Journal of Health, Population and Nutrition

RESEARCH Open Access

Level of intestinal permeability markers and selected aspects of diet and BMI of Polish e-sports players

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Abstract

Background The intestinal microbiota, also called visceral brain, exhibits high biological activity and influences health status. The aim of this study was to evaluate selected dietary determinants of the levels of intestinal permeability markers (zonulin and LPS endotoxin) in a group of e-sportsmen.

Materials and methods The study was conducted among 174 male athletes (18–28 years old), training at the professional ($n = 44$) and semi-professional level ($n = 130$). The study included: weight and height measurements (Holtain anthropometer, Tanita TBF300), assessment of BMI, determination of zonulin and LPS levels in fecal samples (ELISA tests) and assessment of frequency of consumption of selected food groups (FFQ). Statistical analysis was performed using chi^2 and Student's t tests and Spearman's rank correlation, at a significance level of $p < 0.05$.

Results The group was dominated by e-sportsmen with elevated levels of LPS endotoxin (66.67%), zonulin (85.74%) and normative BMI (59.70%), with no significant differences according to sports level. There was a positive correlation between BMI and levels of zonulin ($R = 0.49$; $p < 0.001$) and LPS ($R = 0.24$; $p < 0.05$). Zonulin levels also increased with more frequent consumption of sweet cereals ($R = 0.21$; $p < 0.05$), pork meats ($R = 0.21$; $p < 0.05$) and red meat dishes ($R = 0.18$; $p < 0.05$).

Conclusions Excessive body weight and a poor health diet were shown to have a negative effect on increasing intestinal permeability, suggesting the rationale for monitoring and rationalizing diet and nutritional status to optimize the intestinal microbiota of e-sportsmen.

Keywords Intestinal permeability, Zonulin, LPS, Diet, BMI, E-sportsmen

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Introduction

One important aspect of maintaining and improving physical and mental health potential is a properly functioning gut microbiota [1]. The gut microbiome in a state of eubiosis influences normal metabolic processes and the functioning of the endocrine, nervous and immune systems [2]. The bidirectional gut microbiota-brain axis also influences mental health [3]. By stimulating the production of gut mediators reaching the central nervous system, the gut microbiota is involved in modulating mood and behaviour [4]. In turn, intestinal dysbiosis, associated with an increase in intestinal permeability (IP), increasing the risk of leaky gut syndrome, stimulates the immune system, increasing the risk of developing inflammation and allergic and autoimmune diseases. It also increases the risk of developing chronic diseases, including cardio-metabolic diseases, cancer and possibly psychiatric disorders [5–8].

Biomarkers of increased intestinal permeability (Increased Intestinal Permeability) include zonulin levels and lipopolysaccharide (LPS) translocation. Zonulin is a physiological modulator of tight intercellular junctions in the gut, reversibly regulating intestinal barrier permeability. In contrast, lipopolysaccharide (LPS), which is produced by Gram-negative bacteria in the intestinal ecosystem, enhances the secretion of pro-inflammatory cytokines and generates systemic inflammation and endotoxaemia [9].

Causes of intestinal disorders may include dietary factors and exposure to psychological stress [2]. Studies have shown that excessive body weight and poor dietary health (excess processed foods, saturated fatty acids and simple sugars) increase the risk of dysbiosis, with weakened intestinal barrier integrity, increased intestinal permeability and elevated zonulin levels [7, 10]. On the other hand, a nutrient-dense diet rich in omega-3 polyunsaturated fatty acids, dietary fibre, antioxidant substances and probiotics has a significant effect on improving intestinal barrier tightness and reducing zonulin and LPS levels, which has been confirmed in different population groups [8, 11, 12] and in meta-analytical work [7].

