (2017). Nutritional recommendations and guidelines for women in gymnastics: current aspects and critical interventions. *Science of Gymnastics Journal*, *9*(1), 27–40.

Dallas, G., Dallas, C., & Simatos, J. (2016). Nutritional status and dietary assessment of elite female artistic and rhythmic gymnasts - a case study. *Science of Gymnastics Journal*, *8*(3), 255–269. http://eds.b.ebscohost.com.nukweb.nuk.uni-lj.si/eds/detail/detail?vid=0&sid=059ffe90-025d-4fe6-a8e8-20a835c709ef%40pdc-v-sessmgr06&bdata=Jmxhbmc9c2wmc2l0ZT1lZHMtbGl2ZQ%3D%3D#AN=119297738&db=s3h

De Keyzer, W., Dekkers, A., Van Vlaslaer, V., Ottevaere, C., Van Oyen, H., De Henauw, S., & Huybrechts, I. (2013). Relative validity of a short qualitative food frequency questionnaire for use in food consumption surveys. *The European Journal of Public Health*, *23*(5), 737–742.

Desideri, G., Castaldo, G., Lombardi, A., Mussap, M., Testa, A., Pontremoli, R., Punzi, L., & Borghi, C. (2014). Is it time to revise the normal range of serum uric acid levels? *European Review for Medical and Pharmacological Sciences*, *18*(9), 1295–1306. http://www.ncbi.nlm.nih.gov/pubmed/24867507

Deutz, R. C., Benardot, D., Martin, D. E., & Cody, M. M. (2000). Relationship between energy deficits and body composition in elite female gymnasts and runners. *Medicine and Science in Sports and Exercise*, *32*(3), 659–668.

DGE/ÖGE/SGE. (2018). *Ergaenzlieferung D-A-CH Referenzwerte für die Nährstoffzufuhr [Reference Values for Nutrient Intake]* (4th ed, pp. 1–56).

EFSA. (2017). Dietary Reference Values for nutrients Summary report. *EFSA Supporting Publications*, *14*(12), e15121.

FIG. (2022). *Kysselef Tjaša - FIG Athlete Profile*. Federation Internationale De Gymnastique. https://www.gymnastics.sport/site/athletes/bio_detail.php?id=25211

Food and Agriculture Organization of the United Nations. (2003). *Food energy – methods of analysis and conversion factors*. https://www.sennutricion.org/media/Docs_Consenso/Food_energy_methods_of_analysis_and_conversion_factors-FAO_2002.pdf

Freeman, A. M., Morris, P. B., Barnard, N., Esselstyn, C. B., Ros, E., Agatston, A., Devries, S., O'Keefe, J., Miller, M., Ornish, D., Williams, K., & Kris-Etherton, P. (2017). Trending Cardiovascular Nutrition Controversies. *Journal of the American College of Cardiology*, *69*(9), 1172–1187.

Hageman, S., Pennells, L., Ojeda, F., Kaptoge, S., Kuulasmaa, K., de Vries, T., Xu, Z., Kee, F., Chung, R., Wood, A., McEvoy, J. W., Veronesi, G., Bolton, T., Achenbach, S., Aleksandrova, K., Amiano, P., Sebastian, D.-S., Amouyel, P., Andersson, J., … Di Angelantonio, E. (2021). SCORE2 risk prediction algorithms: new models to estimate 10-year risk of cardiovascular disease in Europe. *European Heart Journal*, *42*(25), 2439–2454.

Heaney, R. P. (2005). The Vitamin D requirement in health and disease. *The Journal of Steroid Biochemistry and Molecular Biology*, *97*(1–2), 13–19.

Holick, M. F. (2009). Vitamin D Status: Measurement, Interpretation, and Clinical Application. *Annals of Epidemiology*, *19*(2), 73–78.

Institute of Medicine. (1998). Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Pantothenic Acid, Biotin, and Choline. In *Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Pantothenic Acid, Biotin, and Choline*. National Academies Press (United States).

Jakše, B., Jakše, B., Čuk, I., & Šajber, D. (2021). Body Composition, Training Volume/Pattern and Injury Status of Slovenian Adolescent Female High-Performance Gymnasts. *International Journal of Environmental Research and Public Health*, *18*(4), 2019.

Jakše, B., Jakše, B., Fidler Mis, N., Jug, B., Šajber, D., Godnov, U., & Čuk, I. (2021). Nutritional Status and Cardiovascular Health in Female Adolescent Elite-Level Artistic Gymnasts and Swimmers: A Cross-Sectional Study of 31 Athletes. *Journal of Nutrition and Metabolism*, *2021*, 8810548. https://doi.org/10.1155/2021/8810548

Jakše, B., Jakše, B., Godnov, U., & Pinter, S. (2021). Nutritional, Cardiovascular Health and Lifestyle Status of 'Health Conscious' Adult Vegans and Non-Vegans from Slovenia: A Cross-Sectional Self-Reported Survey. *International Journal of Environmental Research and Public Health*, *18*(11), 5968.

