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Quality of life and health status of female and male vegetarian, vegan, and omnivorous endurance runners

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For my beloved wife and my wonderful daughters.

The present work is a cumulative dissertation and consists of the following published articles:

1. Boldt P, Knechtle B, Nikolaidis P, Lechleitner C, Wirnitzer G, Leitzmann C, Rosemann T, Wirnitzer K. Quality of life of female and male vegetarian and vegan endurance runners compared to omnivores - results from the NURMI Study (step 2). *J Int Soc Sports Nutr*. 2018; 15:33.

2. Boldt P, Knechtle B, Nikolaidis P, Lechleitner C, Wirnitzer G, Leitzmann C, Wirnitzer K. Sex differences in the health status of endurance runners: results from the NURMI Study (Step 2). *J Strength Cond Res*. 2019. doi: 10.1519/JSC.0000000000003010

3. Wirnitzer K, Boldt P, Lechleitner C, Wirnitzer G, Leitzmann C, Rosemann T, Knechtle B. Health status of female and male vegetarian and vegan endurance runners compared to omnivores-results from the NURMI Study (step 2). *Nutrients*. 2018; 11. pii: E29.

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1. Introduction

Humans have been running since the beginning of history. The ability to walk upright was the beginning in the evolution from the *climbing anthropoid* to the *walking and running Homo species* (Sollas, 1924). Today, endurance running is of high popularity and can be performed in different distances, such as 10 kilometers, half-marathon, marathon, and ultramarathon (Knechtle et al., 2011). In particular, the number of recreational runners who participate in road running events, such as marathons, has consistently been on a high level in the last years (Scheerder et al., 2015). For example, two of the largest marathons take place in Paris and Berlin. In 2018, there were 42,522 participants in Paris (Paris Marathon's Organization Committee, 2019), and 40,650 runners in Berlin (Berlin Marathon's Organization Committee, 2019). The high number of running competitions, which are arranged all over the world would enable, interested athletes to compete in a race nearly every week (Scheerder et al., 2015).

1.1 Race distances

10-kilometer races are of one of the most popular race distances (Cushman et al., 2014). In particular, recreational runners prefer this distance, as it is a serious challenge; meanwhile not much training is necessary to be able to cover the distance. Beyond that, it contributes to a good fitness level, and does not require much time (Cushman et al., 2014). In competitions, running pace is usually close to maximal oxygen intake (Fay et al., 1989). The world track record of 10,000 meters is 29:43 minutes in women and 26:44 minutes in men (IAAF, 2018). In addition to single 10-kilometer races, a 10-kilometer race is a part of an Olympic triathlon (Bentley et al., 2002).

A half-marathon is a race of 21.0975 kilometers and is usually performed on the road. It is pretty popular particularly among recreational athletes, since it is supposed to be a greater challenge than a 10-kilometer-race, but it does not require as much training as a marathon. Well-trained athletes use to have a running pace, which is close to lactate threshold (Gómez-Molina et al., 2017). Therefore, a half marathon can be regarded as both as a competition and as a training distance for a full marathon (Karp, 2007). The world record is 01:04:51 hours in women and 00:58:23 hours in men (IAAF, 2018).

A marathon is a race of 42.195 kilometers and is usually performed on the road. Running pace is usually chosen close to aerobic-anaerobic threshold. Performance-limiting factors are anthropometric variables, such as BMI and skeletal muscle profile (Knechtle et al., 2012), physiological factors, such as maximal oxygen uptake (Joyner and Coyle, 2008) and training characteristics, such as volume, training intensity, and training speed (Schmid et al., 2012). As training characteristics can be improved to a certain degree, some researchers assume that humans possess the physiological ability to improve the world record of marathon from 02:15:25 hours in women and 02:02:57 hours in men (IAAF, 2018) to approximately 01:58:00 hours (Joyner, 1991).

An ultramarathon can be defined either by the length as any running event with a distance longer than a marathon or by the time as a race which lasts at least 6 hours (Zaryski and Smith, 2005). The longest official ultramarathon is the *Self-Transcendence 3,100 Mile Race*, which covers a distance of 4,989 kilometers (www.3100.ws). Beyond that, there are multi-stage races, where athletes cross countries and continents (DUV, 2018). The extraordinary challenge and thus the increased exercise-induced stress leads to a couple of pathophysiological changes, such as an increase of acute phase proteins, a decrease of testosterone, an increase of liver values, hemolysis, skeletal muscle cell damage, microhematuria, and a loss of bone mass. It is noteworthy that these changes are usually reversible within a few days (Knechtle and Nikolaidis, 2018). However, it has been shown that ultramarathoners are supposed to be healthier compared to the general population (Hoffmann and Krishnan, 2014). Thus, it is assumed that, if athletes are aware of possible side effects, favorable health effects due to endurance exercise outweigh detrimental effects (Knechtle and Nikolaidis, 2018).

1.2 Sex differences

Differences and similarities between women and men in running performance have been of particular interest in the past years. Regarding the world records of the endurance race distances mentioned above, it is striking that men's best times use to be significantly faster than women's best times (IAAF, 2018). According to current evidence, this difference is attributed to physiological differences. Men are usually larger, have lower proportional amounts of fat, and have a higher aerobic capacity as well as higher levels of hemoglobin and hematocrit, which are inevitable for the metabolism of oxygen and for its related pathways (Coast et al., 2004). Anyhow, on the base of differences in fuel utilization, muscle damage following exercise, relative improvements in performance over the past decades and on the analysis of marathon and ultramarathon performances of men and women, it was assumed that sex differences might disappear with an increase in distance (Coast et al., 2004). This assumption was supported by the fact that women could reduce the gap to men in most timed ultramarathons between 1975 and 2013 (Knechtle et al., 2016) and in ultramarathons of 50 miles and 100 miles (Zingg et al., 2015). However, in most races from 100 meters to 200 kilometers (Coast et al., 2004) as well as ultramarathons of other distances than the abovementioned (Zingg et al., 2014), the gender gap remained. Thus, to date it seems to be unlikely that women will ever outrun men, regardless of the race distance (Coast et al., 2004; Zingg et al., 2014). The remaining gaps appear to be mainly explained by biological sex differences, such as body composition and differences in physiological characteristics (Cheuvront et al., 2005; Coast et al., 2004).

1.3 Health-related effects

Health-related effects of endurance running are well-known. Numerous studies revealed beneficial effects on overall mortality (Schnohr et al., 2015) and the prevention of severe diseases, such as cardiovascular disease (Lee et al., 2014), different types of cancer (Chomistek et al., 2012), hypertension and hypertriglyceridemia (Williams, 1997), diabetes mellitus type 2 (Dubé et al., 2012), and obesity (Williams, 2013). These advantageous effects are based on a large number of adaptions, such as changes in the musculoskeletal system and heart muscle cells, modifications in hormonal response, an increased maximal oxygen uptake, the activation of both inflammatory response and detoxification processes, the involvement of pathways associated to immune response, lipid transport and coagulation, and further genetic adaptions (Bishop-Bailey, 2013; Dalle Carbonare et al., 2018). Beyond that, endurance running is known as to favorably affect well-being and psyche (Shipway and Holloway, 2010). Meanwhile, in particular ambitious novice endurance athletes and elite runners have to be aware of side effects, which could be caused by vigorous exercise and immoderate training volumes, such as sudden cardiac death (Waite et al., 2016), serious injuries (van Gent et al., 2007), and unintended body weight loss (Manore, 2015).

1.4 Diet choice

Maximal endurance performance cannot be achieved without adequate dietary strategies. Hence, there has been an intensive research in order to identify the best appropriate dietary patterns for athletes considering the special requirements of athletes (Deldicque and Francaux, 2005; Turner-McGrievy et al., 2015). There are several kinds of diet, which meet these requirements to different degrees. Basically, these dietary patterns can be categorized as omnivorous dietary patterns or vegetarian kinds of diet.

The so-called Western diet is an omnivorous kind of diet. It is characterized by high-sugar and high-fat foods, such as processed and red meat, chips, dairy products, refined grains, and sweets and desserts. This implies a high intake of saturated and omega-6 fatty acids, a reduced omega-3 fat intake and an overuse of salt as well as refined sugar. This kind of diet usually is consumed in the US and other Western countries but has also spread to other parts of the world, such as China or Russia, in the past years (Myles, 2014). It has been shown that this kind of diet, when not consumed moderately, can be associated with the occurrence of the so-called civilization diseases, such as obesity (Naja et al., 2015), coronary artery disease (Oikonomou et al., 2018), arterial hypertension (Sacks and Campos, 2010), and diabetes mellitus (Sami et al., 2017). Another kind of omnivorous diet is the Mediterranean diet. It usually consists of fish, monounsaturated fats from olive oil, fruits, vegetables, whole grains, legumes, nuts and is characterized by moderate alcohol consumption. Traditionally, it was consumed in countries next to the Mediterranean Sea, such as Italy, Spain and France. It was shown that adhering to Mediterranean diet can prevent the manifestation of several diseases, such as obesity, cardiovascular disease, depression, and cognitive decline. After these health-effects had been published, adherence to this kind of diet was no longer limited to the Mediterranean area but spread all over the world (Widmer et al., 2015).

The common characteristic of vegetarian kinds of diet is that all are devoid of flesh foods, such as meat, poultry, wild game, seafood and their products. The base of all types of vegetarian diets are vegetables, fruits, nuts and seeds, legumes and sprouted grains. Anyhow, defining vegetarian and vegan diets is quite difficult as there is a huge variety in terms of inclusion and exclusion of certain food ingredients among the different subtypes (Melina et al., 2016).

A lacto-ovo vegetarian diet is free of flesh but includes eggs and dairy products. A lacto-vegetarian diet is free of flesh and includes dairy products but no egg products. An ovo-vegetarian diet contains eggs and egg products but no dairy products. A vegan diet excludes eggs and dairy products as well as honey. In addition to the characteristics of a vegan diet, a raw vegan diet contains an amount of uncooked food between 75% and 100 % (Melina et al., 2016). Beyond that, in the past years the term *flexitarianism* has appeared. This kind of diet is characterized by primarily following a vegetarian diet, while meat or fish is consumed occasionally (Derbyshire, 2016).