Various population groups, among them athletes, are exposed to gut microbiota disorders due to health, nutritional and psychological stress, in addition to intense physical exertion [2, 13, 19]. Research confirms a strong link between physical and emotional stress, excessive training load and sleep disturbance and changes in the composition of the gut microbiota [2]. Research suggests that the gut microbiota, by influencing energy metabolism, gastrointestinal physiology, modulating the immune system and regulating gastrointestinal function, can likely affect athletic performance [4, 13]. A healthy microbiota may be an important factor in improving health, performance and energy availability and controlling oxidative stress in athletes [14–18]. Studies among athletes have confirmed, among other things, increased intestinal permeability (Increased Intestinal Permeability) and elevated levels of zonulin [13]. Other studies have confirmed elevated levels of zonulin, occludin and LPS in elite football players [19]. A significant increase in intestinal permeability has also been reported in runners after 90 min of intense exercise [20]. In this context, the International Society of Sports Nutrition Position Stand points to the importance of probiotic supplementation for optimising the state of the gut microbiota and the health and exercise capacity of athletes [21].

An interesting and unexploited research group of athletes are e-sports players. E-sport is a category of competitive video games that in many ways can resemble traditional sports [22]. Achieving success in e-sports requires, among other things, high cognitive ability, responsiveness, and mental toughness [23]. At the same time, e-sports players are exposed to numerous health risks in biological and psychosocial dimensions, including, among others, faulty diet, hypokinesia, excessive body weight and psychological stress [24–26]. The indicated lifestyle aspects can also negatively affect the gut microbiota, which can generate further health problems [2]. The development and professionalisation of e-sports in recent years has led to an increased interest in this form of activity and, at the same time, an awareness of the importance of health and healthy lifestyles for sports performance and health problems associated with e-sports [27]. Previous work in this area has focused on the importance of diet for cognitive performance in e-sports [28], personality traits and psychological care [29, 30], physical activity levels and body composition [31], and dietary patterns of e-sports athletes [31–33, 34] In contrast, there is very little work on the gut microbiome of e-sportsmen [31], which indicates the validity of the presented research. Indeed, dysbiosis and increased intestinal permeability can lead to inflammation, lowered immunity and cognitive decline in e-sportsmen. Assessing the levels of intestinal permeability markers in e-sportsmen, on the other hand, may promote the identification of certain health and nutritional problems.

In this context, assuming the importance of the intestinal microbiota for health and, indirectly, for sporting success, as well as the relationship between diet and the intestinal microbiome, a study was undertaken to evaluate selected dietary determinants of the levels of two intestinal permeability markers in a group of e-sportsmen training at the professional and semi-professional level. The following research questions were developed: 1)How are the levels of zonulin and LPS lipopolysaccharide shaped in e-sportsmen? 2)How are BMI and frequency of consumption of selected food groups shaped in e-sportsmen? 3)What are the relationships between

BMI and frequency of consumption of selected food groups and levels of zonulin and LPS lipopolysaccharide in e-sportsmen? It was hypothesised that levels of intestinal permeability markers increase with increasing BMI and higher frequency of consumption of low nutrient-dense foods.

Materials and methods

Participants

The study was conducted in a group of 174 male Polish e-sports players aged 18–28 years (19.9 ± 2.8), including those training at the professional (n = 44) and semi-professional level (n = 130). Professional players, as opposed to semi-professional players, had professional experience, defined as receiving financial rewards and receiving specialised training. Professionals spent more time on computer games than semi-professionals (8 ± 1.95 h·day-1 vs. 6 ± 1.15 h·day-1). The players surveyed had at least 5 years of training experience (6.4 ± 1.6) and participated in e-sports tournaments, including Counter-Strike: Global Offensive (CS: GO), League of Legends (LoL) and StarCraft. The group consisted of students (33.2%), high school students (22.9%) and professionals (43.8%).

The following criteria were adopted to select participants for the study: having been involved in e-sports for at least 5 years and undertaking regular training, at least 5 times a week, in 5–6 h training units. Exclusion criteria included: lack of informed written consent to participate in the study, age below 18 and above 40 years and female gender. The study was conducted in accordance with the principles of the Declaration of Helsinki 1964, after informed written consent was obtained from the participants, and the study protocol was approved by the Bioethics Committee for Scientific Research in Gdańsk (KB-63/22).