Jakse, B., Sekulic, D., Jakse, B., Cuk, I., & Sajber, D. (2019). Bone health among indoor female athletes and associated factors; a cross-sectional study. *Research in Sports Medicine*, *28*(3), 314–323.

Jeukendrup, A. E. (2017). Periodized Nutrition for Athletes. *Sports Medicine*, *47*(Suppl 1), 51–63.

Jonnalagadda, S. S., Benardot, D., & Dill, M. N. (2000). Assessment of Under-Reporting of Energy Intake by Elite Female Gymnasts. *International Journal of Sport Nutrition and Exercise Metabolism*, *10*(3), 315–325.

Jungert, A., Ellinger, S., Watzl, B., & Richter, M. (2022). Revised D-A-CH reference values for the intake of biotin. *European Journal of Nutrition*, *61*(4), 1779–1787.

Jungert, A., Linseisen, J., Wagner, K. H., & Richter, M. (2020). Revised D-A-CH Reference Values for the Intake of Vitamin B6. *Annals of Nutrition and Metabolism*, *76*(4), 213–222.

Korošec, M., Golob, T., Bertoncelj, J., Stibilj, V., & Seljak, B. K. (2013). The Slovenian food composition database. *Food Chemistry*, *140*(3), 495–499.

Lee, E. C., Fragala, M. S., Kavouras, S. A., Queen, R. M., Pryor, J. L., & Casa, D. J. (2017). Biomarkers in Sports and Exercise: Tracking Health, Performance, and Recovery in Athletes. *Journal of Strength and Conditioning Research*, *31*(10), 2920.

Ljungqvist, A., Jenoure, P., Engebretsen, L., Alonso, J. M., Bahr, R., Clough, A., De Bondt, G., Dvorak, J., Maloley, R., Matheson, G., Meeuwisse, W., Meijboom, E., Mountjoy, M., Pelliccia, A., Schwellnus, M., Sprumont, D., Schamasch, P., Gauthier, J. B., Dubi, C., … Thill, C. (2009). The International Olympic Committee (IOC) Consensus Statement on periodic health evaluation of elite athletes March 2009. *British Journal of Sports Medicine*, *43*(9), 631–643.

Lovell, G. (2008). Vitamin D status of females in an elite gymnastics program. *Clinical Journal of Sport Medicine*, *18*(2), 159–161.

Malsagova, K. A., Kopylov, A. T., Sinitsyna, A., Stepanov, A. A., Izotov, A. A., Butkova, T. V., Chingin, K., Klyuchnikov, M. S., & Kaysheva, A. L. (2021). Sports Nutrition: Diets, Selection Factors, Recommendations. *Nutrients*, *13*(11), 3771.

Manore, M. M. (2015). Weight Management for Athletes and Active Individuals: A Brief Review. *Sports Medicine (Auckland, N.Z.)*, *45*(Suppl 1), 83.

Monteiro, C. A., Cannon, G., Levy, R. B., Moubarac, J. C., Louzada, M. L. C., Rauber, F., Khandpur, N., Cediel, G., Neri, D., Martinez-Steele, E., Baraldi, L. G., & Jaime, P. C. (2019). Ultra-processed foods: what they are and how to identify them. *Public Health Nutrition*, *22*(5), 936–941.

National institute of Public Health of Slovenia. (2020). *Reference values for energy intake and nutrient intake*. https://www.nijz.si/sites/www.nijz.si/files/uploaded/referencne_vrednosti_2020_3_2.pdf

OPKP. (2021). *Computer web-based software: the Open Platform for Clinical Nutrition (OPEN)*. OPKP. Odprta Platforma Za Klinično Prehrano. http://www.opkp.si/sl_SI/fooddiary/diary

Palazón-Bru, A., Hernández-Lozano, D., & Gil-Guillén, V. F. (2021). Which Physical Exercise Interventions Increase HDL-Cholesterol Levels? A Systematic Review of Meta-analyses of Randomized Controlled Trials. *Sports Medicine (Auckland, N.Z.)*, *51*(2), 243–253.

Pfeifer, M., Siuka, D., & Pravst, I. (2020). *Priporočila za nadomeščanje holekalciferola (vitamina D3) v obdobjih respiratornih okužb in za nadomeščanje holekalciferola pri posameznikih s COVID-19*.

Quadri, A., Gorjanovic, B., Noack, P., Fuhrer, C., Steuer, C., Huber, A., & Kriemler, S. (2016). Seasonal variation of vitamin D levels in Swiss athletes. *Swiss Sports & Exercise Medicine*, *64*(1), 19–25.