Being vegetarian or vegan is usually more than just adhering to a certain type of diet. Most vegetarians and vegans live a vegetarian/vegan lifestyle based on a specific set of ethics and beliefs (Kessler et al., 2016). It was found that vegetarians and vegans use to be extraordinary liberal, altruistic, universalistic, empathic, meanwhile they usually have a certain degree of psychic vigor (Beezhold et al., 2010). In accordance with these traits of character, they attach great importance to animal welfare, protection of the environment, political and social interest and engagement and are supposed to be particularly health-conscious (Pfeiler and Egloff, 2018; Wirnitzer 2018, p. 393). It can be assumed that being a vegetarian or vegan for a longer time underpins the moral beliefs, as it was shown that the longer people adhere to a vegetarian or vegan diet, the more important moral and health reasons seem to become for their choice of food (Kessler et al., 2016). Besides, according to current evidence being a vegetarian or vegan is associated with a high IQ, female sex, a high social class, a high academic or vocational qualification, but not with a high income (Gale et al., 2007; Pfeiler and Egloff, 2018).

Health-related effects of vegetarian and vegan diets are well known. Vegetarian kinds of diet are known as to be protective against the occurrence of severe diseases, such as ischemic heart disease (Orlich et al., 2013), arterial hypertension (Appleby et al., 2002), depression (Beezhold et al., 2010) and cancer in general (Tantamango-Bartley et al., 2013). More than this, according to current scientific evidence, a well-planned vegetarian or vegan diet can be appropriate for people all over the life cycle, such as childhood, pregnancy and older adulthood and in different life situations, such as for people suffering from diseases (Melina et al., 2016). In particular, both vegetarian and vegan diets can be appropriate in order to meet the extraordinary nutritional requirements of athletes (Rodriguez et al., 2009; Rogerson, 2017). Meanwhile, vegetarian and vegan athletes have to be aware of their vitamin B 12 and calcium levels, whereby appropriate planning can prevent the occurrence of deficiency symptoms and associated problems (Melina et al., 2016).

1.5 Quality of life

A strong mind is inevitable for optimal performance in endurance running (Morgan, 1985). One important aspect in the genesis of mental strength is a certain degree of life satisfaction. Life satisfaction and mental strength are strongly interconnected so that a high degree of life satisfaction can cause a high degree of mental strength and *vice versa* (Lombardo et al., 2018). Meanwhile, it is generally accepted that a high degree of life satisfaction beneficially affects athletic performance (Farahani et al., 2011; García Naveira, 2015). Measuring life satisfaction can be very difficult, as there is a huge variety of interindividual differences in the subjective definition of well-being and a good mood state (Fava, 2012). One concept, which has been created in order to assess a number of aspects of life satisfaction, is called quality of life (QOL) and was designed by the World Health Organization (WHO; WHO, 1996). The WHO defines QOL as *an individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns*. The WHO conceptualized a short questionnaire (WHOQOLBREF) for the measurement of QOL based on four domains: physical health, psychological well-being, social relationships and environment (WHO, 1996). Its validity is well established and has been scientifically confirmed (*e.g.* Baumann et al., 2010).

1.6 Aims and hypotheses

In order to contribute to the creation of a broad basis of evidence and to provide athletes, coaches, and scientists with a base for the creation of sustainable and healthy dietary strategies, the aim of the present thesis was to investigate the adequacy of a vegetarian or vegan diet for female and male endurance runners based on the health status and QOL-scores under special consideration of sex differences. It was hypothesized that adhering to a vegetarian or vegan diet can be an adequate and at least equal alternative to an omnivorous diet in terms of health and QOL for both female and male endurance runners.

2. Summary of the published results

Data was collected in the context of the NURMI Study. The NURMI Study was an international, interdisciplinary, comparative study of running, which was designed by a team of sport scientists, nutritionists, and physicians. The title of the study *NURMI* is an acronym for *Nutrition and Running High Mileage*, meanwhile it is an allusion to Paavo Nurmi, one of the most important endurance runners of the 20th century. The NURMI Study was conducted using a cross sectional design. Subjects completed an online-survey which was available from October 1, 2014 until December 31, 2015. All questionnaires were standardized and based on self-report. The survey was available via www.nurmi-study.com and subdivided into three steps (Wirnitzer et al., 2016).

2.1 Quality of life of female and male vegetarian and vegan endurance runners compared to omnivores - results from the NURMI Study (step 2)

The content of this chapter has been published in:
Boldt P, Knechtle B, Nikolaidis P, Lechleitner C, Wirnitzer G, Leitzmann C, Rosemann T, Wirnitzer K. Quality of life of female and male vegetarian and vegan endurance runners compared to omnivores - results from the NURMI Study (step 2). *J Int Soc Sports Nutr*. 2018; 15:33.

2.1.1 Method

Quality of life (QoL) was assessed using the WHOQOL-BREF [World Health Organization Quality of Life Assessment- brief (French: bref) version]. The WHOQOL-BREF is a shorter version of the original instrument that is known as to be more convenient for use in large research studies or clinical trials (WHO 1996). The WHOQOL-BREF instrument comprises 26 items, which measure the following broad domains: physical health (activities of daily living, dependence on medication, energy), psychological well-being (bodily image, feelings, self-esteem), social relationships (personal relationships, social support, sexual activity), and environment (resources, safety, access to healthcare).

Characteristics of the participants can be found in Table 1 of the publication. Mean scores for each item can be found in Table 2 in the published article. Statistical details, including statistical methods, are presented in the publication. The main results are summarized in the following:

2.1.2 Sex differences

Men had higher scores in physical health and psychological well-being, but there were no differences with regard to social relationships counts and environment scores compared to women.

2.1.3 Diet choice

No major effect of diet on physical health, and psychological well-being in both sexes, on social relationships in women or on environment in men was observed. However, a minor effect of diet on social relationships in men and environment in women was shown with a higher score in the omnivorous diet group.

2.1.4 Race distance and diet×race distance interaction

No major effect of race distance on physical, psychological well-being, or social relationships for women and men, respectively was shown.

Moreover, no effect of race distance on environment for men was found. However, a minor effect was observed for women, where half-marathoners had a higher environment score than the members of the 10-km control group.

No diet×race distance interaction on physical, psychological well-being or social relationships for women or men, respectively, was observed. A moderate diet×race distance interaction on environment score was shown for men, but no interaction was found for women.

2.2 Sex differences in the health status of endurance runners – results from the NURMI Study (step 2)

The content of this chapter has been published in:
Boldt P, Knechtle B, Nikolaidis P, Lechleitner C, Wirnitzer G, Leitzmann C, Wirnitzer K. Sex differences in the health status of endurance runners: results from the NURMI Study (Step 2). *J Strength Cond Res*. 2019. doi: 10.1519/JSC.0000000000003010

2.2.1 Method

Health was determined using the following variables: body mass (current body mass, body mass change, and reasons for body mass change), smoking habits (current smoking and former smoking), perceived stress, chronic diseases (heart disease requiring treatment, state after heart attack, cancer, diabetes mellitus types 1 and 2, hyperthyroidism, and hypothyroidism), allergies/intolerances, regular medication intake (for thyroid, for high blood pressure, for cholesterol, and hormones), dietary supplement intake, motives for food choice, food choice to avoid certain ingredients/products (refined sugar, sweetener, fat in general, saturated fats, cholesterol, products made with white flour, sweets and confectionery, nibbles, alcohol, and caffeine), food choice to obtain certain valuable ingredients (vitamins, minerals/trace elements, antioxidants, phytochemicals, and fiber), use of enhancement substances in daily life (performance boost and to cope with stress), and health care utilization (frequency of doctor consultations and frequency of use of check-ups/routine health checks).

Characteristics of the participants can be found in Table 1 of the publication. Mean scores for each item can be found in Table 2 in the published article. Statistical details, including statistical methods, are presented in the publication. The main results are summarized in the following:

2.2.2 Body mass

Sex had a small effect on the direction the body weight changed due to running training, with relatively more men than women stating that their body weight decreased. This applied to both the NURMI-Runners as well as the 10-km control group.
In both subgroups, there was no association between sex and whether the body weight changed as a result of change in diet, running training, and the direction that it changed.

2.2.3 Stress perception

No association of sex with feeling pressure or stress was shown, neither in the NURMI-Runners nor in the 10-km control group.

2.2.4 Chronic diseases

A small sex×prevalence effect of hypothyroidism was found with a higher prevalence in women than in men in the NURMI-Runners and in the 10-km control group.
Sex did not associate with heart disease requiring treatment, heart attack, cancer, diabetes mellitus type 1, diabetes mellitus type 2, and hyperthyroidism in both groups the NURMI-Runners as well as the 10-km control group.

2.2.5 Allergies and food intolerances

There was no association between sex and the occurrence of allergies and food intolerances in the NURMI-Runners and in the 10-km control group.

2.2.6 Regular medication intake

Sex had a small effect on the intake of medication for the thyroid with a female predominance in both subgroups. Moreover, there was a moderate association between sex and the intake of hormones, where only women stated consumption in both the NURMI-Runners and in the 10-km control group.
Sex did not associate with the intake of medication for high blood pressure and cholesterol and/or other blood serum lipid values. These results applied to both the NURMI-Runners and the 10-km control group.

2.2.7 Smoking habits

No association between sex and whether they did currently smoke or whether they have ever smoked was observed neither in the NURMI-Runners nor in the 10-km control group.

2.2.8 Supplement intake

There was a small association between sex and supplement intake prescribed by a doctor, where mainly women reported intake in both subgroups.

Sex did not associate with the consumption of performance-enhancing substances in everyday life, at work, or while doing sport as well as with the intake of anything to cope with stress in both subgroups.

2.2.9 Food choice

There was a small effect of sex on food choice in order to obtain phytochemicals, where women were more likely to report to do so in both the NURMI-Runners and in the 10-km control group.

There was no effect of sex on whether food or ingredients are chosen because they are healthy, health-promoting, or good for maintaining health, neither among the NURMI-Runners nor among the members of the 10-km control group. Moreover, there was no correlation between sex and whether food or ingredients are chosen in order to avoid refined sugar, sweetener, fat in general, saturated fats, cholesterol, products made with white flour, sweets and confectionary, nibbles, alcohol, and caffeine or other stimulants in none of the subgroups.

