18% Overall Similarity

The combined total of all matches, including overlapping sources, for each database.

Filtered from the Report

- Bibliography
- Quoted Text

Match Groups

85 Not Cited or Quoted 12%
Matches with neither in-text citation nor quotation marks

51 Missing Quotations 6%
Matches that are still very similar to source material

0 Missing Citation 0%
Matches that have quotation marks, but no in-text citation

0 Cited and Quoted 0%
Matches with in-text citation present, but no quotation marks

Top Sources

14% Internet sources

10% Publications

12% Submitted works (Student Papers)

Match Groups

- **85** Not Cited or Quoted 12%
  Matches with neither in-text citation nor quotation marks
- **51** Missing Quotations 6%
  Matches that are still very similar to source material
- **0** Missing Citation 0%
  Matches that have quotation marks, but no in-text citation
- **0** Cited and Quoted 0%
  Matches with in-text citation present, but no quotation marks

Top Sources

14% Internet sources
10% Publications
12% Submitted works (Student Papers)

Top Sources

The sources with the highest number of matches within the submission. Overlapping sources will not be displayed.

1	Internet	ejurnal.ubharajaya.ac.id	1%
2	Student papers	Universitas Islam Riau on 2025-08-07	1%
3	Internet	repository.ubharajaya.ac.id	<1%
4	Internet	discobolulunefs.ro	<1%
5	Internet	coek.info	<1%
6	Publication	Temirlan Ruslanovich Dudov, Vijaya Jawahar Sarithala, Pavel Vladimirovich Koroy,...	<1%
7	Internet	academic.oup.com	<1%
8	Internet	es.scribd.com	<1%
9	Internet	www.gjphm.org	<1%
10	Student papers	University of Mary Hardin-Baylor on 2024-06-30	<1%

11 Internet
journals.sagepub.com <1%

12 Internet
pmc.ncbi.nlm.nih.gov <1%

13 Internet
epe.lac-bac.gc.ca <1%

14 Internet
ijone.org <1%

15 Internet
api.repository.cam.ac.uk <1%

16 Internet
knepublishing.com <1%

17 Internet
sajrsper.com <1%

18 Internet
www.mdpi.com <1%

19 Internet
www.science.gov <1%

20 Internet
hsag.co.za <1%

21 Internet
researchspace.ukzn.ac.za <1%

22 Student papers
Queen Margaret University College, Edinburgh on 2009-08-11 <1%

23 Internet
assets.researchsquare.com <1%

24 Student papers
London School of Hygiene and Tropical Medicine on 2015-10-23 <1%

25 Internet

www.jhse.es <1%

26 Internet

pafmj.org <1%

27 Student papers

Endeavour College of Natural Health on 2018-09-15 <1%

28 Student papers

Manchester Metropolitan University on 2026-01-10 <1%

29 Student papers

University of East London on 2011-03-16 <1%

30 Student papers

University of South Florida on 2020-03-18 <1%

31 Internet

www.embibe.com <1%

32 Internet

www.irrodl.org <1%

33 Internet

www.tandfonline.com <1%

34 Internet

wikimili.com <1%

35 Internet

www.researchgate.net <1%

36 Publication

Rody G. Sy, Elmer Jasper B. Llanes, Paul Ferdinand M. Reganit, Nina Castillo-Caran... <1%

37 Internet

digitallibrary.msforpublish.com <1%

38 Internet

freidok.uni-freiburg.de <1%

39	Internet	journals.uni-lj.si	<1%
40	Internet	mothertobaby.org	<1%
41	Internet	qa1.scielo.br	<1%
42	Publication	HU, D.S.. "Perilipin Gene 1237 T>C Polymorphism is not Associated with Obesity ...	<1%
43	Student papers	University of Nottingham on 2021-08-30	<1%
44	Internet	accord.edu.so	<1%
45	Internet	e-hir.org	<1%
46	Internet	neuron.mefst.hr	<1%
47	Internet	open.library.ubc.ca	<1%
48	Internet	repositorio.unb.br	<1%
49	Internet	www.dovepress.com	<1%
50	Student papers	University College Birmingham on 2019-04-25	<1%
51	Internet	farmaciesociala.usmf.md	<1%
52	Internet	www.readkong.com	<1%

53 Student papers

Chester College of Higher Education on 2024-09-22 <1%

54 Student papers

Oxford Brookes University on 2009-03-13 <1%

55 Student papers

University of Wisconsin - Stout on 2022-04-10 <1%

56 Publication

Yan-Yong Yin, Hui-Fang Szu, Zai-Fu Yao. "Collegiate Volleyball Athletes Exhibit Sup... <1%

57 Internet

batadora.trentu.ca <1%

58 Internet

escholarship.org <1%

59 Internet

pubmed.ncbi.nlm.nih.gov <1%

60 Internet

sfleducation.springeropen.com <1%

61 Internet

wiredspace.wits.ac.za <1%

62 Publication

"Fundamentals of Recovery, Regeneration, and Adaptation to Exercise Stress: An ... <1%

63 Student papers

AUT University on 2016-08-19 <1%

64 Publication

Dilip Ghosh, Prasad Thakurdesai. "Fenugreek - Traditional and Modern Medicinal ... <1%

65 Publication

Janis Baines, David Borradale, Janeane Dart, Leisa McCarthy et al. "Food and Nutr... <1%

66 Student papers

Kwame Nkrumah University of Science and Technology on 2016-02-05 <1%

67 Student papers

Texas Woman's University on 2018-03-04 <1%

68 Student papers

University of Hull on 2023-05-05 <1%

69 Student papers

University of Westminster on 2021-08-10 <1%

70 Internet

dspace.nwu.ac.za <1%

71 Internet

ejnpn.springeropen.com <1%

72 Internet

journal.ipb.ac.id <1%

73 Internet

repository.sustech.edu <1%

74 Internet

researchonline.ljmu.ac.uk <1%

75 Internet

theunion.org <1%

76 Internet

tmfv.com.ua <1%

77 Internet

www.ema.europa.eu <1%

78 Internet

www.imrpress.com <1%

79 Internet

www.scielo.br <1%

80 Publication

"Functional Biochemistry of Micronutrients", Springer Science and Business Medi... <1%

81 Student papers

Australian Catholic University on 2025-12-17 <1%

82 Publication

Nathalie Bergeron, Patty W. Siri-Tarino, George A. Bray, Ronald M. Krauss. "Nutrit... <1%

83 Publication

Sylven Masoga, Ntsako Wisdom Mboweni, Khutso Matlala Ramokolo. "Use of Erg... <1%

84 Publication

Danielle Gallegos, Naiyana Wattanapenpaiboon, Mark L. Wahlqvist. "Food and Nu... <1%

85 Publication

Rita S. Brause, John S. Mayher. "Search and re-search - What the inquiring teache... <1%

86 Publication

Sylvia Riedel, Keren de Buys, Abegail M. Tshivhase, Amy E. Mendham et al. "Effect... <1%

87 Student papers

University of South Wales - Pontypridd and Cardiff on 2026-03-19 <1%

88 Student papers

Wageningen University on 2018-06-29 <1%

89 Student papers

West Nottinghamshire College, Nottinghamshire on 2019-01-11 <1%

Journal Coaching Education Sports
https://doi.org/10.31599/jces.v7i1.5088
Vol. 7, No.1, May 2026, pp. 31-52
E-ISSN: 2722-3450 P-ISSN: 2775-3808

Nutrition Intervention in Bodybuilders in Limpopo Province, South Africa: Anthropometric, Serum Lipid and Micronutrient Profiles

Sylven Masoga[1*], Robert Schall[2], Peter Mphekgwana[3], Derik Coetzee[4], Elmine du Toit[1]
[1]Department of Nutrition and Dietetics, School of Health and Rehabilitation Sciences, Faculty of Health Sciences, University of the Free State, Bloemfontein, South Africa
[2]Department of Mathematical Statistics and Actuarial Science, Faculty of Natural and Agricultural Sciences, University of the Free State, Bloemfontein, South Africa
[3]Research Administration and Development, University of Limpopo, Polokwane, South Africa
[4]Department of Exercise and Sport Sciences, School of Health and Rehabilitation Sciences, Faculty of Health Sciences, University of the Free State, Bloemfontein, South Africa
e-mail: sylvenmasoga@gmail.com

Abstract
Bodybuilders follow various diets, with some posing health risks. The study aimed to determine the baseline information on serum lipids and micronutrients, implement meal plans and evaluate the impact on these profiles of bodybuilders. An intervention study was conducted with 26 affiliated bodybuilders. The study was divided into baseline, intervention and post-intervention phases. In the baseline phase, anthropometry, serum lipid and certain micronutrient profiles were measured. The intervention phase was informed by baseline results, with athletes randomly assigned either to the experimental (n=14) or control (n=12) group. The experimental group received designed meal plans for three months. The post-intervention phase repeated measurements of the same variables in the baseline. Independent t-test and Wilcoxon test were used to determine the impact of meal plans between baseline and intervention variables. Total cholesterol (TC) and triglyceride (TG) serum levels were within acceptable standards, with a mean TC of 4.2 mmol/L for the experimental group and 3.8 mmol/L for the control group, and TG of 0.8 mmol/L for the experimental group and 0.7 mmol/L for the control group. High-density lipoprotein (HDL) and low-density lipoprotein (LDL) levels were within normal ranges for both groups. Dietary micronutrient intake and serum levels were mostly within the recommended daily allowance (RDA) and tolerable upper intake level (UL) in both groups. The nutrition intervention maintained bodybuilders' serum lipid and micronutrient profiles within acceptable standards
Keywords: Bodybuilding, Lipid profile, Serum micronutrients, Nutrition intervention

corresponding author: sylvenmasoga@gmail.com
Artikel Info:
Submitted: **23/01/2026** Revised: **02/03/2026** Accepted: **09/03/2026** Published: **01/05/2026**

How to Cite: Masoga, S., Schall, R., Mphekgwana, P., Coetzee, D., Toit. (2026). Nutrition intervention in bodybuilders in Limpopo Province, South Africa: anthropometric, serum lipid and micronutrient profiles. *Journal Coaching Education Sports*, 7(1), 31-52. https://doi.org/10.31599/jces.v7i1.5088
Author's Contribution: a) Desain Penelitian; b) Pengumpulan Data; c) Analisis Statistik; d) Penyusunan Naskah; e) Pengumpulan Dana

E-ISSN: 2722-3450 P-ISSN:2775-3808

A. Introduction

Optimal nutritional status is essential for improved sport performance (Barjaktarovic-Labović et al., 2015). For bodybuilders, body fat percentage (BF%) should be minimal to demonstrate certain muscle cuts during a competition. To achieve this, bodybuilders engage in an intense training schedule and follow adapted diets or nutrition (Garthe et al., 2013; Masoga et al., 2024). Physical activity in the form of exercise is important for optimal health (Kim et al., 2024) as it is thought to improve the serum lipid profile of athletes (Rashid et al., 2023).