Design and procedures

Measurement of somatic characteristics

Body height to the nearest 0.1 cm was measured using an anthropometer (Holtain, UK), following the methodology of Martin and Saller (1957) and Malina, Bourchard, Bar Or (2004). Body weight was measured using a Tanita TBF300 electronic scale (Japan). Body mass index BMI was determined from the formula: body weight / body height (kg/m^2), and its categorisation was performed according to WHO guidelines (WHO 2003).

Measurement of intestinal permeability markers

In order to determine the levels of intestinal permeability markers (LPS and zonulin), a stool sample was collected from the athletes. The athletes were informed about the correct collection of material (faeces) from 3 different locations in order to standardise the samples. The material was placed in sterile containers and stored in a cool place until delivery to the ALAB laboratory. The correct reference range for the intestinal permeability markers analysed is, for LPS below 0.63 EU/ml and for zonulin below 60 ng/ml [30]. The tests were performed using the ELISA technique.

Statistical analysis

Statistical calculations were carried out using Statistica 13 and Excel. Basic descriptive statistics (M, SD, Me, Min, Max and percentages, depending on the type of variables) were presented. Statistical analysis was performed using the chi2 test, Student's t-test and Spearman's rank correlation, Statistical significance was assumed at α = 0.05 and test probability at $p < 0.05$.

Results

Of the intestinal permeability markers analysed in the e-sports group, the mean level of endotoxin LPS in the faecal samples was 0.88 (SD = 0.20) EU/ml and zonulin was 66.3 (SD = 25.7) ng/l. Statistical analysis showed no statistically significant differences in LPS and zonulin levels between the professional and semi-professional player groups ($p > 0.05$). The average BMI of the total group (M = 23.10 kg/m^2; SD = 5.20) also showed no significant variation according to sport level ($p > 0.05$) (Table 1).

Categorisation of the levels of the analysed variables (intestinal permeability markers and BMI) showed that the study group was dominated by e-sportsmen with elevated levels of the endotoxin LPS (66.67% of the total), zonulin (85.74% of the total) and normative BMI (59.70%). Statistical analysis showed no significant variation in LPS and zonulin levels and BMI according to sport level (professional vs. semi-professional players) (Table 2).

Of the product groups included, the surveyed e-sports athletes overall consumed white bread most frequently, i.e. daily (Me = 5). Usually several times per week (Me = 4), they included fruit and vegetables, milk, pork sausages, white meat dishes, butter, vegetable oils and

Table 1 Levels of intestinal permeability markers and BMI among e-sports athletes by sport level

Variables analysed		Total (N = 174)		Professional (n = 44)		Semi-professional (n = 130)		p
		M	SD	M	SD	M	SD	
Intestinal permeability markers	LPS endotoxin (EU/ml)	0,88	0,20	0,61	0,16	0,75	0,22	0,500
	Zonulin (ng/ml)	66,3	25,7	65,08	24,3	68,86	26,25	0,060
Nutritional status index	BMI (kg/m^2)	23,10	5,20	23,80	7,02	22,8	4,20	0,053

Table 2 Level categories of intestinal permeability markers and BMI among e-sportsmen by sport level

		Total (%)	Professional (%)	Semi-professional (%)	p
LPS endotoxin	Normal	33,33	71,11	17,60	0,050
	Above normal	66,67	28,89	82,40	0,880
Zonulin	Normal	14,26	24,44	10,76	0,360
	Above normal	85,74	75,56	89,24	0,060
BMI	Underweight	9,77	6,80	10,77	0,230
	Normal	59,70	52,27	62,30	0,820
	Overweight	23,00	29,50	20,70	0,440
	Obesity	7,50	11,30	6,15	0,440

Table 3 Frequency of consumption of selected food groups among e-sports athletes by sport level