Sacks, F. M., Lichtenstein, A. H., Wu, J. H. Y., Appel, L. J., Creager, M. A., Kris-Etherton, P. M., Miller, M., Rimm, E. B., Rudel, L. L., Robinson, J. G., Stone, N. J., Van Horn, L. V., & American Heart Association. (2017). Dietary Fats and Cardiovascular Disease: A Presidential Advisory From the American Heart Association. *Circulation*, *136*(3), e1–e23.

Schoeneck, M., & Iggman, D. (2021). The effects of foods on LDL cholesterol levels: A systematic review of the accumulated evidence from systematic reviews and meta-analyses of randomized controlled trials. *Nutrition, Metabolism, and Cardiovascular Diseases : NMCD*, *31*(5), 1325–1338.

Scientific Advisory Committee on Nutrition. (2015). *Carbohydrates and Health*. The Stationery Office. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/445503/SACN_Carbohydrates_and_Health.pdf

Sikora-Klak, J., Narvy, S. J., Yang, J., Makhni, E., Kharrazi, F. D., & Mehran, N. (2018). The Effect of Abnormal Vitamin D Levels in Athletes. *The Permanente Journal*, *22*.

Stamler, J., Chan, Q., Daviglus, M. L., Dyer, A. R., Van Horn, L., Garside, D. B., Miura, K., Wu, Y., Ueshima, H., Zhao, L., & Elliott, P. (2018). Relation of dietary sodium (Salt) to blood pressure and its possible modulation by other dietary factors the intermap study. *Hypertension*, *71*(4), 631–637.

Teng, M., Zhao, Y. J., Khoo, A. L., Yeo, T. C., Yong, Q. W., & Lim, B. P. (2020). Impact of coconut oil consumption on cardiovascular health: a systematic review and meta-analysis. *Nutrition Reviews*, *78*(3), 249–259.

Thomas, D. T., Erdman, K. A., & Burke, L. M. (2016). Position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine: Nutrition and Athletic Performance. *Journal of the Academy of Nutrition and Dietetics*, *116*(3), 501–528.

Tobias, D. K., & Hall, K. D. (2021).

Eliminate or reformulate ultra-processed foods? Biological mechanisms matter. *Cell Metabolism*, *33*(12), 2314–2315.

University Medical Centre Ljubljana. (2018). *Laboratorijski vodnik*. https://lab.biarti.si/

Veronese, N., Solmi, M., Caruso, M. G., Giannelli, G., Osella, A. R., Evangelou, E., Maggi, S., Fontana, L., Stubbs, B., & Tzoulaki, I. (2018). Dietary fiber and health outcomes: an umbrella review of systematic reviews and meta-analyses. *The American Journal of Clinical Nutrition*, *107*(3), 436–444.

Visscher, C., Louer, L. E. A. M., & Elferink-Gemser, M. T. (2012). The perfect elite gymnast, does he exist? A systematic review. *Annals of Research in Sport and Physical Activity*, *3*, 39–61.

Visseren, F. L. J., MacH, F., Smulders, Y. M., Carballo, D., Koskinas, K. C., Bäck, M., Benetos, A., Biffi, A., Boavida, J. M., Capodanno, D., Cosyns, B., Crawford, C., Davos, C. H., Desormais, I., DI Angelantonio, E., Franco, O. H., Halvorsen, S., Hobbs, F. D. R., Hollander, M., … Williams, B. (2021). 2021 ESC Guidelines on cardiovascular disease prevention in clinical practice. *European Heart Journal*, *42*(34), 3227–3337.

WHO. (2011). Haemoglobin concentrations for the diagnosis of anaemia and assessment of severity. In *Vitamin and Mineral Nutrition Information System*. World Health Organization. https://apps.who.int/iris/bitstream/handle/10665/85839/WHO_NMH_NHD_MNM_11.1_eng.pdf?sequence=22&isAllowed=y

WHO. (2015). *Guideline: Sugars intake for adults and children*. World Health Organization: page 16. https://www.who.int/publications/i/item/9789241549028

Wolters, M., Ströhle, A., & Hahn, A. (2004). Cobalamin: A critical vitamin in the elderly. *Preventive Medicine*, *39*(6), 1256–1266.

Zhong, G. C., Huang, S. Q., Peng, Y., Wan, L., Wu, Y. Q. Le, Hu, T. Y., Hu, J. J., & Hao, F. B. (2020). HDL-C is associated with mortality from all causes, cardiovascular disease and cancer in a J-shaped dose-response fashion: a pooled analysis of 37 prospective cohort studies. *European Journal of Preventive Cardiology*, *27*(11), 1187–1203.

Zhong, V. W., Van Horn, L., Cornelis, M. C., Wilkins, J. T., Ning, H., Carnethon, M. R., Greenland, P., Mentz, R. J., Tucker, K. L., Zhao, L., Norwood, A. F., Lloyd-Jones, D. M., & Allen, N. B. (2019). Associations of Dietary Cholesterol or Egg Consumption With Incident Cardiovascular Disease and Mortality. *JAMA*, *321*(11), 1081–1095.

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