Also, limiting dietary intake of saturated fats reduces hepatic lipid production (Smart et al., 2024). Combination of the latter two strategies is associated with a lifelong optimal health and improved sport performance (Garthe et al., 2013). However, this rigorous training practised by bodybuilders may leave athletes with unbalanced biochemical characteristics (Melnik et al., 2022) such as serum lipid and suboptimal micronutrient levels. Furthermore, the dietary intake of these athletes is often reported insufficient for some micronutrients, for example, vitamin C and calcium (Masoga et al., 2019). These micronutrients imbalances combined with dyslipidaemia are both risk factors for the development of cardiovascular diseases (CVDs) (Galin et al., 2020; Purva et al., 2020).

To the authors' knowledge, there is a lack of published information on the biochemical profile (serum lipid and micronutrients), and nutrition intervention studies among bodybuilders in Limpopo Province, South Africa (SA). The province has a small but increasing number of athletes who are participating in bodybuilding sport on a part-time basis, particularly in the Capricorn District (Masoga et al., 2024; Masoga et al., 2023; Masoga et al., 2019).

These bodybuilders use different training techniques and adjusted diets to attain the required anthropometry for competitions. Some of the diets, however, promote imbalanced nutrient intake, which may pose a risk to altered serum lipid and micronutrient profiles of athletes. Adherence to optimal nutritional practices by athletes is recommended (Amawi et al., 2024). Therefore, this study aimed to investigate these overlooked gaps with the purpose of suggesting possible nutrition intervention in the form of optimal meal plans tailored to meet bodily and training needs of athletes.

Optimising nutrition according to bodily and training needs for competition performance and recovery (Amawi et al., 2024), and optimal health. This study contributes towards the achievement of the United Nations' Sustainable Development Goal 3.4 on good health and wellbeing (World Health Organization [WHO], 2024), which sports practitioners might find of significance.

Serum lipids

Laboratory assessment is a sensible indicator for monitoring health (Melnik et al., 2022) and risks of CVD among athletes (Bülbül et al., 2022; Umakanth & Ibrahim, 2018). Although serum lipid levels among athletes are generally assumed to be controlled (Beschasnyi et al., 2021), there remains a need to regularly monitor these lipids (Umakanth & Ibrahim, 2018). According to the World Heart Report (WHO, 2024), more than 80% of deaths is due to cardiovascular diseases in developing countries, with a higher incidence in males.

Behavioral and metabolic factors such as insufficient physical activity and increased serum lipid profile have been reported as some of the leading causes of these deaths (Di Cesare et al., 2023). Elevated serum lipids such as low-density lipoproteins (LDL) and cholesterol are linked to an elevated risk for developing

CVDs (Celik et al., 2024; Das & Ingole, 2023; Sovilj, 2012). However, these risks of CVDs are preventable through regular physical activity (Bülbül et al., 2022; Sovilj, 2012) and optimal nutrition or diet (Das & Ingole, 2023; Safari et al., 2020).

Bodybuilders use rigorous training and different diets to transform and shape the body to the required standards (Kairaitis et al., 2024; Smoliga et al., 2023; Oborný & Ferenc, 2019). This type of training used by bodybuilders is associated with increased HDL and reduced LDL (Celik et al., 2024). However, noting the practices of bodybuilders that involve intense training schedules and altered diets, it is concerning whether these athletes do control their serum lipids to optimum levels through combining strategies to confer these health benefits (Smoliga et al., 2023; Kraus et al., 2002).

72 Generally, total cholesterol (TC) and triglycerides (TG) are the two serum lipids of interest in sport (Umakanth & Ibrahim, 2018). These lipids are often assessed in combination with transport proteins called LDL, HDL and very low-density lipoproteins (VLDL) (Das & Ingole, 2023; Rashid et al., 2023; Sovilj, 2012).

The duration and intensity of training have an effect on the levels of these serum lipid parameters (Melnik et al., 2022; Rashid et al., 2023; Sovilj, 2012). Besides posing a CVD risk, serum lipids are the major contributors of energy for athletes during intense training (Purdom et al., 2018) with the TG lipid being the main energy provider (Bülbül et al., 2022). During training, serum lipids are exposed to oxidative stress from lipid peroxidation, which can negatively affect endothelial function (Beschasnyi et al., 2021). 31

However, in the presence of HDL cholesterol (HDL-C), this effect can be minimised due to its anti-inflammatory properties (Bülbül et al., 2022). This lipoprotein is thought to minimise inflammation by transporting the excess cholesterol back to the liver for excretion in bile (Das & Ingole, 2023).

Serum micronutrients

Sport training may negatively affect serum levels of micronutrients, electrolytes and minerals (Melnik et al., 2022). Therefore, athletes should consume a variety of foods to obtain optimal nutrients (Grozenski & Kiel, 2020; Bytomski, 2017). These nutrients are required for physiological and metabolic functions (Tidmas et al., 2022), energy production, haemoglobin synthesis (Ravindra et al., 2020) and maintenance of bone health (Dunford & Doyle, 2019). Optimal micronutrient consumption in heavy training sports, for example, bodybuilding, optimises training and prevents deficiencies (Odysseos & Avraamidou, 2017). Increased micronutrient requirements in sport often results from increased urine and sweat output (Carlsohn et al. 2020), including decreased intestinal absorption (Grozenski & Kiel, 2020).

Adherence to nutritionally inadequate diets or "fad diets" may further aggravate micronutrient deficiencies in some athletes (Bytomski, 2017; Thomas et al., 2016). These "fad diets" often encourage reduced consumption of essential micronutrients that are necessary for antioxidant functioning, and those needed for the conversion of carbohydrates (CHO), fat and protein to usable energy (Grams et al., 2016). Micronutrient deficiencies often influence athletes' general health and sport performance (Wardenaar et al., 2017). Different micronutrients can be implicated for bodybuilding athletes; however, this research focused on selected vitamins and minerals identified as vital in sport.

Water-soluble vitamins

Water-soluble vitamins such as the vitamin B group and vitamin C are essential in facilitating metabolic processes and prevent cell destruction during exercise (Ghazzawi et al., 2023; Brancaccio et al., 2022; Kerksick et al., 2018). These vitamins can be classified on

E-ISSN: 2722-3450 P-ISSN:2775-3808

solubility and according to their effects on energy metabolism, red blood cell formation, antioxidant function, and growth and development (Dunford & Doyle, 2019). For example, vitamin C is water-soluble (Escalante et al., 2021) and an antioxidant (Kerksick et al., 2018).

The antioxidant properties of vitamin C include scavenging of free reactive oxygen species (ROS) and reducing vascular inflammation (Pietrzak et al., 2020). In addition, vitamin C promotes collagen synthesis and facilitates glycogen storage (Bytomski, 2017). Accordingly, bodybuilding athletes can benefit from this vitamin as their training generally stimulates increased oxidative stress (Pietrzak et al., 2020; Heaton et al., 2016). Furthermore, vitamin C is used by bodybuilders during the "peak week" to induce the loss of bodily fluids, given its diuretic effect (Chappell & Simper, 2018). To obtain the antioxidant effects of vitamin C, intake of approximately ≤ 250 mg/day is recommended (Carlsohn et al., 2020).

In sport, however, doses of 500–1000 mg may be feasible to prevent inflammation within 12–24 hours leading to the competition (Escalante et al., 2021). Noting possible adverse effects of high vitamin C doses such as stimulating renal stones (Chappell & Simper, 2018) and osmotic diarrhoea (Escalante et al., 2021) in human health, athletes are advised to limit intake to the recommended dose (Grozenski & Kiel, 2020). On the other hand, athletes should maintain serum vitamin C levels of 0.40–0.99 mg/dL to achieve the stipulated protective effects (Tian et al., 2022).

Similarly, the B-vitamins are significant in sport as they participate in the body's chemical reaction and energy systems, particularly thiamine (B1) and riboflavin (B2) (Inês, 2019). Therefore, the need for these vitamins may increase with an increase in energy intake (Carlsohn et al., 2020; Inês 2019). B-complex vitamins, particularly vitamin B1, is responsible for conversion of carbohydrates (CHO) into usable energy for the muscles (Inês, 2019). Another important micronutrient in sport is vitamin B12 that is responsible for red blood cell formation (Krzywański et al., 2020) and repair of damaged tissues (Ravindra et al., 2020). Due to sports anaemia that is common among athletes, vitamin B12 is required for red blood cell formation (Krzywański et al., 2020).

Minerals and vitamin D

Minerals are important for structural tissue development (Guleria et al., 2018). Calcium and fat-soluble vitamin D are responsible for constructing bone structure (Madden et al., 2017). Athletes adhering to diets restrictive of some nutrients for a prolonged period or female athletes undergoing menstrual cycles, may encounter, for example, calcium deficiencies (Grozenski & Kiel, 2020). These calcium deficiencies among athletes often impose a risk of stress-related osteopenia and eventually osteoporosis (Ravindra et al., 2020). As a result, athletes should maintain optimal serum calcium levels of 2.10–2.50 mmol/L to prevent undesirable bone-related outcomes (Cooper & Gittoes, 2008). Furthermore, training reduces serum calcium levels due to increased dermal loss (Sale & Elliott-Sale, 2019).