In addition, sex did not associate with whether food or ingredients are chosen because they are high in vitamins, minerals/trace elements, antioxidants, and fiber. These results were found in both the NURMI-Runners and in the 10-km control group.

2.2.10 Healthcare utilization

No association between sex and the frequency of doctor consultations, the use of regular check-ups and routine health checks, and the frequency of the use of regular check-ups and routine health checks was observed. These results were found in both the NURMI-Runners and the 10-km control group.

2.3 Health status of female and male vegetarian and vegan endurance runners compared to omnivores - results from the NURMI Study (step 2)

The content of this chapter has been published in:
Wirnitzer K, Boldt P, Lechleitner C, Wirnitzer G, Leitzmann C, Rosemann T, Knechtle B. Health status of female and male vegetarian and vegan endurance runners compared to omnivores-results from the NURMI Study (step 2). *Nutrients*. 201822; 11. pii: E29.

2.3.1 Methods

Health was determined using the following variables: body mass (current body mass, body mass change, and reasons for body mass change), smoking habits (current smoking and former smoking), perceived stress, chronic diseases (heart disease requiring treatment, state after heart attack, cancer, diabetes mellitus types 1 and 2, hyperthyroidism, and hypothyroidism), allergies/intolerances, regular medication intake (for thyroid, for high blood pressure, for cholesterol, and hormones), dietary supplement intake, motives for food choice, food choice to avoid certain ingredients/products (refined sugar, sweetener, fat in general, saturated fats, cholesterol, products made with white flour, sweets and confectionery, nibbles, alcohol, and caffeine), food choice to obtain certain valuable ingredients (vitamins, minerals/trace elements, antioxidants, phytochemicals, and fiber), use of enhancement substances in daily life (performance boost and to cope with stress), and health care utilization (frequency of doctor consultations and frequency of use of check-ups/routine health checks). Results were categorized as health-related indicators (body weight, mental health, chronic diseases, and hypersensitivity reactions, medication intake) and health-related behavior (smoking habits, supplement intake, food choice, healthcare utilization).

Characteristics of the participants can be found in Table 1 of the publication. Scheme 1 shows the categorization of the participants, scheme 2 shows the process of data clearance. Descriptive results can be found in Table 3, 4 and 5. Figure 1 shows indices of both clusters *health-related indicators* and *health-related behavior*. Statistical details, including statistical methods, are presented in the publication. The main results are summarized in the following:

2.3.2 Health-related indicators

2.3.2.1 Body weight/BMI

There was a significant difference in body weight between dietary subgroups, with vegetarians and vegans showing lower body weight than omnivores. However, there was no difference in the health-related item BMI between dietary subgroups. Moreover, vegans had the highest counts for the health-related indicator body weight/BMI.

2.3.2.2 Mental health

There was no significant association between diet group and stress perception. However, vegans had the highest score with regard to mental health.

2.3.2.3 Chronic diseases and hypersensitivity reactions

There was no significant association between diet and the prevalence of cardiovascular diseases and cancer, and even between diet and prevalence of metabolic diseases. However, there was a significant difference between the prevalence of hypersensitivity reactions and diet, where vegan endurance runners stated least often that they had at least one allergy. In addition, omnivores reported having a food intolerance least often. Omnivorous, vegan, and vegetarian runners scored similarly with regard to the health-related indicator chronic diseases and hypersensitivity reactions.

2.3.2.4 Medication intake

There was no significant association between medication intake and dietary subgroup. Furthermore, there was no significant effect of diet on the use of contraceptives. However, vegetarians had the highest scores with regard to medication intake, even though all dietary subgroups had similar scores.

2.3.3 Health-related behavior

2.3.3.1 Smoking habits

Diet and current or former smoking were not significantly associated. Vegetarians showed the best health-related behavior with regard to smoking habits.

2.3.3.2 Supplement intake

There was no significant association between diet and supplement intake prescribed by a doctor, the consumption of performance-enhancing or the intake of substances to cope with stress. Vegans showed the best behavior with regard to supplement intake.

2.3.3.3 Food choice

There was no significant association between diet and food choice (i) because it is healthy and health-promoting; or (ii) in order to obtain, minerals/trace elements, antioxidants, and fiber. Moreover, there was no significant association between diet and the avoidance of the following ingredients: refined sugar, fat in general, white flour, sweets, nibbles, and alcohol.
However, there was a significant effect of diet on food choice, both (i) because it is good for maintaining health, with vegetarians and vegans reporting doing so more often; and (ii) in order to obtain phytochemicals, with vegans reporting doing so more often. Moreover, there was a significant association between diet and the avoidance of the following ingredients: sweetener, saturated fats, cholesterol, and caffeine. Vegans were more likely to report considering avoiding these ingredients in their food choice than vegetarians and omnivores. Vegan athletes had the highest scores in food choice compared to the other dietary subgroups.

2.3.3.4 Healthcare utilization

There was no significant association between the use of regular health check-ups and diet. Vegan athletes had the highest scores with regard to healthcare utilization.

2.4 Declaration of my contributions

I was involved in the process of conceptualization of the study, data collection and data analysis. I wrote the manuscripts and I was responsible for the progress of the publication processes. Furthermore, I had some coordinative functions, such as recruitment of new team members. K. Wirnitzer was study coordinator and B. Knechtle supervised in medical concerns. Both of them supported by critically reviewing the manuscripts and by being my mentors. P. Nikolaidis helped with his knowledge of statistics. C. Leitzmann and T. Rosemann provided with their scientific expertise. C. Lechleitner and G. Wirnitzer supported with regard to IT.

3. Discussion

When creating sustainable dietary and training strategies for endurance athletes, many variables have to be taken into account. These variables are, among others, nutritional requirements, health status, sex differences in terms of nutritional requirements as well as health concerns and the athletes' psyche, personal well-being, and life satisfaction (Deldicque and Francaux, 2015; Jeukendrup, 2011; McAllister et al., 2001).

A first important variable in the creation of dietary and training strategies for athletes is the consideration of nutritional requirements. Endurance runners use to have a high demand for energy, meanwhile a quite low body weight is required for optimal running performance. Hence, their diet has to contain sufficient amounts of carbohydrates, fat, and proteins. Beyond that, they have an increased need of vitamins, trace elements, calcium, iron, zinc, magnesium, some antioxidants such as vitamins C and E, beta-carotene, and selenium (Rodriguez et al., 2009). It has to be considered, that the demand for micronutrients and macronutrients is not constant but depends on the athlete's training cycle. In a period of intensive training, the demands increase, whereas for example on the race day moderate consumption before and during the race is required. Most researchers recommend a high consumption of carbohydrates and an adequate fluid intake before and during endurance races in order to avoid undesired side effects, such as hypoglycemia or dehydration (Jeukendrup, 2011).
Even though levels of minerals, vitamins and trace elements were not measured in the context of the present thesis, there are indirect hints which support the notion that vegetarian and vegan diets meet the nutritional requirements of endurance runners. In terms of food choice, most vegetarians and vegans reported to choose food in order to obtain vitamins, minerals, trace elements, antioxidants, while nutritionally unfavorable ingredients, such as refined sugar, are avoided. Beyond that, all participants had a good health status, regardless of the diet choice. In particular, there were no hints for deficiency symptoms, such as anemia. With regard to body weight control, the present thesis revealed no differences between diet groups, while BMI was within the normal range. These findings underpinned the adequacy of vegetarian kinds of diet for a well-balanced energy metabolism and were in line with other studies (*e.g.* Kahleova et al., 2018).

A second important variable in the creation of dietary and training strategies for athletes is the health status.

The findings from the present thesis underpinned the fact that a vegetarian or vegan diet contributes to a good health status and thus can be the base for a good fitness level. With regard to measured health parameters (body weight change, smoking habits, perceived stress, chronic diseases, allergies and food intolerances, medication and supplement intake, consumption of performance-enhancing substances, and healthcare utilization), vegetarians and vegans had similar scores to omnivores. Moreover, vegetarians and vegans reported more often to choose food ingredients for maintaining health and in order to avoid cholesterol and caffeine. Meanwhile, in terms of the choice of food ingredients because they are healthy and health-promoting vegetarians and vegans had similar scores compared to omnivores. These findings support the notion that vegetarians and vegans are extraordinary health-conscious. This was in line with current evidence. In addition to reasonable food choice, vegetarians' and vegans' health-consciousness is based on the avoidance of harmful practices, such as drinking and smoking, a certain amount of physical activity, and enough time for rest and relaxation (Wirnitzer, 2018, p. 393).

Current evidence provides with a couple of explanations why vegetarian kinds of diet contribute to a good health status. A recent study investigated fitness levels and health in endurance athletes and identified two main factors, which affect athletes' health adversely. These factors were too high training intensity and the modern-day highly processed, high glycemic diet (Maffetone and Laursen, 2016). Regular consumption of such a diet can impair fat oxidation rates (Volek et al., 2016) and contribute to the production of inflammation and pain (Juanola-Falgarona et al., 2014). Moreover, the production of reactive oxygen species is increased (Ruiz-Nunez et al., 2013). In the course of time, this leads to hyperinsulinemia and chronic inflammation (Wilcox, 2005). The same applies to immoderate, vigorous exercise, which can cause chronic inflammation and an increase in reactive oxygen species as well (Ruiz-Nunez et al., 2013). Chronic inflammation can cause a couple of undesired, adverse health effects, such as plantar fasciitis, tendonitis, fatigue, maximal and submaximal performance decrements, and asthma. In order to avoid these undesired health effects, training strategies, which include periods of reduced training intensity and recovery, and a natural unprocessed diet consisting mainly of components with a low glycemic index were recommended (Maffetone and Laursen, 2016).