	Total Me (Min-Max)	Professional Me (Min-Max)	Semi-professional Me (Min-Max)	p
Fruit	4 (1–6)	4 (1–6)	4 (1–6)	0,845
Vegetables	4 (1–6)	4 (1–6)	4 (1–6)	0,814
White bread	5 (1–6)	5 (1–6)	5 (1–6)	0,435
Whole meal bread	2 (1–6)	2,5 (1–6)	2 (1–6)	0,271
Oatmeal, muesli	2 (1–6)	2 (1–6)	2 (1–6)	0,664
Sweet cereal	2 (1–6)	2 (1–5)	2 (1–6)	0,056
Milk	4 (1–6)	4 (1–6)	4 (1–6)	0,662
Fermented dairy	3 (1–6)	3 (1–6)	3 (1–6)	0,790
Pork sausages	4 (1–6)	4 (1–6)	4 (1–6)	0,650
Poultry meats	3 (1–6)	3 (1–5)	3 (1–6)	0,526
Red meat (dishes)	2 (1–6)	2 (1–5)	2 (1–6)	0,241
White meat (dishes)	4 (1–6)	4 (1–5)	4 (1–6)	0,364
Fish	2 (1–5)	3 (1–5)	2 (1–5)	0,087
Legume seeds	2 (1–5)	2 (1–4)	2 (1–5)	0,778
Nuts, oilseed	2 (1–5)	2 (1–5)	2 (1–5)	0,733
Butter	4 (1–6)	4 (1–6)	4 (1–6)	0,497
Vegetable oil	4 (1–6)	4 (1–6)	4 (1–6)	0,301
Fast food	3 (1–5)	2 (1–5)	3 (1–5)	0,308
Sweets, confectionery	4 (1–6)	4 (1–6)	4 (1–6)	0,481

Legend: 1_never, less than once a month; 2_1–3 times a month; 3_once a week; 4_few times a week; 5_once a day; 6_few times a day; Me_median

sweets and confectionery in their diet. Less frequently, usually once a week (Me = 3), they reached for fermented dairy products and poultry sausages. Occasionally (1–3 times per month), they consumed wholemeal bread, oatmeal, muesli-type and sweet breakfast cereals, red meat dishes, fish, pulses and nuts. Statistical analysis showed no significant variation in the frequency of consumption of the analysed food groups according to sport level ($p > 0.05$) (Table 3).

Statistical analysis showed a positive correlation between BMI and zonulin ($R = 0.49$; $p < 0.001$) and LPS ($R = 0.24$; $p < 0.05$) levels in e-sportsmen. Zonulin levels in the total group also increased with more frequent consumption of sweet cereals ($R = 0.21$; $p < 0.05$), pork meats ($R = 0.21$; $p < 0.05$) and red meat dishes ($R = 0.18$; $p < 0.05$). In groups of e-sportsmen distinguished by sport level, positive associations were described for zonulin and sweet cereals in semiprofessional players ($R = 0.21$; $p < 0.5$) and zonulin and pork meats in professional players ($R = 0.46$; $p < 0.01$) (Table 4).

Discussion

The present study showed elevated levels of the analysed intestinal permeability markers (zonulin and LPS) and a relationship between zonulin levels and dietary choices and BMI in a group of Polish e-sportsmen. The results obtained allowed a positive verification of the adopted research hypothesis.

Referring to the levels of the analysed intestinal permeability markers, elevated levels of zonulin (66.33 ng/l) and LPS endotoxin (0.88 EU/ml) were found in the studied group of e-sportsmen, with concentrations exceeding the reference values in approximately 67% and 86% of the total group, respectively. The results may indicate a disturbed intestinal microbiota and a potential state of dysbiosis, associated with increased permeability of the intestinal barrier and elevated concentrations of relevant markers. However, there was no statistically significant difference in zonulin and LPS concentrations in the stool samples of professional and semi-professional players.