Linked to calcium is vitamin D (Grozenski & Kiel, 2020), which also regulates bone health and inflammation (Bytomski, 2017). Vitamin D facilitates the absorption and metabolism of calcium and phosphorus (Grozenski & Kiel, 2020; Kreider et al., 2010) and improves muscle strength (Kerksick et al., 2018). While this vitamin may be activated from the cholesterol in the body through ultraviolet light, dietary sources can cover 10% of vitamin D requirements when consumed optimally (Carlsohn et al., 2020; Grozenski & Kiel, 2020).

Although controversies remain around optimal serum vitamin D levels for athletes, values of 50–125 nmol/L (20–50 ng/mL) are considered optimal (Carlsohn et al., 2020; Sikora-Klak et al., 2018; Larson-Meyer & Willis, 2010;). Athletes should avoid a state of insufficient serum vitamin D levels (12–19 ng/ml) as this triggers metabolic reactions that maximise calcium resorption from the bones, posing a risk for osteoporosis (Larson-Meyer & Willis, 2010).

Magnesium (Mg) is another mineral of importance in sport as it supports the neuromuscular system functions and prevents cramps (Ravindra et al., 2020). The use of supplementary Mg is common practice among bodybuilders (King et al., 2021), although this practice is not entirely supported (Garthe & Maughan, 2018).

Therefore, it was of interest to establish the profile of anthropometry, serum lipids and micronutrients among bodybuilding athletes and further develop meal plans for intervention to encourage optimal health and maintenance on these profiles. Information from this research may assist bodybuilders and other athletes in making informed decisions about their overall health and wellbeing while involved in sport. The objective of the research was to provide a platform to establish sport health discussions on biochemical parameter dynamics, particularly in bodybuilders and athletes in other sporting codes.

B. Methods

An intervention case-control study design was carried out to purposively recruit 54 part-time bodybuilders in Capricorn district, Limpopo Province. These athletes were affiliates of the International Fitness and Bodybuilding Federation (IFBB) in SA. Ethics approval to conduct the study was obtained from the University of the Free State Health Science Research Ethics Committee (ethics clearance number UFS-HSD2020/1680/2302), while permission was sought from IFBB Limpopo, gymnasiums management and bodybuilding coaches.

Of the 54 athletes recruited, 26 (48.1%) consented for blood withdrawal. The other 28 athletes discontinued due to cultural and religious sensitivity around blood withdrawal. Athletes signed an informed consent form before participating in the study. The study took place in the off-season (non-competitive) period and was divided into the baseline, intervention and post-intervention phases (described subsequently). The micronutrient intake and anthropometric profiles of athletes were collected in various gymnasiums (gyms) in the afternoons (16h00 – 18h00) while the biochemical profiles were collected at the Laboratory in the morning between 08h00 and 10h00.

Baseline

In the baseline phase, the general characteristics of the 26 athletes, such as age, gender and training profile were collected. The anthropometric status of athletes which included weight and height to calculate body mass index, body fat percentage (BF%) and waist circumference (WC) were measured. Digital scale 813 with high capacity and portable stadiometer 213 from SECA were used to measure weight and height respectively. Body composition was measured using non-stretchable ergonomic circumference measuring tape and Harpenden skinfold calliper from SECA.

Measurements were conducted at various gymnasiums in accordance with standards by International Society of Advancement for the Kinanthrometry (ISAK). Micronutrient intake was determined from the athletes' dietary information collected using two separate 24-hour-recall questionnaires, one during the week and the other over the weekend. The record was filled by the researchers while athletes were in the food and beverage recall process. Food mannequins (from Nesco company) and marked household food utensils were used to assist athletes in quantifying food or fluids consumed. The 24-hour-recall

E-ISSN: 2722-3450 P-ISSN:2775-3808

questionnaire was validated by Food Frequency Questionnaire (FFQ).

Biochemical profiles were measured on different appointment days immediately following dietary data collection of each athlete. These profiles included serum lipids (lipogram) included TG, TC, LDL, HDL and VLDL, and micronutrients which comprised selected vitamins and minerals in sport such as vitamins C, B1, B12, D, Mg and calcium (Ca2+). The specimens to determine these biochemical parameters were collected by a phlebotomist at Ampath Laboratories, a private pathology service, Limpopo Province (Polokwane city), in the morning after a fasting period of 10–12 hours. The researchers arranged with the laboratory a day before each group of athletes was brought for withdrawals to minimise waiting and anxiety.

Measurements were collected in a quiet consulting room of the laboratory. Results obtained in this phase informed the design of meal plans for intervention. These meal plans were determine using the bodybuilding weight categories following energy and macronutrient recommendations stipulated by the International Society of Sports Nutrition (ISSN) (2018). The meal plan incorporated the South African Food Based Dietary Guideline (SAFBDG) messages (Voster et al. 2013) and incorporated indigenous foods of the area.

Intervention

In the intervention phase, 26 athletes were randomly assigned to the intervention (experimental; n=14; 54%) and control (n=12; 46%) groups. The intervention group was provided with meal plans according to body weight categories based on guidelines by the IFBB (IFBB, 2024). The meal plans were designed by the researchers (registered dietitians) in accordance with principles or messages by the South African Food-Based Dietary Guidelines (SAFBDG) (Vorster et al., 2013) and incorporated certain indigenous food items such as African green leafy vegetable given their consumption popularity in the area (Rankoana, 2021; Faber et al., 2010).

Calculations of the nutritional requirements for these meals adhered to the recommendations by the International Society of Sports Nutrition (ISSN) (Kerksick et al., 2018). The macronutrient distribution ranges of the meal plan were analysed for adequacy. These meal plans were further evaluated and approved for nutritional adequacy by experts in the field of dietetics and nutrition.

Athletes in the intervention group were administered with the suggested meal plans according to their weight categories and monitored for compliance at least three times a week while those in the control group were being observed on their routine practices. During monitoring, athletes were inquired of any dietary difficulties brought by the meal plans. Athletes mostly inquired about food alternatives from the indigenous category to match or substitute nutrient values.

Adherence was further encouraged through continuous nutrition education on the SAFBDG and by collection of the 24-hour-recall intake at random visit days. On the other hand, the control group only received nutrition education. The intervention period lasted for three months which was followed by the post-intervention period.

Post-intervention phase

The post intervention phase involved measurement of the variables similar to those in the baseline to determine the effects of nutrition intervention (meal plans). Procedures and tools applied in the baseline phase were repeated again the post-intervention phase for reliability. Twenty-six athletes participated in this phase, as the experimental (n=14; 54%) and control (n=12; 46%) groups. The post-intervention phase took place at various gyms for dietary data collection and the laboratory for biochemical parameters. This phase lasted for two months given the diverse group of athletes the study had.

Data analysis

Micronutrients intake of athletes was analysed using the South African Food Finder Software (version 3) (Medical Research Council; Cape Town, South Africa). The mean micronutrient intake of the 24-hour recalls was considered for further analysis. Biochemical profile for serum lipids and micronutrients was analysed by the Ampath Laboratory Medical Scientist and results issued for each athlete within 24-hours. The Statistical Package for Social Sciences (SPSS) (IBM SPSS Statistics for Windows, v-28.0; Armonk, NY, USA) was used to analyse anthropometric, micronutrients intake and biochemical data for each athlete in the baseline and post-intervention phases.

Descriptive statistics (means and standard deviations) were used to report general characteristics, anthropometry, and biochemical profiles of athletes in the baseline and post-intervention phases. The independent t-test (normally distributed data) and non-parametric, Wilcoxon signed rank test (for skewed data) were calculated to characterise the developments and compare means among variables of the intervention and control groups respectively. The p-value was set at 0.05 for variables to be significant to each other with confidence interval of 95%.

The WHO (2011) standards, Dunford and Doyle (2018) guidelines, and recommendations by Larson-Meyer et al. (2018) and the Institute of Medicine (US) Panel on Dietary Antioxidants and Related Compounds (2000) were used to evaluate the participants' anthropometric status, serum lipids and micronutrients. Results obtained during the baseline were compared to those in the post-intervention phase for the entire group (Table 1 – 4) and as also as randomised into intervention and control groups (Table 5 – 8). and are reported as below, within or above standards or recommendations..

C. Result and Discussion

Result

The study included 26 bodybuilders, of whom 21 (80.8%) were male. The mean (SD) age was 23.4 (3.4) years. With regard to level of education, the athletes either had grade 12 (male 42.8%; female 20%) or a tertiary degree (male 47.6%; female 60.0%). However, the majority were unemployed (male 76.2%; female 100%). Less than half of the males (42.8%) and 60% of females used ergogenic substances. Athletes participated in bodybuilding sport for a mean period of 2.1 (0.9) years, training once (1.5 [0.5]) per day; three times per week (3.5 [0.9] times) at baseline. On average, athletes spent two hours per day on training (males, 2.2 hours versus 2.0 hours for females). Athletes showed no statistically significant change ($p<0.05$) from baseline in the frequency of training per day or week between males and females in either the intervention or control group.

Table 1 shows the anthropometric characteristics of athletes at baseline and post-intervention. On average, athletes had normal anthropometry. Body mass index (BMI) was within standards for both male and female participants at baseline and slightly increased for males at the post-intervention phase. The BF% for males were also slightly above recommendations both at baseline and post-intervention. The athletes' waist circumference (WC) was within normal limits. Similarly, athletes had acceptable anthropometry during the post-intervention phase.

Table 1. The anthropometry of athletes at baseline and post-intervention (N=26).