Such a diet can be a vegetarian or vegan dietary pattern. Well-planned vegetarian kinds of diet are usually high in carbohydrates with a low glycemic index, such as vegetables, many fruits, nuts, grains, and legumes (Waldmann et al., 2007). It was shown that chronic inflammation can be reduced significantly by adhering to vegetarian kinds of diet (Haghighatdoost et al., 2017), which prevents the occurrence of the adverse health effects mentioned above (Watzl, 2008). Beyond that, vegetarians and vegans usually have a good fitness level due to a healthy and active lifestyle combined with a certain degree of health-consciousness (Wirnitzer, 2018, p. 393). More than this, there are various health effects beyond the improvement of athletic performance and an increase of the fitness level. Protective effects against the occurrence of severe diseases, such as ischemic heart disease (Kahleova et al., 2018), arterial hypertension (Appleby et al., 2002), depression (Liu et al., 2016) and total cancer (Tantamango-Bartley et al., 2013) were found. Especially in the treatment of the so-called civilization diseases, such as obesity and diabetes mellitus type 2, vegetarian and vegan dietary interventions have been identified to be effective (Kahleova et al., 2017). Therefore, current scientific evidence suggests that vegetarian or vegan diets can be appropriate for people all over the life cycle, such as childhood, pregnancy and older adulthood and in different life situations, such as for people suffering from diseases (Melina et al., 2016). The findings from the present study support this assumption.

Additional important variables in the creation of dietary and training strategies for endurance athletes are sex differences in nutritional requirements and health concerns. Athletes in general should be aware of their total energy intake in order to avoid unintended body weight loss. In this context, in particular female athletes are affected, as they have to change their body composition further from their natural body shape than men to achieve a body weight which is optimal for performance (Deldicque and Francaux, 2015). Immoderate body weight control may have severe health implications, such as the so-called *female athlete triad*, which is an umbrella term for the coincidence of restrained eating, menstrual dysfunction and poor bone health (De Souza et al., 2014).

In terms of body weight control, vegetarian diets have been identified to be adequate by offering all important nutrients, while intake of high-glycemic food is limited (Kahleova et al., 2018). The findings from the present thesis support this notion, since there were no differences in terms of body weight change between female and male vegetarians, vegans and omnivores, while BMI was within the normal range in all subgroups.

Moreover, female endurance athletes are often at risk for low vitamin D levels. This nutrient is crucial for bone health, immune and muscle functions, and sports performance (Larson-Meyer, 2014). The main reason for a poor vitamin D status is the lack of good dietary sources (Bailey et al., 2010). Vitamin D levels are closely connected to calcium levels (Cashman, 2007). In this context, especially postmenopausal female athletes have to be aware of their bone health, as evidence suggests that inadequate estrogen levels are risk factors for bone diseases, such as osteoporosis, by adversely affecting calcium levels (Bansal et al., 2013). In the present thesis the supplement which was reported to be consumed most frequently by women was vitamin D. This was in line with current evidence, as it was shown that vitamin D deficiency is a common problem among female endurance runners (Larson-Meyer, 2014). However, there were no differences between diet groups. This supports the notion that vegetarian kinds of diet are at least equivalent to omnivorous dietary patterns in terms of vitamin D, what was consistent with literature available as well (Schüpbach et al., 2017). In this context it is noteworthy, that vitamin D levels seem to depend more on other factors than dietary intake, such as degree of skin pigmentation and amount and intensity of sun exposure (Chan et al., 2009). With regard to calcium levels, which are closely connected to vitamin D levels (Cashman, 2007), the adequacy of vegetarian kinds of diet is estimated inconsistently in current evidence. It seems as both those who adhere to vegetarian kinds of diet and those who follow omnivorous dietary patterns have to be aware of low calcium levels (Turner et al., 2014).

Another special characteristic of female athletes is a higher prevalence of thyroid diseases, such as hypothyroidism. This higher prevalence was displayed in the sample of the present thesis as well. This is not specific for female athletes, but a common problem among the general female population (Dunn and Tuner, 2016). Nonetheless, athletes may be particularly affected, as subclinical hypothyroidism, where free thyroxine (fT4) is normal and thyroid-stimulating hormone (TSH) is increased, can be an unidentified performance limiting factor (Duhig and McKeag, 2009). In this context, a vegan diet can be advantageous. A recent study identified vegan kinds of diet to be associated with a lower incidence of hypothyroidism and highlighted protective effects in terms of the occurrence of hypothyroidism. Meanwhile, the authors described a higher prevalence of hypothyroidism in vegetarians (Tonstad et al., 2013). The findings of the present thesis bear out the hypothesis that vegetarian kinds of diet are not associated with an increased risk for hypothyroidism, as there were no differences between vegetarians, vegans and omnivores in terms of the prevalence of hypothyroidism. Meanwhile, a higher prevalence among vegetarians could not be found. However, early recognition and therapy are inevitable in order to prevent the occurrence of further symptoms and to avoid performance decrease in athletes.

Further important factors in the creation of sustainable dietary and training strategies are the athlete's personal well-being and QOL. QOL is an abstract construct which is based on a couple of variables, such as physical health, social acceptance, a good work-life balance and mental stability. Thus, a high degree QOL requires, among other aspects, an optimized training volume and well-planned dietary strategies. Meanwhile, optimized training volume means avoidance of overtraining and injuries but having maximum performance improvements (Houston et al., 2016). Well-planned dietary strategies do not only consider health concerns but also personal preferences and wishes what is essential for a high degree of QOL (Gigic et al., 2018). Since overall QOL scores were high in vegetarian and vegan endurance runners, the findings of the present thesis support the notion that a vegetarian or vegan lifestyle is associated with a high degree of QOL and thus can be the base for a sustainable dietary and training strategy for both female and male athletes. When comparing vegetarians and vegans to omnivorous endurance runners, it was shown that there was no major effect of diet group on the QOL dimensions physical health and psychological well-being in either sex, on social relationships for women and on environment for men. Meanwhile, a minor effect of diet on social relationships for men and environment for women was shown with higher scores for omnivores. These findings were in line with current scientific evidence. Research investigating vegetarians and vegans from the general population also revealed high QOL counts (*e.g.* Kahleova et al., 2013). It was assumed that these high QOL counts are based on the character profiles of people who adhere to vegetarian kinds of diet. As mentioned above, it was found that vegetarians and vegans use to be extraordinary liberal, altruistic, universalistic, empathic, meanwhile they usually have a certain degree of psychic vigor (Beezhold et al., 2010). Moreover, they attach great importance to animal welfare, protection of the environment, political and social interest and engagement, and are supposed to be particularly health-conscious (Pfeiler and

Egloff, 2018; Wirnitzer, 2018, p. 393). This assumption was underpinned by the findings from the present thesis, in particular in terms of health-consciousness. As mentioned above, it was found that omnivores had higher scores in the QOL dimensions social relationships and environment. When taking the character profiles of vegetarians and vegans into account, the lower scores reported might be caused by differences in expectations. Since vegetarians and vegans are particular altruistic, universalistic as well as interested in social and political concerns (Beezhold et al., 2010; Pfeiler and Egloff, 2018), they are supposed to have high standards in terms of social relationships. Moreover, it was found that vegetarians and vegans particularly care about environmental protection (Kessler et al., 2016). This entails higher standards in this regard, which would explain low scores in the QOL dimension environment.

3.1 Limitations and implications for future research

Some limitations of the study should be noted. The survey was following a cross-sectional design and based on self-reporting. Thus, the reliability of the data depended on the conscientiousness of the subjects. However, by using questions to control for diet and race distance this effect was minimized. Moreover, the small sample size and the pre-selection of the subjects due to the fact that only highly motivated runners took part led to a lack of statistical representativeness which might have affected the results. Nonetheless, the high intrinsic motivation of the participants led to an increase in the accuracy of their answers and thus to a high quality of the generated data.

Future studies should be performed on large randomized samples in order to improve statistical representativeness. Items could be elaborated in order to specify generated data.

3.2 Conclusions

In summary, the findings of the present thesis revealed that the endurance runners of the present sample had a good health status and reported a high degree of QOL, regardless of diet choice, sex and race distance. Moreover, vegetarian and vegan endurance runners seemed to be particularly health-conscious. Women reported a higher intake of hormones and supplements and more often to be affected by hypothyroidism. Men reported more often a decrease in body weight due to running training. These findings support the notion that vegetarian kinds of diet can be an adequate and at least an equal alternative to an omnivorous diet for both female and male endurance runners with regard to health-concerns and in terms of QOL.

All in all, the permanent linkage of vegetarian kinds of diet with endurance running seems to be a good base for a healthy, sustainable, and contented lifestyle. Beyond beneficial effects for athletes and humans in general all over the lifecycle (Melina et al., 2016), there are numerous further possible motives for the decision in favor of a vegetarian or vegan lifestyle, such as animal welfare, environmental protection, ecological reasons, and social concerns (Leitzmann, 2005). In the end, a decision in favor of or against a certain lifestyle has to be taken individually and based on the personal set of ethics and beliefs. Whatever the decision might be, there is not only *one* right way. This appears to be accurately summed up by the old proverb *All roads lead to Rome*.

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5. Appendix

Verzeichnis der akademischen Lehrerinnen und Lehrer

Meine akademischen Lehrenden waren in Gießen:

Askevold, Dr. Ingolf

Beuerlein, Dr. Knut

Deinzer, Prof. Dr. Renate

Dettmeyer, Prof. Dr. Dr. Reinhard

Ehrhardt, PD. Dr. Harald

Galuska, PD Dr. Sebastian

Gärtner, PD Dr. Ulrich

Gattenlöhner, Prof. Dr. Stefan

Göttlich, Prof. Dr. Richard

Hanewald, Dr. Bernd

Hauch, Dr. Holger

Heiß, Univ.-Prof. Dr. Dr. Christian

Howaldt, Prof. Dr. Dr. Hans-Peter

Imirzalioglu, PD Dr. Can

Jung, Prof. Dr. Andreas

Jurkat, PD Dr. Harald

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Quality of life of female and male vegetarian and vegan endurance runners compared to omnivores – results from the NURMI study (step 2)

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Abstract

Background: Health-related effects of a vegetarian or vegan diet are known to support parameters positively affecting exercise performance in athletes, whereas knowledge about psyche and wellbeing is sparse. Therefore, the aim of the Nutrition and Running High Mileage (NURMI) Study (Step 2) was to compare Quality of Life (QOL) scores among endurance runners following a vegetarian or vegan diet against those who adhere to an omnivorous diet.