Table 4 Associations between BMI and frequency of consumption of selected food groups and levels of intestinal permeability markers among e-sports players by sport level

	Total		Professional		Semi-professional	
	Zonulin	LPS	Zonulin	LPS	Zonulin	LPS
BMI	0,01	0,08	0,49***	-0,25	-0,13	0,24*
Fruit	0,08	-0,01	0,14	0,04	-0,04	-0,01
Vegetables	0,06	0,01	0,09	0,20	0,03	-0,01
White bread	0,14	-0,12	0,06	-0,18	0,10	-0,13
Whole meal bread	-0,06	-0,09	-0,07	-0,05	0,01	-0,06
Oatmeal, muesli	0,02	-0,12	-0,13	-0,25	0,16	-0,05
Sweet cereal	0,21*	0,06	0,12	-0,03	0,21*	0,04
Milk	0,06	0,04	0,13	0,02	-0,01	0,06
Fermented dairy	0,08	0,13	0,17	0,07	-0,01	0,15
Pork sausages	0,21*	-0,05	0,46**	0,17	0,06	-0,11
Poultry meats	0,16	-0,01	0,21	-0,07	0,15	0,01
Red meat (dishes)	0,18*	0,07	0,27	0,15	-0,02	-0,05
White meat (dishes)	-0,13	-0,04	-0,19	0,24	-0,13	-0,07
Fish	-0,07	-0,11	0,15	-0,24	-0,03	-0,02
Legume seeds	0,05	-0,05	0,15	0,09	-0,01	-0,08
Nuts, oilseed	-0,05	0,04	-0,07	0,02	0,01	0,05
Butter	0,06	-0,02	0,02	0,16	0,11	-0,04
Vegetable oil	-0,01	0,08	0,10	0,18	-0,03	0,09
Fast food	0,01	-0,03	-0,01	-0,02	-0,05	-0,09
Sweets, confectionery	0,04	-0,06	-0,13	0,24	0,08	-0,16

Legend: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Similar trends of increased intestinal permeability and elevated levels of relevant markers in athletes have also been found in studies from other research centres. Thus, elevated levels of circulating zonulin (tight junction modulator), occludin (tight junction protein) and LPS translocation have been confirmed in elite Italian football players [19], as well as increased intestinal permeability (Increased Intestinal Permeability) and elevated zonulin levels in Polish athletes [13]. At the same time, the cited Polish studies showed varying levels of zonulin in individuals with different physical activity (physically inactive, amateur athletes and professional athletes), with elevated levels described only in athletes, more often professional athletes than amateurs (55% vs. 22%) [13]. A significant increase in intestinal permeability (as determined by zonulin and LPS levels) was also reported in Finnish runners after 90 min of intense exercise [20]. It should therefore be noted that, despite the different nature of sporting activity, elevated levels of intestinal permeability markers are found in both e-sport players and athletes in traditional sports.

When discussing the level of the analysed nutritional status indicator - the body mass index (as an effect of, among other things, diet and physical activity), the results obtained among the studied e-sportsmen show that, although there was a predominance of people with a normative BMI (approximately 60%), there were also athletes with an above-normal body weight (approximately 30%) and underweight (approximately 10%) in the group. The average BMI of 23.10 kg/m^2 was also within the WHO norm. The group showed no statistically significant variation in BMI according to sport level (professional vs. semi-professional).

In this context, it is important to note the importance of assessing body mass index BMI in e-sports players, who, by exercising a lot in a sedentary position, are at risk of the negative effects of prolonged sitting and hypokinesia, increasing the risk of developing chronic diseases, including cardiometabolic diseases in the future. This is supported by a study among US college e-sports gamers aged 18–25 against a control group, which showed significantly lower physical activity and higher body fat, lower lean body mass and lower bone mineral content, despite no significant differences in BMI between e-sports gamers and the control group (23.7 vs. 24.9 kg/m^2) [31]. It is also worth pointing out the similar average BMI in the study group of Polish e-sports players (23.10 kg/m^2) and e-gamers in the cited US study (23.7 kg/m^2) [31]. In light of our own and other authors' studies, it therefore seems important to promote a pro-healthy, active lifestyle to reduce the risk of excessive body weight and its complications in this population group.

In terms of the qualitative assessment of the diet of the surveyed e-sports players, the study in question showed abnormalities related to the low frequency of intake of nutrient-dense products constituting a high health quality diet, including fruit, vegetables, whole-grain cereal products, milk and its products, fish, pulses and nuts.