Variable	Gender	Range Min–Max	Mean (SD)	Reference values (WHO, 2011)
Baseline				
Height (cm)	Male (n=21)	152.0–184.0	169.4 (7.5)	

E-ISSN: 2722-3450 P-ISSN:2775-3808

Variable	Gender	Range Min–Max	Mean (SD)	Reference values (WHO, 2011)
	Female (n=5)	155.0–164.0	158.6 (3.4)	
Weight (kg)	Male (n=21)	51.7–88.0	69.6 (10.4)	
	Female (n=5)	44.3–71.9	60.9 (12.9)	
BMI (kg/m^2)	Male (n=21)	19.2–32.6	24.4 (2.9)	<18.5 underweight
	Female (n=5)	19.9–29.3	24.2 (4.4)	18.5–24.9 normal 25–29.9 overweight
BF%	Male (n=21)	4.8–25.0	10.1 (11.2)	5–8%*
	Female (n=5)	11.2–22.7	14.6 (4.6)	10–15%*
WC (cm)	Male (n=21)	65.0–95.5	75.5 (7.5)	< 88 cm
	Female (n=5)	61.0–95.5	74.5 (8.7)	< 101 cm
Post-intervention (after 3 months)				
Height (cm)	Male (n=21)	152.0–184.0	169.4 (7.5)	
	Female (n=5)	155.0–164.0	158.6 (3.4)	
Weight (kg)	Male (n=21)	53.8–112.3	73.6 (12.0)	
	Female (n=5)	52.2–68.4	61.2 (6.8)	
BMI (kg/m^2)	Male (n=21)	21.0–31.6	25.2 (2.8)	<18.5 underweight
	Female (n=5)	21.0–25.4	23.9 (1.9)	18.5–24.9 normal 25–29.9 overweight
BF%	Male (n=21)	3.9–26.2	8.9 (4.7)	5–8%*
	Female (n=5)	9.0–17.0	13.3 (2.9)	10–15%*
WC (cm)	Male (n=21)	69.0–93.0	79.0 (6.5)	< 88 cm
	Female (n=5)	68.5–83.0	76.1 (5.7)	< 101 cm

*Jeukendrup and Gleeson (2019).
BF%, body fat percentage; BMI, body mass index; cm, centimeter; kg, kilogram; kg/m^2, kilogram per meter squared; Min–Max, minimum and maximum; SD, standard deviation; WC, waist circumference; WHO, World Health Organization.

According to Table 2, the baseline dietary micronutrients intake was imbalanced. The calcium intake was notably lower in females compared to males in the baseline. However, both genders had lower intake in the post intervention phase. Conversely, both genders consumed vitamin D below the recommended daily allowance (RDA) while vitamin B_{12} and Mg were mostly consumed above the tolerable upper intake levels (UL). The intake of vitamin C and B_1 was within recommendations in both genders during the base line and post-intervention phases.

Table 2. Dietary micronutrient intakes of athletes at baseline and post-intervention (N=26).

Variable	Gender	Range Min–Max	Mean (SD)	RDA*	UL
Baseline					
Calcium (mg/day)#	Male (n=21)	115.0–4 811.0	1 033.6 (1 142.3)	1000	2500
	Female (n=5)	33.0–1 286.0	639.2 (484.4)	1000	
Magnesium (mg/day)	Male (n=21)	57.0–965.0	489.0 (218.5)	400	420
	Female (n=5)	8.6–527.0	291.5 (89.0)	310	321
Vitamin C (mg/day)	Male (n=21)	3.0–168.0	57.8 (50.3)	90	2000
	Female (n=5)	12–170.0	89.0 (77.3)	75	
Vitamin D (µg/day)#	Male (n=21)	0.5–45.4	12.0 (12.7)	15	100
	Female (n=5)	7.2–28.7	11.7 (9.4)	15	
Vitamin B_1 (mg/day)	Male (n=21)	0.2–5.6	1.9 (1.3)	1.2	–
	Female (n=5)	0.1–3.9	1.5 (1.4)	1.1	
Vitamin B_{12} (µg/day)	Male (n=21)	0.0–46.9	10.6 (10.7)	2.4	–

Variable	Gender	Range Min–Max	Mean (SD)	RDA*	UL
	Female (n=5)	5.6–10.4	7.9 (1.9)	2.4	
Post-intervention (after 3 months)					
Calcium (mg/day)	Male (n=21)	141.0–2 390.0	805.5 (544.1)	1 000	–
	Female (n=5)	29.1–1 286.0	775.2 (540.5)	1 200	
Magnesium (mg/day)	Male (n=21)	228.0–3415.0	549.7 (671.4)	400	420
	Female (n=5)	288.0–527.0	384.4 (105.5)	310	321
Vitamin C (mg/day)	Male (n=21)	422.0–50.5	143.2 (111.3)	90	2000
	Female (n=5)	56.0–371.0	183.4 (119.8)	75	
Vitamin D (µg/day)#	Male (n=21)	0.3–49.0	12.8 (11.1)	15	100
	Female (n=5)	11.7–28.7	19.3 (6.5)	15	
Vitamin B_1 (mg/day)	Male (n=21)	0.0–2.1	1.4 (0.5)	1.2	–
	Female (n=5)	1.0–5.2	2.2 (1.6)	1.1	
Vitamin B_{12} (µg/day)	Male (n=21)	0.0–51.4	9.2 (12.9)	2.4	–
	Female (n=5)	6.6–19.5	11.1 (5.0)	2.4	

*Institute of Medicine (US) Panel on Dietary Antioxidants and Related Compounds (2000).
#Ross et al. (2011).
mg/day, milligram per day; µg/day, microgram per day; Min–Max, minimum and maximum; RDA, recommended daily allowance; SD, standard deviation; UL, tolerable upper intake level.

Table 3 summarises the athletes' serum lipid levels. The mean TC and TG levels were within acceptable standards both at baseline and post-intervention. However, males had higher levels of HDL-C (mean 1.4 [0.3] mmol/L) compared to the recommended range of 1–1.3 mmol/L. Also, at baseline, the athletes had higher mean VLDL-C levels (males, 1.3 mmol/L and females, 1.6 mmol/L) than the standard (< 1.0 mmol/L), which decreased when measured post-intervention. The other serum lipid levels were maintained within acceptable standards in the post-intervention phase, except for LDL-C which was lower than 2.5–3.3 mmol/L in both genders.

Table 3. Serum lipid profile of athletes (N=26).

Variables	Gender	Range Min–Max	Mean (SD)	Cut-off values*
Baseline				
Triglycerides (mmol/L)	Male (n=21)	0.4–1.7	0.7 (0.3)	< 1.7
	Female (n=5)	0.4–2.2	1.1 (0.7)	
Total cholesterol (mmol/L)	Male (n=21)	2.7–6.6	4.4 (0.8)	< 5.1
	Female (n=5)	2.2–5.1	3.8 (1.1)	
HDL-C (mmol/L)	Male (n=21)	0.6–2.5	1.4 (0.3)	1–1.3
	Female (n=5)	1.3–1.8	1.4 (0.2)	1.3–1.5
LDL-C (mmol/L)	Male (n=21)	1.2–4.9	2.7 (0.8)	2.5–3.3
	Female (n=5)	0.6–3.4	1.9 (1.1)	
VLDL-C (mmol/L)	Male (n=21)	0.3–3.6	1.3 (1.0)	<1.0
	Female (n=5)	0.1–3.6	1.6 (1.4)	
Post-intervention (after 3 months)				
Triglycerides (mmol/L)	Male (n=21)	0.3–2.0	0.8 (0.3)	<1.7
	Female (n=5)	0.4–1.0	0.6 (0.2)	
Total cholesterol (mmol/L)	Male (n=21)	2.0–6.3	4.1 (0.9)	<5.1
	Female (n=5)	2.3–4.6	3.7 (1.0)	
HDL-C (mmol/L)	Male (n=21)	1.0–1.8	1.3 (0.2)	1–1.3
	Female (n=5)	1.1–1.6	1.3 (0.1)	1.3–1.5
LDL-C (mmol/L)	Male (n=21)	0.9–4.4	2.4 (0.8)	2.5–3.3

E-ISSN: 2722-3450 P-ISSN:2775-3808

Variables	**Gender**	**Range Min–Max**	**Mean (SD)**	**Cut-off values***
	Female (n=5)	0.8–2.9	2.0 (1.1)	
VLDL-C (mmol/L)	Male (n=21)	0.2–1.0	0.6 (0.2)	<1.0
	Female (n=5)	0.2–0.8	0.5 (0.2)	

*Larson-Meyer et al. (2018).
HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; Min-Max, minimum and maximum; mmol/L, millimoles per liter; SD, standard deviation; VLDL-C, very low-density lipoprotein cholesterol.

The serum micronutrients of athletes at baseline are shown in Table 4. The median micronutrient levels of the athletes were within acceptable standards at baseline. Athletes maintained their serum micronutrient levels within acceptable standards at post-intervention investigations.

Table 4. Serum micronutrient levels of athletes at baseline and post-intervention (N=26).

Variable	**Gender**	**Range Min–Max**	**Median***	**Reference values#**
Baseline				
Calcium (mmol/L)	Male (n=21)	2.2–2.5	2.3	2.15–2.50
	Female (n=5)	2.3–2.5	2.3	
Magnesium (mmol/L)	Male (n=21)	0.7–0.9	0.8	0.66–1.07
	Female (n=5)	0.7–0.8	0.8	
Vitamin C (nmol/L)	Male (n=21)	20.9–50.6	32.5	10.0–45.1
	Female (n=5)	23.5–50.6	44.9	
Vitamin D (nmol/L)	Male (n=21)	15.1–40.4	29.5	20–60
	Female (n=5)	22.5–34.1	24.3	
Vitamin B_1 (nmol/L)	Male (n=21)	8.8–18.2	12.6	6.65–20.0
	Female (n=5)	10.3–15.2	12.6	
Vitamin B_{12} (pmol/L)	Male (n=21)	106–521.0	279.0	107–418
	Female (n=5)	114.0–521.0	266.8	
Post-intervention (after 3 months)				
Calcium (mmol/L)	Male (n=21)	2.2–2.5	2.3	2.15–2.50
	Female (n=5)	2.3–2.5	2.3	
Magnesium (mmol/L)	Male (n=21)	0.7–0.9	0.8	0.66–1.07
	Female (n=5)	0.7–0.8	0.8	
Vitamin C (nmol/L)	Male (n=21)	20.9–50.6	32.5	10.0–45.1
	Female (n=5)	23.5–50.6	41.7	
Vitamin D (nmol/L)	Male (n=21)	15.1–83.0	29.5	20–60
	Female (n=5)	22.5–34.1	24.3	
Vitamin B_1 (nmol/L)	Male (n=21)	8.8–18.2	12.6	6.65–20.0
	Female (n=5)	10.3–15.2	12.3	
Vitamin B_{12} (pmol/L)	Male (n=21)	106.0–789.0	279.0	107–418
	Female (n=5)	114.0–521.0	265.0	

*Wilcoxon test; #Larson-Meyer et al. (2018).
Min–Max, minimum and maximum; mmol/L, millimoles per liter; nmol/L, nanomoles per liter; pmol/L, picomoles per liter.