Methods: The study was conducted following a cross-sectional design. A total of 281 recreational runners (159 women, 122 men) completed the WHOQOL-BREF questionnaire consisting of the domains physical health, psychological wellbeing, social relationships and environment, which generates scores on a scale from 4 to 20. Data analysis was performed using ANOVA.

Results: It was found that 123 subjects followed an omnivorous diet and 158 adhered to a vegetarian/vegan diet. There were 173 runners who met the inclusion criteria ('NURMI-Runners'), among them 103 half-marathoners and 70 marathoners and ultramarathoners, as well as 108 10 km runners as control group. Overall QOL scores were high (~ 16.62 ± 1.91). Men had higher scores than women due to high scores in the physical health and psychological well-being dimensions. Adhering to an omnivorous diet affected environment scores for women and social relationships scores for men. A minor effect concerning race distance was observed in women, where half-marathoners had a higher environmental score than 10-km runners. A moderate diet×race distance interaction on environment scores was shown for men.

Conclusions: The results revealed that endurance runners had a high QOL regardless of the race distance or diet choice. These findings support the notion that adhering to a vegetarian or vegan diet can be an appropriate and equal alternative to an omnivorous diet.

Trial registration: ISRCTN73074080. Registered 12th June 2015, retrospectively registered.

Keywords: Vegetarian, Vegan, Diet, Nutrition, Marathon running, Quality of life, Life satisfaction, WHOQOL-BREF

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Background

In the past 15 years, the number of participants in endurance running events, such as marathon or half-marathon races, has consistently been at a high level [1, 2]. More and more athletes among these adhere to a vegetarian or vegan diet [3, 4].

Health-related effects of a vegetarian or vegan diet have been found in athletes and are known to support parameters that positively affect exercise performance, such as physical fitness, resilience to chronic diseases, and weight control [5–7]. However, the knowledge about psychological and personal well-being is sparse. In order to generate an impression of an individual's life situation, meaning her/his needs, problems, concerns and emotional state, it can be appropriate to measure Quality of Life (QOL): a multidimensional concept that measures life satisfaction, including family, physical health, education, employment, wealth, religious beliefs, finance and environment factors [8, 9].

Variables that affect QOL include sex, dietary habits and physical activity [10–14]. The investigation of the impact of sex on QOL has yielded various results. Whereas in some studies higher QOL scores have been found in men [15–17], it has also been reported that women have higher scores [14]. The dimension of social relationships especially has had higher scores in female subjects [18]. In terms of sex differences in QOL-scores in endurance runners, no data has been made available yet.

The impact of diet choice on QOL has been investigated in the general population. A high QOL in general has been reported for both vegetarians [13] and vegans [10], as well as the beneficial effects of a meatless diet rich in fruits and vegetables on the QOL dimensions of 'depression' [19], 'anxiety' [20] and 'felt stress' [21, 22]. The rationale for this interconnectedness is that being a vegetarian or vegan is both a dietary habit and a lifestyle [23]. For many, vegetarianism and veganism are philosophies of how life should be lived and hence they are connected with certain characteristics, such as being health-conscious, liberal and having a humanistic view of the world [24]. As vegetarian and vegan dietary patterns are frequently considered in the dietary strategies of athletes [6], the purpose of the present study was to investigate to what extent findings from the general population apply to endurance athletes.

Similar results have been found for physical activity. It has been shown that physical activity in general can lead to a high QOL [12, 25]. This has been confirmed by other studies investigating strength training [26], cycling [27] and musculoskeletal fitness [28]. As 'physical health' is an important requirement for life satisfaction, the synergistic effects of persistent adherence to a healthy diet and regular sport necessarily strongly influences QOL [23]. Further beneficial effects of an active lifestyle have been shown for numerous facets of QOL, such as 'life satisfaction' [29], 'sleep architecture' [30], 'felt stress' [31], 'anxiety' [32] and 'depression' [33].

All in all, some knowledge exists in terms of QOL and its interconnectedness with sex, diet choice and physical activity for the general population, suggesting there may be positive effects of a vegetarian and vegan diet on QOL. However, the data in terms of endurance runners and QOL is sparse. Therefore, in the Nutrition and Running High Mileage (NURMI) Study Step 2 we focused on the QOL of endurance runners, in particular in half-marathoners and marathoners. In the context of a rising number of athletes following a vegetarian or vegan diet [3, 4] and a lack of scientific literature concerning these groups, the aim of the study was to investigate QOL in endurance runners adhering to a vegetarian or vegan diet and compare them to endurance runners following a mixed diet.

Based on the findings from the general population, we hypothesized that QOL of omnivorous and vegetarian/vegan endurance runners would be similar. Hence, a vegetarian or vegan diet could be an equivalent alternative to an omnivorous diet for endurance athletes.

Methods

Experimental approach to the problem

We assessed QOL using the WHOQOL-BREF [World Health Organization Quality of Life Assessment- brief (French: *bref*) version]. The WHOQOL-BREF is a shorter version of the original instrument that may be more convenient for use in large research studies or clinical trials [34]. The WHOQOL-BREF's validity is well established and has been confirmed by a number of studies [9, 35, 36].

The WHOQOL-BREF instrument comprises 26 items, which measure the following broad domains: physical health (i.e. activities of daily living, dependence on medicinal substances and medical aids, energy and fatigue, mobility, pain and discomfort, sleep and rest, work capacity; DOM 1), psychological well-being (i.e. bodily image and appearance, negative feelings, positive feelings, self-esteem, spirituality/religion/personal beliefs, thinking, learning, memory and concentration; DOM 2), social relationships (i.e. personal relationships, social support, sexual activity; DOM 3) and environment (i.e. financial resources, freedom, physical safety and security, health and social care: accessibility and quality, home environment, opportunities for acquiring new information and skills, participation in and opportunities for recreation/leisure activities, physical environment (i. e. pollution/noise/traffic/climate, transport; DOM 4).

Each item was rated on a 5-point Likert scale. The typical Likert scale is a 5-point ordinal scale used by respondents to rate the degree to which they agree or disagree with a statement (i.e. higher scores denote stronger agreement or disagreement, respectively).

Afterwards, four domain scores were derived. Raw domain scores for the WHOQOL were transformed to a 4–20 score and scaled in a positive direction (i.e. higher scores denote higher QOL). The mean score of items within each domain was used to calculate the domain score [34].

Subjects

The NURMI Study was conducted in three steps following a cross-sectional design. We recruited endurance runners mainly from German-speaking countries, such as Germany, Austria and Switzerland. In addition, we approached people from all over Europe. The subjects were contacted mainly via social media, websites of the organizers of marathon events, online running communities, email-lists, runners' magazines as well as magazines for health, vegetarian and/or vegan nutrition and lifestyle, sports fairs, fairs on vegetarian and vegan nutrition and lifestyle, and through personal contacts.

The study protocol [4] was approved by the ethics board of St. Gallen, Switzerland on May 6, 2015 (EKSG 14/145). The trial registration number is ISRCTN73074080.

Procedures

The participants completed an online survey within the NURMI Study Step 2, provided in German and English, which was available on https://www.nurmi-study.com/en from February 1st 2015 until December 31st 2015.

The survey started with a written description of the procedure and participants gave their informed consent to take part in the study. Afterwards, they completed the WHOQOL-BREF questionnaire (for further information see below) including questions concerning physical health, psychological well-being, social relationships and environment. In addition, we asked for age, sex and preferred diet.

For successful participation, the following criteria were required: written informed consent (1), at least 18 years of age (2), WHOQOL-BREF questionnaire completed (3), successful participation in a running event of either half-marathon or marathon distance in the past two years (4). Incomplete and inconsistent data sets were eliminated. Those who met all inclusion criteria but named a 10-km race as their running event were kept as controls. In the following they are called '10-km control group', whereas those who met the inclusion criteria to the full extent are referred to as 'NURMI-Runners'.

Participants were classified into two diet groups: omnivorous diet (commonly known as Western diet, no dietary restrictions) versus vegetarian (no meat)/vegan (no products from animal sources, such as meat, fish, milk and dairy products, eggs and honey) diet [5]. Moreover, they were categorized into three race distances: 10 km, half-marathon and marathon/ultramarathon.

Statistical analyses

The statistical software IBM SPSS version 23.0 (SPSS, Chicago, USA) and GraphPad Prism version 7.0 (GraphPad Software, San Diego, USA) performed all statistical analyses. The Kolmogorov-Smirnoff test of normality and visual inspection of normal Q-Q plots examined the normality of all variables. Mean values and standard deviation (SD) were calculated for all variables. The student t-test examined sex differences in the four domains of WHOQOL and Cohen's d ($d \leq 0.2$, trivial; $0.2 < d \leq 0.6$, small; $0.6 < d \leq 1.2$, moderate; $1.2 < d \leq 2.0$, large; and $d > 2.0$, very large) evaluated the magnitude of these differences. A two-way ANOVA, followed by a Bonferroni post-hoc analysis, examined the main effects of nutrition and race distance, the nutrition*race distance interaction on WHOQOL. The magnitude of differences in the ANOVA was evaluated using eta squared (η^2) as trivial ($\eta^2 < 0.01$), small ($0.01 \leq \eta^2 < 0.06$), moderate ($0.06 \leq \eta^2 < 0.14$) and large ($\eta^2 \geq 0.14$). The level of statistical significance was set at $p \leq 0.05$.

Results

A total of 317 endurance runners completed the survey, of whom 281 (159 women and 122 men) with a mean age of 40 ± 11 years remained after data clearance. Their countries of origin were Germany ($n = 200$), Switzerland ($n = 14$), Austria ($n = 50$) and some others ($n = 17$; Belgium, Brazil, Canada, Italy, Luxemburg, Netherlands, Poland, Spain, United Kingdom).

With regard to dietary subgroups, 123 subjects followed an omnivorous diet and 158 adhered to a vegetarian/vegan diet. Concerning race distances, there were 173 NURMI-Runners (103 half-marathoners, 70 marathoners/ultramarathoners) and 108 members of the 10-km control group. Characteristics of our subjects are presented in Table 1.