There was no statistically significant variation in the frequency of consumption of the analysed product groups in professional and semi-professional players. Relating the described habitual frequency of intake to the nutritional value of food groups, a low intake of products rich in vitamins, including antioxidant vitamins (vegetables and fruits), dietary fibre (vegetables, fruits, wholemeal cereals, pulses), probiotics (fermented dairy products) and unsaturated fatty acids, including omega 3 (sea fish and nuts) was found. Meanwhile, these are components with health-promoting properties associated with, among other things, the antioxidant potential of the diet, detoxification of the body, regulation of the gut microbiota and prevention of chronic diseases [35–37]. The preference for red meat products and the frequent use of sweets and confectionery, associated with the supply of saturated fatty acids and simple sugars and trans isomers, shown in the study group of e-sportsmen, may also exacerbate health risks, including those associated with the development of obesity, type 2 diabetes and cardiovascular disease [37]. The dietary abnormalities described, defining the nutritional and health value of the diet, indicate potential distant health risks, including those associated with disruption of the gut microbiota and shifting towards dysbiosis, which also exacerbates the risk of chronic diseases, including cardiometabolic diseases [1, 6, 37, 38]. Demonstrated abnormalities may also impair the cognitive abilities of e-sportsmen, which are negatively affected by an excess of processed foods rich in saturated fatty acids and simple sugars and a deficit of certain vitamins (B group, D) and minerals (iodine, zinc, selenium, iron, magnesium, phosphorus, potassium) and bioactive substances (antioxidants and probiotics) [39, 40]. Therefore, it can be assumed that the described nutritional irregularities have the potential to negatively affect not only health, but also the sporting success of e-players.

The dietary abnormalities described among the e-gamers studied generally correspond to trends found by other authors among e-gamers, including Polish, German, Portuguese and Brazilian as well as Norwegian and American e-gamers [28, 32, 41]. Other Polish studies among e-gamers (18–26 years) also confirmed the dominance of unhealthy dietary patterns, associated with excessive consumption of fast food, highly processed foods, sweets and confectionery and fatty dairy products, with insufficient intake of vegetables and fruit [28]. Low fruit and vegetable intake has also been described among German, Portuguese and Brazilian e-sports players [41, 42, 43] Also, a cross-sectional study to assess the dietary behaviour of video game players and e-sports gamers in Germany showed a high intake of high energy-density and low nutrient-dense products, including energy drinks and fast food, correlated with the time spent playing video games [32]. Also, an American study among e-sports gamers showed nutritional abnormalities, both quantitative (deficiencies of B vitamins and some mineral salts - magnesium, potassium, zinc and selenium) and qualitative (low intake of vegetables, fruit and dairy products), which indicates the need for dietary rationalisation and nutritional education among e-sports gamers [40]. A new Turkish study further indicated the need to monitor e-sports players for the risk of eating disorders, as the prevalence of night eating syndrome (13.3%), obesity (13.5%), and food addiction (21.4%) has been shown among e-sports players from academia in Turkey [41]. Similar nutritional abnormalities have also been described among traditional athletes representing various sports [44, 45].

Referring to the aim of the study, the present research showed statistically significant positive associations between the levels of both analysed intestinal permeability indices (zonulin and LPS) and BMI, with zonulin levels increasing with increasing BMI in professional players and LPS levels in semi-professional players.

These results confirm the negative impact of overweight and obesity on the intestinal microbiota and the increase in intestinal permeability, and thus follow the trends described by other authors. A current review of the literature in this area confirmed that overweight and obese individuals have elevated levels of zonulin, indicating increased intestinal permeability [7]. Also, a study among Caucasian men in Spain showed that circulating zonulin levels increased with increasing BMI and waist-to-hip circumference ratio (WHR) [46]. It should also be pointed out that the gut microbiota, by influencing energy metabolism, depending on the state of eubiosis or dysbiosis, can positively or negatively influence body weight and body composition [47, 48], which was also confirmed in laboratory studies in which it was additionally shown that a high energy diet (and excessive body weight) was associated with increased levels of pro-inflammatory lipopolysaccharide (LPS), which is one marker of increased intestinal permeability [49].