Table 5 shows that after the intervention, athletes in the experimental group had a normal BMI (mean 24.7 [2.7] kg/m^2) compared to the control group (mean 25.3 [2.6] kg/m^2). The BF% of athletes in both the experimental and control groups were higher than recommendations for bodybuilding sport. However, athletes in all groups (experimental and control) had acceptable WC values. There was no significant difference between the two groups regarding their anthropometry.

Table 5. Bodybuilders' post-intervention anthropometric profile: comparison of the experimental and control group (N=26).

Variables	Experimental group (n=14)		Control group (n=12)		P-value
	Range (Min–Max)	Mean (SD)	Range (Min–Max)	Mean (SD)	
Height (cm)	156.0–180.0	168.7 (7.2)	154.0–179.0	166.9 (8.2)	0.568
Weight (kg)	52.2–86.3	70.8 (9.8)	53.8–112.3	71.8 (14.8)	0.830
BMI (kg/m^2)	21.0–31.6	24.7 (2.7)	21.0–31.0	25.3 (2.6)	0.610
BF%	5.0–15.0	9.0 (3.3)	3.9–26.2	10.7 (5.9)	0.368
WC (cm)	68.5–92.0	79.4 (6.8)	69.0–93.0	77.3 (1.7)	0.428

BF%, body fat percentage; BMI, body mass index; Min–Max, minimum and maximum; SD, standard deviation; WC, waist circumference.

The post-intervention dietary micronutrient intake of athletes is summarised in Table 6. Vitamins C, D and B_{12} were consumed within the RDA, but lower than the UL in both the experimental and control group, while calcium intake was suboptimal in both groups. Conversely, Mg and vitamin B_1 were consumed excessively. There was a statistically significant difference observed between the two groups for vitamin D consumption.

Table 6. Dietary micronutrients profile post-intervention: comparison of the experimental and control group (N=26).

Variables	Experimental group (n=14)		Control group (n=12)		P-value*
	Range (Min–Max)	Median	Range (Min–Max)	Median	
Calcium (mg/day)	29.1–1 289	937.0	314.0–2 390.0	733.0	0.810
Magnesium (mg/day)	228.0–3415.0	462.0	256.0–715.0	357.0	0.271
Vitamin C (mg/day)	30.0–3460	153	26.0–422.0	92.0	0.616
Vitamin D (mg/day)	2.5–45.9	15.2	0.3–32.4	7.9	0.021*
Vitamin B_1 (mg/day)	0.0–5.2	1.7	0.6–2.0	1.2	0.142
Vitamin B_{12} (mg/day)	0.0–39.9	7.7	1.2–51.4	9.4	0.566

*Wilcoxon test ($p<0.05$). Min–Max, minimum and maximum.

In Table 7, almost all athletes in the experimental and control groups had normal serum lipid profiles within the recommended standards. There was no statistically significant difference between the experimental and control groups.

Table 7. Serum lipid profile post-intervention: comparison of the experimental and control group (N=26).

Variables	Experimental group (n=14)		Control group (n=12)		P-value*
	Range (Min–Max)	Mean (SD)	Range (Min–Max)	Mean (SD)	
Triglycerides (mmol/L)	0.3–2.0	0.8 (0.4)	0.4–1.1	0.7 (0.1)	0.580
Total cholesterol (mmol/L)	3.0–6.3	4.2 (1.0)	2.3–5.2	3.8 (0.8)	0.305

E-ISSN: 2722-3450 P-ISSN:2775-3808

Variables	Experimental group (n=14)		Control group (n=12)		P-value*
	Range (Min–Max)	Mean (SD)	Range (Min–Max)	Mean (SD)	
HDL-C (mmol/L)	1.1–1.8	1.3 (0.2)	1.1–1.7	1.3 (0.2)	0.928
LDL-C (mmol/L)	0.8–4.4	2.4 (0.8)	0.9–4.4	2.3 (0.9)	0.859
VLDL-C (mmol/L)	0.2–1.5	0.7 (0.2)	0.2–0.9	0.5 (0.2)	0.113

HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; Min–Max, minimum and maximum, SD, standard deviation; VLDL-C, very low-density lipoprotein cholesterol.

According to Table 8, athletes in both groups maintained their serum micronutrient levels within the recommended ranges, and no statistically significant difference occurred between the experiment and the control group.

Table 8. Serum micronutrients profile of athletes' post-intervention (N=26).

Variables	Experimental group (n=14)		Control group (n=12)		P-value*
	Range (Min–Max)	Median	Range (Min–Max)	Median	
Calcium (mmol/L)	2.3–2.5	2.4	2.2–2.5	2.3	0.142
Magnesium (mmol/L)	0.7–0.9	0.8	0.7–0.9	0.8	0.994
Vitamin C (nmol/L)	21.2–50.6	35.9	20.9–50.6	36.7	0.271
Vitamin D (nmol/L)	21.9–28.3	25.3	15.1–39.7	27.4	0.382
Vitamin B_1 (nmol/L)	8.8–14.3	13.3	10.1–18.2	14.5	0.375
Vitamin B_{12} (pmol/L)	118.0–704.0	289.5	106.0–789.0	447.5	0.896

*Wilcoxon test. Min–Max, minimum and maximum.

Discussion

To our knowledge, this study is the first to investigate the serum lipid and micronutrient profiles of bodybuilding athletes in the Limpopo Province of South Africa. Athletes had normal anthropometric status, optimal serum lipid and micronutrient profiles at baseline. They maintained the status for WC, serum lipid, serum micronutrients into the post-intervention phase.

Although not statistically significant, athletes in both the intervention and control group had slightly higher BMI and BF%, with optimal WC in both groups. Varying body composition results from experimental studies supporting our findings were also reported among athletes elsewhere. For instance, a study in Brazil compared 11 male bodybuilders (mean age 26.8 [2.3] years) assigned either to an experimental (high energy intake: mean 67.5 [1.7] kcal/kg/day; n=6) or control (lower energy intake: mean 50.1 [0.5] kcal/kg/day; n=5) group over a period of six weeks (Ribeiro et al. 2019).

This study reported a significant change (increase) of BF% (p<0.01) in higher amount of energy group during from the pre-intervention (mean 16.2 [4.6] to the post-intervention phase (17.4% [4.6]) compared to the moderate energy group (mean 13.3% [2.7] pre-intervention and 13.4% [2.6] post-intervention).

In another study, body composition of four amateur bodybuilders was evaluated for a two months' pre-contest preparation period (De Souza et al., 2018). In this study, athletes showed lower BF% during the pre-contest phase (male one, 4%; male two, 8.6%; female one, 17.3%; female two, 8.9%) compared to pre-cutting values (male one, 13.3%; male two, 17.4%; female one 23.6%, female two 18%). However, higher

BF% was reported among novice and elite groups in another study involving 20 bodybuilders (10 elite and 10 novice) in Thailand (Sukwong et al., 2022). It is possible that the increased BF% in the latter study could have resulted from using anabolic steroids, which is common among bodybuilding athletes (Smoliga et al. 2023).

Significant variations with regard to BF% between 29 male professional competitive and amateur bodybuilders were reported (Makiel et al., 2020). In the latter study, professional bodybuilders had lower BF% (5.6% [3.5]) compared to the amateur group (18.7% [5.6]). However, the professional athletes had increased BMI (27.2 kg/m2) values compared to the amateur group (25.2 kg/m2). The primary goal of bodybuilding athletes is to increase muscle mass, possibly explaining the BMI results in our study and those reported by Makiel et al. (2020).

Although specific training programs followed by athletes in our study were not extensively studied as per se, researchers acknowledge the role physical activity might have contributed towards the control of serum lipids to within acceptable standards (Celik et al., 2024; Melnik et al., 2022; Dunford & Doyle 2019; Sovilj, 2012). Engaging in vigorous intensity physical activity in the form of, for instance, bodybuilding training for 75–150 minutes two or more days a week, has been associated with additional health benefits (WHO, 2020), optimal serum lipid levels (Celik et al., 2024) and improved body composition (Garthe et al., 2013).

We suspect that the post-intervention outcomes of the current research might partly be explained by the training frequency of three days per week that these athletes adhered to. The training frequency observed in the current study might have possibly been influenced by the nutrition education offered to athletes on the SAFBDG (2013) during the intervention phase.

The education encouraged, among others, physical activity in the form of exercise for three days or more to accomplish optimal health benefits. The effect of training on serum lipid improvements is supported in the literature (Barakat et al., 2020; Barjaktarović-Labović et al., 2015; Celik et al., 2024; Elsayyad et al., 2015). Therefore, a combination of training with practice of optimal nutrition can be assumed to make a positive contribution towards serum lipids and body composition control.

We found that athletes in our study had the required level of BF% for bodybuilding sports, which is associated with improved cardiovascular functioning and controlled serum lipids (Turocy et al., 2011). The decreased BF% with increased muscle mass in bodybuilding is associated with success during competitions (Barakat et al., 2020). In this study, athletes' lipid profile was mostly within acceptable standards at baseline and post-intervention phases. Although intake of energy and macronutrients were reported imbalanced in this group (Masoga et al., 2023), results in the current study are not surprising as athletes mostly mentioned boiling and steaming as their primary methods of cooking their foods.

These cooking methods are thought to minimise the intake of trans-fatty acids as divergent to deep frying, which suppresses HDL-C and increases LDL-C (Dunford & Doyle, 2019), explaining the lipid outcomes in this study. Additionally, the athletes' breakfast as suggested in the meal plans included food items such as oats, known to contain soluble fibre. This could also have contributed towards the control of the serum lipids as this fibre is thought to reduce the absorption of cholesterol and fatty acids (Reamy & Thompson, 2004), ultimately improving the TC serum levels (Hannon et al., 2018).