Sex differences in quality of life

Scores for physical health were 17.6 ± 1.4 (85.13%) in women and 18.0 ± 1.3 (87.24%) in men, for psychological wellbeing 16.0 ± 2.1 (74.71%) and 16.8 ± 1.8 (80.16%), for social relationships 15.5 ± 2.6 (71.59%) and 15.4 ± 2.9 (70.97%), and for environment 16.8 ± 1.6 (80.05%) and 17.0 ± 1.7 (80.99%). Men had higher scores in physical health ($p = 0.037$, d = 0.26) and psychological wellbeing ($p < 0.001$, d = 0.45), but there were no differences with regard to social relationships counts ($p = 0.761$, d = 0.03) and environment scores ($p = 0.445$, d = 0.09) compared to women (Fig. 1a, b, 2a, b).

Table 1 Anthropometric and Demographic Characteristics of the Subjects Displayed by Diet Group

		Total	Omnivorous	Vegetarian/Vegan	*p*
Number of Subjects		281 (100%)	123 (43.77%)	158 (56.23%)	
Sex	Female	159 (56.58%)	58 (47.15%)	101 (63.92%)	0.005
	Male	122 (43.42%)	65 (52.85%)	57 (36.08%)	
Mean Age (years)		40.00 ± 11.00	41.96 ± 11.02	38.26 ± 10.84	0.005
Race Distance					
Control Group	10 km	108 (38.43%)	43 (34.96%)	65 (41.14%)	0.561
NURMI-Runners	Half-Marathon	103 (36.65%)	47 (38.21%)	56 (35.44%)	
	Marathon/Ultramarathon	70 (24.91%)	33 (26.83%)	37 (23.42%)	
Mean Body Weight (kg)		65.62 ± 10.53	67.91 ± 10.78	63.85 ± 10.01	0.001
Mean Height (m)		1.72 ± 0.87	1.73 ± 0.08	1.72 ± 0.90	0.134
Mean BMI_{CALC} (kg/m^2)		22.03 ± 2.49	22.55 ± 2.44	21.63 ± 2.45	0.002
Academic Qualification	No Qualification	1 (< 1%)	0 (< 1%)	1 (< 1%)	0.464
	Upper Secondary Education/Technical Qualification/GCSE or Equivalent	94 (33.45%)	45 (36.59%)	49 (31.01%)	
	A Levels or Equivalent	62 (22.06%)	32 (26.02%)	30 (18.99%)	
	University Degree/Higher Degree (*i. e.* doctorate)	96 (34.16%)	36 (29.27%)	60 (37.97%)	
	No Answer	28 (9.96%)	10 (8.13%)	18 (11.39%)	
Marital Status	Divorced/Separated	16 (5.69%)	3 (2.44%)	13 (8.23%)	0.004
	Married/Living with Partner	190 (67.62%)	94 (76.42%)	96 (60.76%)	
	Single	75 (26.69%)	26 (21.14%)	49 (31.01%)	
Country of Residence	Austria	50 (17.79%)	28 (22.76%)	22 (13.92%)	0.010
	Germany	200 (71.17%)	85 (69.11%)	115 (72.78%)	
	Switzerland	14 (4.98%)	8 (6.5%)	6 (3.8%)	
	Other	17 (6.05%)	2 (1.63%)	15 (9.49%)	

Note. Results are presented as mean ± SD. 10 km – 10 Kilometer Control Group. BMI_{CALC} – Body Mass Index (calculated). p – p-value for difference among groups

Main effects of diet choice on quality of life

Scores for physical health were 17.5 ± 1.5 (84.6%) in female omnivorous runners, 18.0 ± 1.4 (87.4%) in male omnivorous runners, 17.7 ± 1.5 (85.4%) in female vegetarian/vegan runners and 17.9 ± 1.1 (87.0%) in male vegetarian/vegan runners. With regard to psychological wellbeing, mean scores were 16.4 ± 2.0 (77.3%) in female omnivorous runners, 17.0 ± 1.9 (81.5%) in male omnivorous runners, 15.7 ± 2.0 (73.3%) in female vegetarian/vegan runners and 16.6 ± 1.7 (78.6%) in male vegetarian/vegan runners. Social relationships scores were 15.5 ± 2.3 (71.7%) in female omnivorous runners, 15.9 ± 2.7 (74.4%) in male omnivorous runners, 15.5 ± 2.8 (71.6%) in female vegetarian/vegan runners and 14.7 ± 2.9 (67.1%) in male vegetarian/vegan runners. In terms of environment, mean scores were 17.2 ± 1.6 (82.2%) in female omnivorous runners, 17.2 ± 1.8 (82.3%) in male omnivorous runners, 16.6 ± 1.6 (78.8%) in female vegetarian/vegan runners and 16.7 ± 1.6 (79.6%) in male vegetarian/vegan runners (Fig. 1a and b).

No major effect of diet on physical health ($p = 0.248$, $\eta^2 = 0.009$ and $p = 0.844$, $\eta^2 < 0.001$), and psychological wellbeing ($p = 0.164$, $\eta^2 = 0.013$ and $p = 0.246$, $\eta^2 = 0.012$) in both sexes, on social relationships in women ($p = 0.691$, $\eta^2 = 0.001$) or on environment in men ($p = 0.358$, $\eta^2 = 0.007$) was observed. However, a minor effect of diet on social relationships in men ($p = 0.047$, $\eta^2 = 0.034$) and environment in women ($p = 0.043$, $\eta^2 = 0.027$) was shown with a higher score in the omnivorous diet (**Fig. 1a, Fig. 1b**). Mean scores for each item are shown in Table 2.

Main effects of race distance on quality of life and diet×race distance interaction

Mean scores in physical health were 17.5 ± 1.5 (84.3%) in female members of the 10-km control group, 18.0 ± 1.1 (87.4%) in male members of the 10-km control group, 17.7 ± 1.3 (85.6%) in female half marathoners, 18.1 ± 1.2 (87.8%) in male half marathoners, 17.8 ± 1.3 (86.5%) in female marathoners/ultramarathoners and 17.8 ± 1.6 (86.4%) in male marathoners/ultramarathoners. In terms of psychological wellbeing, mean scores were 15.8 ± 2.0 (73.9%) in female members of the 10-km control group, 16.7 ± 2.0 (79.1%) in male members of the 10-km control

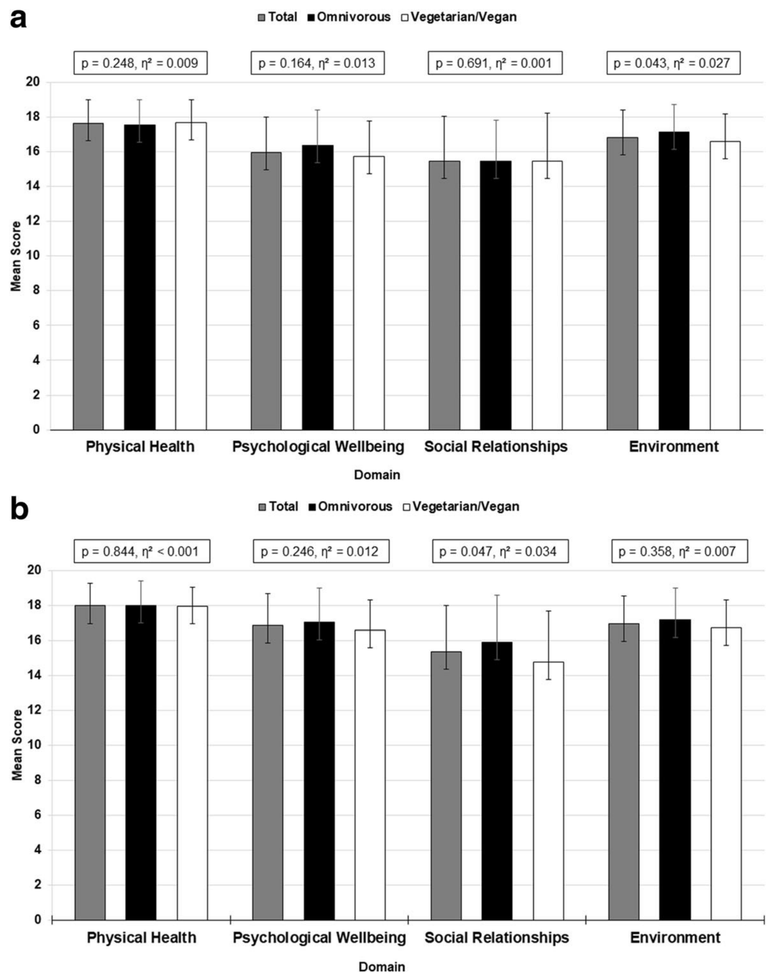

Fig. 1 a Mean WHOQOL-BREF-Domain Scores of Women Displayed by Diet Group. *Note.* Results are presented as mean ± SD. p – *p*-value for differences between groups. η^2 – effect size. **b**. Mean WHOQOL-BREF-Domain Scores of Men Displayed by Diet Group. *Note.* Results are presented as mean ± SD. p – *p*-value for differences between groups. η^2 – effect size

group, 15.8 ± 2.1 (74.0%) in female half marathoners, 16.9 ± 2.0 (80.7%) in male half marathoners, 16.5 ± 2.1 (78.4%) in female marathoners/ultramarathoners and 16.9 ± 1.6 (80.4%) in male marathoners/ultramarathoners. Mean scores in social relationships were 15.4 ± 2.6 (71.3%) in female members of the 10-km control group, 15.0 ± 2.6 (68.7%) in male members of the 10-km control group, 15.4 ± 2.8 (71.5%) in female half marathoners, 15.6 ± 3.0 (72.4%) in male half marathoners, 15.6 ± 2.5 (72.5%) in female marathoners/ultramarathoners and 15.4 ± 1.7 (71.1%) in male marathoners/ultramarathoners. With regard to environment, mean scores were 16.4 ± 1.6 (77.6%) in female members of the 10-km control group, 16.4 ± 1.8 (77.4%) in male members of the 10-km control group, 16.4 ± 1.5 (77.6%) in female half marathoners, 17.28 ± 1.7 (83.0%) in male half marathoners, 17.2 ± 1.3 (82.3%) in female marathoners/ultramarathoners and 17.1 ± 1.7 (81.6%) in male marathoners/ultramarathoners.