Significant positive associations between faecal zonulin levels and frequency of consumption of products of poor health quality, including those rich in simple sugars (sweet cereals) and saturated fatty acids and cholesterol (red meat and processed meats), were also described in the study group of e-sports players. A group-wide trend towards an association of higher zonulin levels with more frequent consumption of sweet cereals was also described in semi-professional players, and an association of higher zonulin with more frequent consumption of red meat products (cold cuts etc.) in professional players. These results confirm the negative impact of a poor health diet on the gut microbiota and the increase in intestinal permeability, and thus partly fit in with the trends described by other authors.

Indeed, research in this area generally indicates a positive effect of a high nutrient-dense diet (rich in polyphenols, omega 3 PACs, dietary fibre and probiotics) and a negative effect of a low nutrient-dense diet (rich in processed foods, saturated fatty acids, simple sugars) on the gut microbiota [21, 47]. Referring to athletes, a review of the literature on the relationship between diet, physical activity and the gut microbiota in athletes showed that a high intake of proteins and simple sugars and a low intake of fibre can adversely affect the gut microbiota and therefore increase intestinal permeability. In contrast, a diet rich in dietary fibre, omega 3 and probiotics promotes health and optimises exercise capacity [47]. It should be added, however, that research findings on the effect of diet on the gut microbiota in athletes are inconclusive, as some studies do not support these associations [50–52].

In concluding, the presented study may contribute to further research on the determinants of the state of the gut microbiota in e-sportsmen and, given the scarcity of work in this area, also serve as a point of reference. In the context of the correlations found between an above-normal BMI and faulty dietary choices and increased concentrations of intestinal permeability markers (zonulin and LPS), it seems reasonable to monitor diet, nutritional status and intestinal microbiota and intestinal permeability in e-sportsmen. Limitations of the study are mainly related to the self-reporting nature of the tool to assess dietary choices, the limited number of variables related to intestinal barrier permeability and the lack of a control group. Further studies should take into account the indicated limitations, including a broader spectrum of determinants of the gut microbiota, thus also other modifiable factors related to lifestyle, also psychological aspects. Indeed, these factors are interrelated and crucial to the psycho-physical health of e-sports athletes. Indeed, an adequate diet and maintenance of a normal body weight can be linked to a state of eubiosis, while faulty dietary choices and excessive body weight can be linked to a state of dysbiosis, increasing health risks.

Limitations

Limitations of the study are primarily related to the self-descriptive nature of the tool for assessing dietary choices, the limited number of variables related to intestinal barrier permeability, and the lack of a control group and the inclusion of only men in the study group, which makes it impossible to generalize the results and relate them to the broader population. Further studies should take into account the indicated limitations, including a broader spectrum of determinants of the gut microbiota, so also other modifiable factors related to lifestyle, also psychological aspects, including stress management. Quantitative dietary assessment methods and various indicators of nutritional and health status (including anthropometric and biochemical) could also be included as part of the broader spectrum of variables analyzed. Subsequent studies should be planned with a control group and women to allow interpretation of the results in relation to the broader population.

Conclusions

A group of Polish e-sportsmen showed significant associations between intestinal permeability and body mass index and dietary health quality, with levels of intestinal permeability markers increasing with increasing BMI and higher frequency of consumption of low nutrient-dense foods. This suggests a rationale for monitoring and rationalizing diet and nutritional status to optimize the gut microbiota of e-sports athletes.

Author contributions

"PMK was responsible for the conception and design of the study, data collection and assembly, data analysis and interpretation, writing the article. MS and ARB were responsible for data collection and collection. MG the writing of the article. AK revised the article. BF was responsible for the conception and design of the study, final approval of the article. All authors read and approved the final version of the manuscript."

Funding

The publication was financed under the programme of the Minister of Science - 'Regional Excellence Initiative' in 2024-2027, project No. RID/SP/0027/2024/01, in the amount of PLN 4,053,904.00.

Data availability

No datasets were generated or analysed during the current study.

Declarations

Competing interests

The authors declare no competing interests.

Received: 16 October 2024 / Accepted: 26 January 2025
Published online: 27 March 2025

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