During the delivery of nutrition education, athletes in our study were encouraged to trim off fat from food items such as meat and poultry, avoid processed food products that may contain hidden fats, consume plant protein and oils, and

E-ISSN: 2722-3450 P-ISSN:2775-3808

~~consume more fruit and vegetables. Our~~ results were different from findings reported by De Souza et al. (2018), who investigated the biochemical profile and body composition alteration among four amateur athletes (two male and two female) during the pre-contest phase. Their results showed increased levels of serum lipids (TC, LDL-C and decreased HDL-C) in females compared to baseline values. The use of anabolic androgen steroids (AAS) is a common practice among bodybuilders (Smoliga et al. 2023). Therefore, the increased serum lipid levels among females in the study by De Souza et al. (2018) could possibly be explained by the use of AAS reported in that group.

Dietary intake of same athletes was also investigated and imbalanced nutrients (suboptimal energy and carbohydrates, optimal protein and increased fat) intake of were reported elsewhere (Masoga et al., 2023). In the report by Masoga et al. (2023), limited use of supplements among athletes (40%) was reported as well. The dietary micronutrients intake analysis in the current revealed optimal intakes with reference to the RDAs and UL for vitamins C and B1, including Ca for males, at baseline. Similar results were found during a 12-week study investigating the dietary strategies of 16 male modern bodybuilders (Lenzi et al., 2021). In their research, athletes' vitamin C (174.1 [114.5] mg/day [bulking] versus 162.2 [311.1] mg/day [cutting]) intake was optimal (higher than RDAs but lower than UL) in all phases of the quasi-experimental research.

In another study conducted among 52 bodybuilders in Polokwane municipality, athletes consumed vitamin C optimally (Masoga et al., 2019). Conversely, athletes in our research consumed vitamins C, and B1 optimally, while calcium and Magnesium intake was suboptimal and excessive in both the experimental and control group. Optimal intake of vitamin C is beneficial to reduce risks associated with kidney stones formation and gastrointestinal symptoms ~~such as diarrhoea (FAO/WHO, 2001), and~~ promote the training recovery process (Close et al., 2006).

Minerals such as Mg offer antioxidant benefits while participating in many cellular metabolic processes (Lee, 2017). However, hypermagnesemia can induce diarrhoea and kidney malfunction and substantially reduces the absorption of calcium (Dunford & Doyle, 2019). Vitamin D intake was imbalanced between the groups (optimal in the experimental group versus suboptimal in the controls). Optimal vitamin D status has been linked to various health benefits including calcium phosphate regulation (El Hoss et al., 2023).

Excessive oral intake of water-soluble vitamins has minimal risks (Richardson, 2014) as are readily excreted due to its solubility (Rafeeq et al., 2020). Generally, excessive intake of Mg and vitamins such as vitamins C, and B1 is unusual among athletes (Dunford & Doyle, 2019), particularly in bodybuilders around the Limpopo province. For instance, optimal intake of vitamins B1 and Mg was reported in a study among the 52 bodybuilding athletes (Masoga et al., 2019). This was also the case regarding the serum micronutrients findings in our group as micronutrients (calcium, Mg, vitamins C, D and B1) were retained within acceptable standards among almost all athletes (experimental and control group).

Excesses for vitamin B12 were observed in the control group which can be explained by frequent intake of dairy products, fish and chicken, which appeared on the 24-hour-recall questionnaires of athletes. These food items are rich sources of B12, thus preventing possible development of anaemia (Watanabe et al., 2014) in this group. Excessive serum levels of vitamin B12 (5.3 [3.8] versus 4.7 [4.9] µg/day) were reported among bodybuilders during bulking and cutting phases (Lenzi et al., 2021).

Training is considered to alter serum biomarkers (Melnik et al., 2022). Although increased consumption of

4 vitamin C might be prominent during training, the solubility nature (water-soluble) and increased oxidative role it plays and vulnerability to excretion during training could be the reasons explaining suboptimal serum levels of this vitamin in our group. Optimal vitamin D levels were expected in our group as ultraviolet B (UVB) exposure from the sun may have served as a boost (Ghazzawi et al., 2023) as athletes resided in a country that exposed 10 them to sufficient ultraviolet B (UVB) sunlight for promoting vitamin D synthesis (Wright et al., 2012).

Generally, laboratory intervention studies involving blood withdrawal are rarely conducted among bodybuilders in Limpopo. Therefore, trypanophobia (fear or phobia for needles) was a barrier for many of our participants. Of the total who participated (n=54), less than half (n=26) completed the study. Lastly, other biochemical variables such as hormonal, kidney and liver tests could not be measured due to budget constraints

D. Conclusion

8 The aim of this study was to assess the effect of nutrition intervention on the serum lipid and micronutrient profiles of bodybuilding athletes in Capricorn District. Bodybuilding athletes in this area had mostly normal anthropometric status and optimal serum lipid levels. However, athletes had varying dietary and serum micronutrient profiles at baseline and post-intervention. Therefore, the nutrition intervention through meal plans in this research optimally maintained the serum lipid and some dietary and serum micronutrient levels of bodybuilders. Interventions involving biochemical markers specifically in bodybuilding still warrant further research. More studies using larger numbers of bodybuilding athletes are recommended to cover existing gaps.

E. Acknowledgments

The researchers acknowledge the bodybuilders, IFBB, coaches, and gymnasium managers in the Capricorn District of Limpopo Province for participation in the study. Additionally, we appreciate the expertise of the phlebotomist, physician and Ampath Laboratories for facilitating blood withdrawals and analysis. The researchers also acknowledge the University of Limpopo, Research Administration and Development, for funding this research; and Dr. Daleen Struwig, medical writer and editor, Faculty Health Sciences, University of the Free State, for technical and editorial preparation of the article.

F. Conflict of Interest

The authors have no conflict of interest to declare.

References

Amawi, A., AlKasasbeh, W., Jaradat, M., Almasri, A., Alobaidi, S., Hammad, A.A., Bishtawi, T., Fataftah, B., Turk, N., Saoud, H.A., Jarrar, A. & Ghazzawi, H. (2024). Athletes' nutritional demands: a narrative review of nutritional requirements. *Frontiers in Nutrition*, *18*(10), 1331854. https://doi.org/10.3389/fnut.2023.1331854

Barjaktarovic-Labović, S., Andrijević, V., Banjari, I., Kurgaš, H. & Zejnilović, M. (2015). Lipid status of professional athletes. *Medical Data*, *7*(1), 21–25. Available at: https://www.academia.edu/61307950/Lipid_Status_of_Professional_Athletes

Barakat, C., Pearson, J., Escalante, G., Campbell, B. & De Souza, E.O. (2020). Body recomposition: can trained individuals build muscle and lose fat at the same time? *Strength and Conditioning Journal*, *42*(5), 7–21. https://doi.org/10.1519/SSC.0000000000000584

Beschasnyi, S., Hasiuk, O., Shakhman, N.

& Sheldahayeva, H. (2021). Oxidative stress in athletes after occasional smoking. *Journal of Physical Education and Sport*, *21*(2), 942–947. https://doi.org/10.7752/jpes.2021.02117

Brancaccio, M., Mennitti, C., Cesaro, A., Fimiani, F., Vano, M. & Gargiulo, B., Caiazza M, Amodio F, Coto I, D'Alicandro G, Mazzaccara C, Lombardo B, Pero R, Terracciano D, Limongelli G, Calabrò P, D'Argenio V, Frisso G, Scudiero O. (2022). The biological role of vitamins in athletes' muscle, heart and microbiota. *International Journal of Environmental Research and Public Health*, *19*(3), 1249. https://doi.org/10.3390/ijerph19031249

Bülbül, A., Özsoy, Ş., Ocalık, S. & Ölçücü, B. (2022). The effect of heavy exercise on plasma lipid levels in elite volleyball male athletes. *Mediterranean Journal of Sport Science*, *5*(3), 604–612. https://doi.org/10.38021asbid.1154758

Bytomski, J.R. (2017). Fuelling for performance. *Sports Health*, *10*(1), 47–53. https://doi.org/10.1177/1941738117743913

Carlsohn, A., Braun, H., Großhauser, M., König, D., Lampen, A., Mosler S, Nieß A, Oberritter H, Schäbethal K, Schek A, Stehle P, Virmani K, Ziegenhagen R, Heseker H. (2020). Minerals and vitamins in sports nutrition. Position of the working group sports nutrition of the German Nutrition Society (DGE). *Ernährungs Umschau*, *66*(12), 250–257. https://doi.org/10.4455/eu.2019.050

Celik, H., Tuysuz, M.Z., Aktas, Y., Eren, M.A. & Demirbag, R. (2024). Assessment of paraoxonase 1 and arylesterase activities and lipid profile in bodybuilders: a comparative study of physical activity and anthropometry on atherosclerosis. *Medicina (Kaunas), 60*(10), 1717. https://doi.org/10.3390/medicina60101717

Chappell, A.J. & Simper, T.N. (2018). Nutritional peak week and competition day strategies of competitive natural bodybuilders. *Sports*, *6*, 126. https://doi.org/10.3390/sports6040126

Close, G.L., Ashton, T., Cable, T., Doran, D., Holloway, C., McArdle, F., et al. (2006). Ascorbic acid supplementation does not attenuate post-exercise muscle soreness following muscle-damaging exercise but may delay the recovery process. *British Journal of Nutrition*, *95*(5), 976–981. https://doi.org/10.1079/bjn20061732

Cooper, M.S. & Gittoes, N.J. (2008). Diagnosis and management of hypocalcaemia. *British Medical Journal*, *336*(7656), 1298–1302. https://doi.org/10.1136/bmj.39582.589433.BE

Das, P. & Ingole, N. (2023). Lipoproteins and their effects on the cardiovascular system. *Cureus*, *15*(11), e48865. https://doi.org/10.7759/cureus.48865

De Souza, D.C., Santos, J.A.B., De Jesus, D.M. & Gentil, P. (2018). Biochemical profile and body composition alteration of amateur bodybuilders during the pre-contest period. *Journal of Functional Morphology and Kinesiology, 3*(2), 26. https://doi.org/10.3390/jfmk3020026

Di Cesare, M, Bixby, H., Gaziano, T., Hadeed, L., Kabudula, C., McGhie, D.V., et al. (2023). World Heart Report: confronting the world's number one killer. Geneva: World Heart Federation. Available at:

https://world-heart-federation.org/wp-content/uploads/World-Heart-Report-2023.pdf

Dunford, M, & Doyle, J.A. (2019). *Nutrition for Sports and Exercise*. 4th ed. Boston, MA: Cengage Learning, Inc.