No major effect of race distance on physical health ($p = 0.586$, $\eta^2 = 0.007$ and $p = 0.847$, $\eta^2 = 0.003$), psychological wellbeing ($p = 0.379$, $\eta^2 = 0.013$ and $p = 0.818$, $\eta^2 = 0.003$), or social relationships ($p = 0.986$, $\eta^2 < 0.001$ and $p = 0.838$, $\eta^2 = 0.003$) for women and men, respectively was shown.

Also, no effect of race distance on environment for men was found ($p = 0.121$, $\eta^2 = 0.036$). However, a minor effect was observed for women ($p = 0.014$, $\eta^2 = 0.054$), where half-marathoners had a higher environment score than the members of the 10-km control group (Fig. 2a, 2b, Table 3).

No diet×race distance interaction on physical health ($p = 0.346$, η2 = 0.014 and $p = 0.060$, η2 = 0.047), psychological well-being ($p = 0.672$, η2 = 0.005 and $p = 0.026$, η2 = 0.061) or social relationships ($p = 0.490$, η2 = 0.009 and $p = 0.112$, η2 = 0.037) for women or men, respectively, was observed. A moderate diet×race distance interaction on environment score was shown for men ($p =$

Table 2 Mean Likert-Scores of the WHOQOLBREF-Items Displayed by Diet Group

Question	Total	Omnivorous	Vegetarian/Vegan	p	η^2
How would you rate your Quality of Life? [1]					
Women	4.33 ± 0.58	4.38 ± 0.59	4.30 ± 0.58	0.450	0.002
Men	4.48 ± 0.65	4.46 ± 0.74	4.49 ± 0.53		
How satisfied are you with your health? [2]					
Women	4.09 ± 0.93	4.03 ± 1.11	4.13 ± 0.82	0.176	0.007
Men	4.30 ± 0.95	4.11 ± 1.13	4.51 ± 0.68		
To what extent do you feel that physical pain prevents you from doing what you need to do? [3]					
Women	1.33 ± 0.58	1.31 ± 0.65	1.35 ± 0.54	0.145	0.008
Men	1.34 ± 0.57	1.42 ± 0.62	1.25 ± 0.52		
How much do you need any medical treatment to function in your daily life? [3]					
Women	1.15 ± 0.42	1.24 ± 0.55	1.10 ± 0.34	0.357	0.003
Men	1.22 ± 0.67	1.23 ± 0.68	1.21 ± 0.65		
How much do you enjoy life? [3]					
Women	4.17 ± 0.71	4.31 ± 0.79	4.09 ± 0.67	0.354	0.003
Men	4.17 ± 0.71	4.20 ± 0.73	4.14 ± 0.69		
To what extent do you feel your life to be meaningful? [3]					
Women	4.16 ± 0.65	4.19 ± 0.71	4.15 ± 0.62	0.487	0.002
Men	4.28 ± 0.77	4.31 ± 0.86	4,25 ± 0.67		
How well are you able to concentrate? [3]					
Women	3.89 ± 0.75	4.02 ± 0.82	3.81 ± 0.72	0.217	0.006
Men	4.01 ± 0.72	4.00 ± 0.78	4.02 ± 0.65		
How safe do you feel in your daily life? [3]					
Women	4.16 ± 0.65	4.19 ± 0.71	4.15 ± 0.62	0.904	< 0.001
Men	4.28 ± 0.77	4.31 ± 0.86	4.25 ± 0.67		
How healthy is your physical environment? [3]					
Women	3.91 ± 0.78	3.93 ± 0.75	3.90 ± 0.81	0.190	0.006
Men	3.98 ± 0.80	4.11 ± 0.80	3.82 ± 0.81		
Do you have enough energy for everyday life? [4]					
Women	4.18 ± 0.64	4.16 ± 0.70	4.19 ± 0.61	0.893	< 0.001
Men	4.34 ± 0.61	4.34 ± 0.62	4.35 ± 0.61		
Are you able to accept your bodily appearance? [4]					
Women	4.00 ± 0.70	3.79 ± 0.73	4.02 ± 0.69	0.407	0.002
Men	4.24 ± 0.69	4.28 ± 0.66	4.19 ± 0.72		
Have you enough money to meet your needs? [4]					
Women	3.98 ± 0.79	4.14 ± 0.63	3.89 ± 0.88	0.261	0.005
Men	3.93 ± 0.82	3.94 ± 0.86	3.91 ± 0.77		
How available to you is the information that you need in your day-to-day life? [4]					
Women	4.65 ± 0.50	4.79 ± 0.43	4.57 ± 0.54	0.093	0.010
Men	4.71 ± 0.46	4.72 ± 0.46	4.70 ± 0.46		
To what extent do you have the opportunity for leisure activities? [4]					
Women	4.33 ± 0.70	4.43 ± 0.73	4.28 ± 0.68	0.089	0.010
Men	4.28 ± 0.69	4.22 ± 0.75	4.35 ± 0.61		
How well are you able to get around? [1]					
Women	4.84 ± 0.39	4.78 ± 0.46	4.87 ± 0.34	0.198	0.006

Table 2 Mean Likert-Scores of the WHOQOLBREF-Items Displayed by Diet Group *(Continued)*

Question	Total	Omnivorous	Vegetarian/Vegan	p	η^2
Men	4.88 ± 0.33	4.89 ± 0.32	4.86 ± 0.35		
How satisfied are you with your sleep? [2]					
Women	3.82 ± 0.91	3.64 ± 0.85	3.92 ± 0.95	0.030	0.017
Men	3.96 ± 0.85	4.05 ± 0.85	3.86 ± 0.86		
How satisfied are you with your ability to perform your daily living activities? [2]					
Women	4.26 ± 0.72	4.36 ± 0.62	4.20 ± 0.78	0.197	0.006
Men	4.34 ± 0.58	4.32 ± 0.62	4.37 ± 0.53		
How satisfied are you with your capacity for work? [2]					
Women	4.23 ± 0.71	4.28 ± 0.67	4.23 ± 0.71	0.717	< 0.001
Men	4.46 ± 0.65	4.52 ± 0.68	4.39 ± 0.61		
How satisfied are you with yourself? [2]					
Women	3.75 ± 0.60	4.00 ± 0.62	3.94 ± 0.82	0.821	< 0.001
Men	4.14 ± 0.72	4.18 ± 0.79	4.09 ± 0.64		
How satisfied are you with your personal relationships? [2]					
Women	4.02 ± 0.82	4.09 ± 0.76	3.98 ± 0.86	0.366	0.003
Men	4.08 ± 0.80	4.22 ± 0.79	3.93 ± 0.83		
How satisfied are you with your sex life? [2]					
Women	3.58 ± 0.96	3.52 ± 0.98	3.62 ± 0.95	0.170	0.007
Men	3.58 ± 1.09	3.69 ± 1.11	3.46 ± 1.08		
How satisfied are you with the support you get from your friends? [2]					
Women	3.99 ± 0.73	4.00 ± 0.62	3.98 ± 0.79	0.067	0.012
Men	3.85 ± 0.76	4.02 ± 0.72	3.67 ± 0.81		
How satisfied are you with the conditions of your living place? [2]					
Women	4.13 ± 0.90	4.28 ± 0.89	4.04 ± 0.91	0.386	0.003
Men	4.14 ± 0.91	4.34 ± 0.95	3.91 ± 0.88		
How satisfied are you with your access to health services? [2]					
Women	4.19 ± 0.81	4.22 ± 0.75	4.18 ± 0.84	0.654	0.001
Men	4.25 ± 0.75	4.31 ± 0.84	4.18 ± 0.66		
How satisfied are you with your transport? [2]					
Women	4.25 ± 0.79	4.31 ± 0.63	4.22 ± 0.87	0.830	< 0.001
Men	4.36 ± 0.78	4.38 ± 0.83	4.33 ± 0.72		
How often do you have negative feelings such as blue mood, despair, anxiety, depression? [5]					
Women	2.23 ± 0.83	1.95 ± 0.76	2.23 ± 0.83	0.261	0.005
Men	1.63 ± 0.88	1.54 ± 0.94	1.74 ± 0.81		

Note. Results are presented as mean ± SD. p – *p*-value for ANOVA test. η^2 – effect size
[1] 1 = very poor, 2 = poor, 3 = neither poor nor good, 4 = good, 5 = very good
[2] 1 = very dissatisfied, 2 = dissatisfied, 3 = neither satisfied nor dissatisfied, 4 = satisfied, 5 = very satisfied
[3] 1 = not at all, 2 = a little, 3 = a moderate amount, 4 = very much, 5 = an extreme amount
[4] 1 = not at all, 2 = a little, 3 = moderately, 4 = mostly, 5 = completely
[5] 1 = never, 2 = seldom, 3 = quite often, 4 = very often, 5 = always

0.013, η2 = 0.072), but no interaction was found for women ($p = 0.925$, η2 = 0.001).

Discussion

This study aimed to investigate QOL of female and male endurance runners following a vegetarian or vegan diet and to compare it to female and male endurance runners adhering to an omnivorous diet. The hypothesis was that QOL would be equal in both groups and hence a vegetarian or vegan diet could be an equivalent alternative to an omnivorous diet.