El Hoss, K., Salla, M., Khaled, S., Krayem, M., Hassan, H, & El Khatib, S. (2023). Update on vitamin D deficiency and its impact on human health major challenges and technical approaches of food fortification. *Journal of Agriculture and Food Research*, *12*, 100616. https://doi.org/10.1016/j.jafr.2023.100616

Elsayyad, L., Hatem, A.H., Alzahrani, N., Gharib, A.F., Shami, A., Khalifa, O.M., et al. (2020). Effect of short-term aerobic exercise on lipid profile. *Biomedical Science Journal*, *1*, 5. https://www.researchgate.net/profile/Khadiga-Ismail-2/publication/342232064_Effect_of_Short-Term_Aerobic_Exercise_on_Lipid_Profile/links/5ee9c889458515814a653a49/Effect-of-Short-Term-Aerobic-Exercise-on-Lipid-Profile.pdf

Escalante, G., Stevenson, S.W., Barakat, C., Aragon, A.A. & Schoenfeld, B.J. (2021). Peak week recommendations for bodybuilders: an evidence-based approach. *BMC Sports Science, Medicine and Rehabilitation*, *13*(1), 68. https://doi.org/10.1186/s13102-021-00296-y

Faber, M., Van Jaarsveld, P., Wenhold, F., & van Rensburg, J. (2010). African leafy vegetables consumed by households in the Limpopo and KwaZulu-Natal provinces in South Africa. *South African Journal of Clinical Nutrition*, *23*(1). https://www.ajol.info/index.php/sajcn/article/view/52748

Food and Agriculture Organization (FAO); World Health Organization (WHO). (2001). Human vitamin and mineral requirements. Report of a joint FAO/WHO Expert consultation Bangkok, Thailand. https://wfp.tind.io/record/6878?ln=en

Galin, P., Galyaveeva, A., Bataev, H. & Safonov, V. (2020). The role of micronutrients and vitamins in the prevention and remote treatment of heart failure. *Revista Latinoamericana de Hipertension*, *15*(1), 26–32. http://saber.ucv.ve/ojs/index.php/rev_lh/article/view/18723

Garthe, I. & Maughan, R.J. (2018). Athletes and supplements: prevalence and perspectives. *International Journal of Sports Nutrition, Exercise and Metabolism*, *28*(2), 126–138. https://doi.org/10.1123/ijsnem.2017-0429

Garthe, I., Raastad, T., Refsnes, P.E. & Sundgot-Borgen, J. (2013). Effect of nutritional intervention on body composition and performance in elite athletes. *European Journal of Sport Science*, *13*(3), 295–303. https://doi.org/10.1080/17461391.2011.643923

Ghazzawi, H.A., Hussain, M.A., Raziq, K.M., Alsendi, K.K., Alaamer, R.O., Jaradat, M., et al. (2023). Exploring the relationship between micronutrients and athletic performance: a comprehensive scientific systematic review of the literature in sports medicine. *Sports (Basel)*, 11(6), 109. https://doi.org/10.3390/sports11060109

Grams, L., Garrido, G., Villacieros, J. & Ferro, A. (2016). Marginal micronutrient intake in high-performance male wheelchair basketball players: a dietary evaluation and the effects of nutritional advice. *PLoS One*, *11*(7), e0157931.

https://doi.org/10.1371/journal.pone.0157931

Grozenski, A. & Kiel, J. (2020). Basic nutrition for sports participation, Part 2: vitamins and minerals. *Current Sports Medicine Reports*, *19*(12), 508–510. https://doi.org/10.1249/JSR.0000000000000779

Guleria, P., Mahavidyalaya Kharkhoda, K., Sapna Dhawan, I., Chand, P., Kaushik, A. & Dhawan, S. (2018). Role of nutrients and sports drinks on sports performance: a review. *International Journal of Physiology, Nutrition and Physical Education*, 3(1), pp.184–189. https://www.researchgate.net/publication/354311843_Role_of_nutrients_and_sports_drinks_on_sports_performance_A_review

Hannon, B.A., Thompson, S.V., Edwards, C.G., Skinner, S.K., Niemiro, G.M., Burd, N.A., et al. (2018). Dietary fiber is independently related to blood triglycerides among adults with overweight and obesity. *Current Developments in Nutrition*, *3*(2), nzy094. https://doi.org/10.1093/cdn/nzy094

Heaton, L.E., Davis, J.K., Rawson, E.S., Nuccio, R.P., Witard, O.C., Stein, K.W., et al. (2017). Selected in-season nutritional strategies to enhance recovery for team sport athletes: a practical overview. *Sports Medicine*, *47*(11), 2201–2218. https://doi.org/10.1007/s40279-017-0759-2

Inês, G. (2019). Complex B vitamins in physical exercise. *JOJ Public Health*, *4*(4), 555624. https://doi.org/10.19080/jojph.2019.04.555642

Institute of Medicine (US) Panel on Dietary Antioxidants and Related Compounds. (2000). Dietary reference intakes for vitamin C, vitamin E, selenium, and carotenoids. Washington DC: National Academies Press.

International Fitness and Bodybuilding Federation (IFBB). (2024). IFBB Federation rules for bodybuilding and fitness. https://ifbb.com/wp-content/uploads/2024/08/01-IFBB-General-Rules-2024-edition-1.pdf

Jeukendrup, A. & Gleeson, M. (2019). *Sport Nutrition*. 4th ed. Champaign, IL: Human Kinetics.

Kairaitis, R., Mamkus, G., Degens, H. & Kamandulis, S. (2024). Nutrition practices of Lithuanian elite international and national-level male bodybuilders in the pre-competition period. *Journal of Musculoskeletal and Neuronal Interactions*, *24*(3), 232–242. https://hylonome-publications.fra1.digitaloceanspaces.com/jmni/published/97/jmni_24_232.pdf

Kerksick, C.M., Wilborn, C.D., Roberts, M.D., Smith-Ryan, A., Kleiner, S.M., Jäger, R., et al. (2018). ISSN exercise and sports nutrition review update: research and recommendations. *Journal of the International Society of Sports Nutrition*, *15*(1), 38. https://doi.org/10.1186/s12970-018-0242-y

Kim, H.K., Kimura, Y., Takahashi, M., Nakaoka, T., Yamada, Y., Ono, R., et al. (2024). Morning physical activity may be more beneficial for blood lipids than afternoon physical activity in older adults: a cross-sectional study. *European Journal of Applied Physiology*, *124*(11), 3253–3263. https://doi.org/10.1007/s00421-024-05526-y

King, K.M., Woltring, M.T. & Jubenville, C.B. (2021). Amateur bodybuilders and their perceptions of supplements: a qualitative analysis. *Journal of Exercise and Nutrition*, *4*(2), 6. https://doi.org/10.53520/jen2021.103103

Kraus, W.E., Houmard, J.A., Duscha, B.D., Knetzger, K.J., Wharton, M.B., McCartney, J.S., et al. (2002). Effects of the amount and intensity of exercise on plasma lipoproteins. *New England Journal of Medicine*, *347*(19), 1483–1492. https://doi.org/10.1056/NEJMoa020194

Kreider, R.B., Almada, A.L., Antonio, J., Broeder, C., Earnest, C., Greenwood, M., et al. (2010). ISSN exercise sport nutrition review: research and recommendations. *Journal of the International Society of Sports Nutrition*, *7*(7), 9–16. https://doi.org/10.1186/1550-2783-7-7

Krzywański, J., Mikulski, T., Pokrywka, A., Młyńczak, M., Krysztofiak, H., Frączek, B., et al. (2020). Vitamin B_{12} status and optimal range for hemoglobin formation in elite athletes. *Nutrients*, *12*(4), 1038. https://doi.org/10.3390/nu12041038

Larson-Meyer, D.E. & Willis, K.S. (2010). Vitamin D and athletes. *Current Sports Medicine Reports*, *9*(4), 220–226. https://doi.org/10.1249/JSR.0b013e3181e7dd45

Larson-Meyer, D.E., Woolf, K. & Burke, L. (2018). Assessment of nutrient status in athletes and the need for supplementation. *International Journal of Sport Nutrition, Exercise and Metabolism*, *28*(2), 139–158. https://doi.org/10.1123/ijsnem.2017-0338

Lee, N. (2017). A review of magnesium, iron, and zinc supplementation effects on athletic performance. *Korean Journal of Sport Studies*, *56*(1), 797–806. https://doi.org/10.23949/KJPE.2017.01.56.1.59

Lenzi, J.L., Teixeira, E.L., de Jesus, G., Schoenfeld, B.J. & de Salles Painelli, V. (2021). Dietary strategies of modern bodybuilders during different phases of the competitive cycle. *Journal of Strength and Conditioning Research*, *35*(9), 2546–2551. https://doi.org/10.1519/JSC.0000000000003169

Madden, R.F., Shearer, J. & Parnell, J.A. (2017). Evaluation of dietary intakes and supplement use in paralympic athletes. *Nutrients, 9*(11), 1266. https://doi.org/10.3390/nu9111266

Makiel, K., Suder, A., Kasza, S. & Kubasiak, K. (2020). Body composition and dietary patterns in professional and amateur bodybuilders. *Anthropology Reviews*, *83*(2), 225–238. https://doi.org/10.2478/anre-2020-0016

Masoga, S, Makuse, S.H.M. & Bopape, M.M. (2019). Dietary intake of amateur bodybuilding athletes around Polokwane Municipality in Limpopo Province, South Africa. *Global Journal of Health Sciences*, *11*(9),134–144. https://doi.org/10.5539/gjhs.v11n9p134

Masoga, S., Mboweni, N.W. & Ramokolo, KM. (2023). Use of ergogenic substances amongst bodybuilding athletes around Polokwane Municipality, Limpopo Province, South Africa. *Arab Journal of Nutrition and Exercise, 7*(1), 33–46. https://doi.org/10.18502/ajne.v7i1.13427

Masoga, S., Du Toit, E., Coetzee, F. & Schall, R. (2024). Fluid intake hydration strategies of bodybuilders in the Capricorn District, Limpopo Province, South Africa. *Journal Coaching Education Sports*, *5*(1), 141–158. https://doi.org/10.31599/jces.v5i1.3721

Melnik, S.N., Belaya, L.A., Brel, Y.I., Konovalenko, V,P. & Haustova, E.S. (2022). Blood biochemical parameters in athletes of different types of sports. *Opera Medical Physiology*, *9*(2), 35–41. https://doi.org/10.24412/2500-2295-2022-2-35-41

Oborný, J. & Ferenc, I. (2019). Fitness and bodybuilding as a physical activity and its importance for physical development, physical fitness and mental wellbeing. *Advances in Social Sciences Research Journal*, *6*(2), pp. 112–122. https://doi.org/10.14738/assrj.62.6135

Odysseois, C. & Avraamidou, M. (2017). Weight management for athletes: important things to be considered. *Arab Journal of Nutrition and Exercise*, *1*(3), 155–170. https://doi.org/10.18502/ajne.v1i3.1232

Pietrzak, A., Kęska, A., Saghebjoo, M. & Nezamdoost, Z. (2020). Intake of antioxidant vitamins in women with different physical activity levels. *Biomedical Human Kinetics*, *12*(1), 166–172. https://doi.org/10.2478/bhk-2020-0021

Purdom, T., Kravitz, L., Dokladny, K. & Mermier, C. (2018). Understanding the factors that affect maximal fat oxidation. *Journal of the International Society of Sports Nutrition*, *15*(1), 3. https://doi.org/10.1186/s12970-018-0207-1

Purva, A., Sharma, K. & Khan, M.S. (2020). A review on dyslipidemia: types, risk factors and management. *Asian Journal of Pharmaceutical Research and Development*, *8*(2), 96–98. https://doi.org/10.22270/ajprd.v8i2.682

Rafeeq, H., Basit, I., Jabeen, R., Shehzadi, I., Shafique, K., Tariq, S., et al. (2020). Biochemistry of water-soluble vitamins, sources, biochemical functions and toxicity. *Haya Saudi Journal of Life Sciences*, *5*(9), 188–196. https://doi.org/10.36348/sjls.2020.v05i09.007

Rankoana, S.A. (2021). Indigenous plant foods of Dikgale community in South Africa. *Journal of Ethnic Foods*, *8*(5). https://doi.org/10.1186/s42779-021-00080-w

Rashid, M., Azad, A., Jamal, S., Seerwan, R., Faridoon, Q. & Raheleh, S. (2023). Assessment of lipid profiles among athletes and non-athletes in Kalar City. *Modern Sport*, *22*(4), 122–130. https://doi.org/10.54702/ms.v22i4.1214

Ravindra, P.V., Janhavi, P., Divyashree, S. & Muthukumar, S.P. (2022). Nutritional interventions for improving the endurance performance in athletes. *Archives of Physiology and Biochemistry*, *128*(4), 851–858. https://doi.org/10.1080/13813455.2020.1733025

Reamy, B.V. & Thompson, P.D. (2004). Lipid disorders in athletes. *Current Sports Medicine Reports*, *3*(2), 70–76. https://doi.org/10.1249/00149619-200404000-00004.

Ribeiro, A.S., Nunes, J.P., Schoenfeld, B.J., Aguiar, A.F. & Cyrino, E.S. (2019). Effects of different dietary energy intake following resistance training on muscle mass and body fat in bodybuilders: a pilot study. *Journal of Human Kinetics*, *70*(1), 125–134. https://doi.org/10.2478/hukin-2019-0038

Richardson, D.P. (2014). Risk management approaches to the setting of maximum levels of vitamins and minerals in food supplements for adults and for children aged 4–10 years. *Brussels: Food Supplements Europe*. https://foodsupplementseurope.org/wp-content/themes/fse-theme/documents/publications-and-guidelines/fseriskmanagement.pdf

Ross, A.C., Manson, J.E., Abrams, S.A., Aloia, J.F., Brannon, P.M., Clinton, S.K., Durazo-Arvizu, R.A., Gallagher, J.C., Gallo, R.L, Jones, G., Kovacs, C.S., Mayne, S.T., Rosen, C.J. & Shapses, S.A. (2011). The 2011 report on dietary reference intakes for calcium and vitamin D from the Institute of Medicine: what clinicians need to know. *Journal of Clinical Endocrinology and Metabolism*, *96*(1), 53– 58. https://doi.org/10.1210/jc.2010-2704

Safari, A., Moradi, M. & Khansooz, M. (2020). Effect of aerobic exercise and kefir consumption on anthropometric indices, lipid profile and blood pressure in overweight non-athletic women. *Journal of Arak University of Medical Sciences*, *23*(2), 236–245. https://doi.org/10.32598/JAMS.23.2.4428.3

Sale, C. & Elliott-Sale, K.J. (2019). Nutrition and athlete bone health. *Sports Medicine*, *49*(Suppl 2), 139–151. https://doi.org/10.1007/s40279-019-01161-2

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. *Permanente Journal, 22*, 17–126. https://doi.org/10.7812/TPP/17-216

Smart, A.N., Downes, D., van der Touwm T., Hada, S., Dieberg, G. & Pearson, M.J., et al. (2024). The effect of exercise training on blood lipids: a systematic review and meta-analysis. *Sports Medicine*, *55*(1), 67–78. https://doi.org/10.1007/s40279-024-02115-z

Smoliga, J.M, Wilber, Z.T. & Robinson, B.T. (2023). Premature death in bodybuilders: what do we know? *Sports Medicine*, *53*(5), 933–948. https://doi.org/10.1007/s40279-022-01801-0

Sovilj, M. (2012). Prenatal memory and learning. *Medicinska Revija*, *4*(3), 259–266. http://www.md-medicaldata.com/files/05-MD-Vol%204%20No%203-Sovilj.pdf

Sukwong, T., Chinnasee, P., Prajongjai, V., Chinnasee, C., Md Nadzalan, A. & Mohamad, N.I. (2022). The difference of anthropometric characteristics between elite and novice bodybuilders in Thailand. *Physical Education Theory and Methodology*, *22*(1), 101–105. https://doi.org/10.17309/tmfv.2022.1.14

Thomas, D.T., Erdman, K.A. & Burke, L.M. (2016). American College of Sports Medicine joint position statement. Nutrition and athletic performance. *Medicine and Science in Sports and Exercise*, *48*(3), 543-568. https://doi.org/10.1249/MSS.0000000000000852

Tian, T., Jian, S., Zhimei, S., Xueli, S., Yan, L., Ling, C., et al. (2022). Association of serum vitamin C with all-cause and cause-specific death: data from National Health and Nutrition Examination Survey (NHANES 2003–2006). *Nutrition*, *101*, 111696. https://doi.org/10.1016/j.nut.2022.111696

Tidmas, V., Brazier, J., Hawkins, J., Forbes, S.C., Bottoms, L. & Farrington, K. (2022). Nutritional and non-nutritional strategies in bodybuilding : impact on kidney function. *International Journal of Environmental Research and Public Health*, *19*(7), 4288. https://doi.org/10.3390/ijerph19074288

Turocy, P.S., DePalma, B.F., Horswill, C.A., Laquale, K.M., Martin, T.J. & Perry, A.C., et al. (2011). National athletic trainers' association position statement: Safe weight loss and maintenance practices in sport and exercise. *Journal of Athletic Training*, *46*(3), 322–336. https://doi.org/10.4085/1062-6050-46.3.322

Umakanth, M. & Ibrahim, M. (2018). Fasting and non-fasting lipid profile among health care workers at teaching hospital Batticaloa SriLanka. *Journal of Biosciences and Medicine*, *6*, 15–22. https://doi.org/10.4236/jbm.2018.67002

Vorster, H.H., Badham, J.B. & Venter, C.S. (2013). An introduction to the revised food-based dietary guidelines for South Africa. *South African Journal of Clinical Nutrition*, *26*(3 Suppl), S5–S12. https://www.ajol.info/index.php/sajcn/article/view/97787

Wardenaar, F., Brinkmans, N., Ceelen, I., Rooij, B., Mensink, M., Witkamp, R., et al. (2017). Micronutrient intakes in 553 Dutch elite and sub-elite athletes: prevalence of low and high intakes in users and non-users of nutritional supplements. *Nutrients*, *9*(2), 142. https://doi.org/10.3390/nu9020142

Watanabe, F., Yabuta, Y., Bito, T. & Teng, F. (2014). Vitamin B_{12}-containing plant food sources for vegetarians. *Nutrients*, *6*(5), 1861–1873. https://doi.org/10.3390/nu6051861

World Health Organization (WHO). (2011). Waist circumference and waist-hip ratio: report of a WHO expert consultation. Geneva, 8–11 December 2008. https://www.who.int/publications/i/item/9789241501491

World Health Organization (WHO). (2020). WHO guidelines on physical activity and sedentary behaviour. Geneva: World Health Organization. https://www.who.int/publications/i/item/9789240015128

World Health Organization (WHO). (2024). Non-communicable diseases: key facts. https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases

Wright, C.Y., Norval, M., Summers, B., Davids, L.M., Coetzee, G. & Oriowo, M. (2012). Solar ultraviolet radiation exposure and human health in South Africa: finding a balance. *South African Medical Journal*, *102*(8), 665–666. https://doi.org/10.7196/SAMJ.5921