The main findings were that *(i)* men had higher scores in physical health and psychological well-being as compared to women, but there were no sex differences in

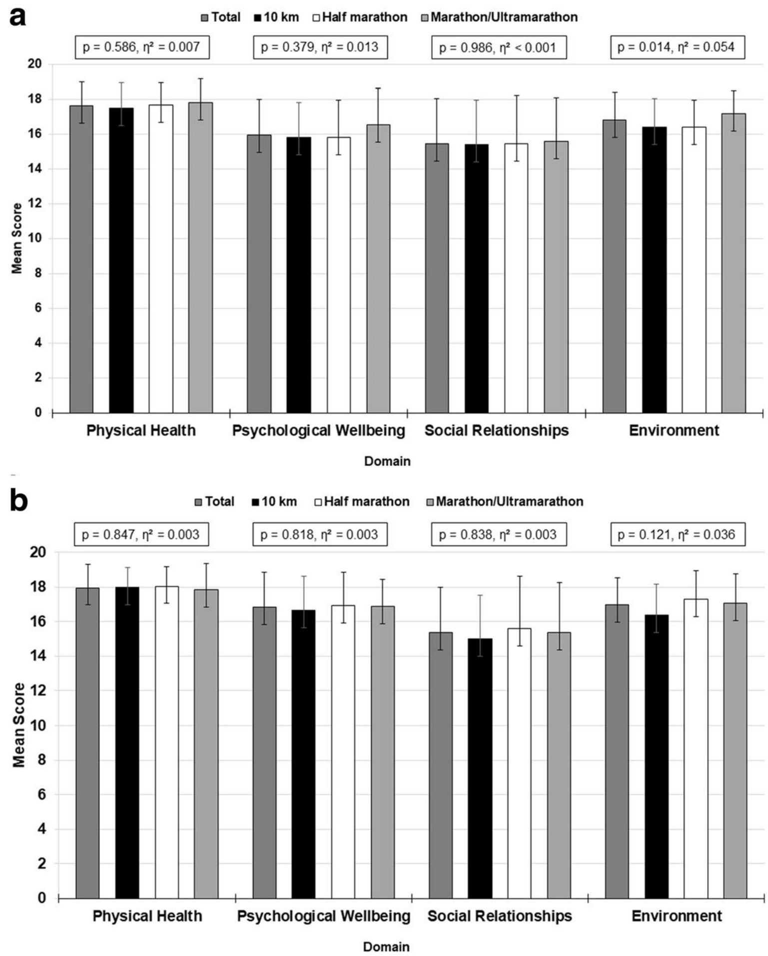

Fig. 2 a Mean WHOQOL-BREF-Domain Scores of Women Displayed by Race Distance. *Note.* Results are presented as mean ± SD. p – *p*-value for differences between groups. η^2 – effect size. **b** Mean WHOQOL-BREF-Domain Scores of Men Displayed by Race Distance. *Note.* Results are presented as mean ± SD. p – *p*-value for differences between groups. η^2 – effect size

terms of social relationships counts and environment scores, *(ii)* no major effect of diet on physical health and psychological wellbeing in either sex, on social relationships for women or on environment for men, was observed, *(iii)* a minor effect of diet on social relationships for men and environment for women was shown, with higher score for omnivores, *(iv)* no major effect of race distance on physical health, psychological and social relationships was shown for either women or men, *(v)* no effect of race distance on environment for men was found, but a minor effect was observed for women, where half-marathoners had a higher environment score than the members of the 10-km control group, *(vi)* no diet×race distance interaction on physical health, psychological wellbeing or social relationships was observed for women or men, and *(vii)* a moderate diet×race distance interaction on environment score was shown for men, although no interaction was found in women.

Sex differences in quality of life

A first important finding was that male endurance runners have higher overall QOL scores compared to female endurance runners, mainly based on higher counts in the domains of physical health and psychological wellbeing. These sex differences have been observed in other studies as well [11, 16, 17], particularly relating to psychological factors [37].

A potential explanation could be that women are more emotional and sensitive to perceived pressure, as compared to men [38, 39]. It has been shown that women are more willing to report symptoms [40] whereas men often stick to traditional role concepts. They think society expects them to be strong and self-reliant ('Macho-Concept', 'Social desirability'), but they must not complain about symptoms or other 'sissy-stuff' [41, 42]. The phenomenon that women report poorer (physical) health is well known and is termed 'gender paradox'. Although women live

Table 3 Mean Likert-Scores of the WHQOLBREF-Items Displayed by Race Distance

		Control Group	NURMI-Runners			
Question	Total	10 KM	HM	M/UM	p	η^2
How would you rate your Quality of Life? [1]						
Women	4.33 ± 0.58	4.33 ± 0.58	4.26 ± 0.62	4.44 ± 0.51	0.111	0.016
Men	4.48 ± 0.65	4.45 ± 0.58	4.59 ± 0.56	4.37 ± 0.79		
How satisfied are you with your health? [2]						
Women	4.09 ± 0.93	3.93 ± 1.03	4.18 ± 0.89	4.37 ± 0.69	0.111	0.016
Men	4.30 ± 0.95	4.39 ± 0.68	4.30 ± 1.03	4.21 ± 1.04		
To what extent do you feel that physical pain prevents you from doing what you need to do? [3]						
Women	4.67 ± 0.58	4.67 ± 0.58	4.72 ± 0.53	4.56 ± 0.70	0.314	0.008
Men	4.66 ± 0.57	4.85 ± 0.36	4.67 ± 0.56	4.51 ± 0.69		
How much do you need any medical treatment to function in your daily life? [3]						
Women	4.82 ± 0.43	4.83 ± 0.42	4.89 ± 0.45	4.81 ± 0.40	0.746	0.002
Men	4.78 ± 0.66	4.82 ± 0.47	4.85 ± 0.63	4.67 ± 0.81		
How much do you enjoy life? [3]						
Women	4.17 ± 0.71	4.13 ± 0.72	4.18 ± 0.73	4.26 ± 0.66	0.924	0.001
Men	4.17 ± 0.71	4.12 ± 0.60	4.11 ± 0.90	4.28 ± 0.55		
To what extent do you feel your life to be meaningful? [3]						
Women	4.11 ± 0.78	4.05 ± 0.84	4.12 ± 0.76	4.26 ± 0.66	0.950	< 0.001
Men	4.31 ± 0.81	4.24 ± 0.71	4.30 ± 1.03	4.37 ± 0.62		
How well are you able to concentrate? [4]						
Women	3.89 ± 0.76	3.87 ± 0.74	3.89 ± 0.80	3.93 ± 0.73	0.903	0.001
Men	4.01 ± 0.71	3.97 ± 0.59	3.96 ± 0.70	4.09 ± 0.81		
How safe do you feel in your daily life? [4]						
Women	4.16 ± 0.66	4.04 ± 0.71	4.23 ± 0.60	4.37 ± 0.57	0.267	0.010
Men	4.28 ± 0.76	4.30 ± 0.68	4.26 ± 0.91	4.28 ± 0.67		
How healthy is your physical environment? [4]						
Women	3.91 ± 0.78	3.75 ± 0.84	4.07 ± 0.73	4.04 ± 0.65	0.220	0.011
Men	3.98 ± 0.80	4.00 ± 0.71	4.07 ± 0.88	3.86 ± 0.77		
Do you have enough energy for everyday life? [4]						
Women	4.18 ± 0.64	4.07 ± 0.70	4.28 ± 0.56	4.26 ± 0.59	0.888	0.001
Men	4.34 ± 0.59	4.18 ± 0.64	4.37 ± 0.53	4.44 ± 0.59		
Are you able to accept your bodily appearance? [4]						
Women	4.00 ± 0.70	3.95 ± 0.70	4.00 ± 0.71	4.15 ± 0.72	0.349	0.008
Men	4.24 ± 0.64	4.15 ± 0.80	4.35 ± 0.53	4.19 ± 0.63		
Have you enough money to meet your needs? [4]						
Women	3.98 ± 0.79	3.91 ± 0.87	4.00 ± 0.73	4.15 ± 0.66	0.826	0.001
Men	3.93 ± 0.82	3.79 ± 0.82	3.98 ± 0.86	3.98 ± 0.77		
How available to you is the information that you need in your day-to-day life? [4]						
Women	4.65 ± 0.50	4.64 ± 0.51	4.68 ± 0.47	4.63 ± 0.57	0.242	0.010
Men	4.71 ± 0.45	4.55 ± 0.51	4.78 ± 0.42	4.77 ± 0.43		
To what extent do you have the opportunity for leisure activities? [4]						
Women	4.33 ± 0.70	4.21 ± 0.76	4.51 ± 0.57	4.30 ± 0.72	0.481	0.005
Men	4.28 ± 0.68	4.00 ± 0.66	4.41 ± 0.69	4.35 ± 0.65		

Table 3 Mean Likert-Scores of the WHQOLBREF-Items Displayed by Race Distance *(Continued)*

		Control Group	NURMI-Runners			
How well are you able to get around? [1]						
Women	4.84 ± 0.37	4.76 ± 0.43	4.91 ± 0.29	4.93 ± 0.27	0.394	0.007
Men	4.88 ± 0.33	4.85 ± 0.36	4.87 ± 0.34	4.91 ± 0.29		
How satisfied are you with your sleep? [2]						
Women	3.82 ± 0.91	3.83 ± 0.95	3.81 ± 0.85	3.81 ± 0.96	0.530	0.005
Men	3.96 ± 0.85	4.12 ± 0.76	4.00 ± 0.81	3.79 ± 0.97		
How satisfied are you with your ability to perform your daily living activities? [2]						
Women	4.26 ± 0.72	4.23 ± 0.75	4.18 ± 0.74	4.52 ± 0.58	0.226	0.011
Men	4.34 ± 0.57	4.21 ± 0.49	4.39 ± 0.54	4.40 ± 0.66		
How satisfied are you with your capacity for work? [2]						
Women	4.23 ± 0.71	4.23 ± 0.67	4.18 ± 0.69	4.33 ± 0.88	0.884	0.001
Men	4.46 ± 0.61	4.45 ± 0.56	4.43 ± 0.62	4.49 ± 0.63		
How satisfied are you with yourself? [2]						
Women	3.96 ± 0.72	3.95 ± 0.73	3.91 ± 0.66	4.11 ± 0.80	0.095	0.017
Men	4.14 ± 0.61	4.09 ± 0.77	4.28 ± 0.46	4.02 ± 0.60		
How satisfied are you with your personal relationships? [2]						
Women	4.02 ± 0.82	4.05 ± 0.80	3.96 ± 0.84	4.04 ± 0.85	0.699	0.003
Men	4.08 ± 0.80	4.00 ± 0.71	4.11 ± 0.85	4.12 ± 0.82		
How satisfied are you with your sex life? [2]						
Women	3.58 ± 0.96	3.64 ± 0.94	3.51 ± 1.04	3.59 ± 0.84	0.698	0.003
Men	3.58 ± 1.09	3.48 ± 1.15	3.54 ± 1.13	3.70 ± 1.01		
How satisfied are you with the support you get from your friends? [2]						
Women	3.99 ± 0.73	3.87 ± 0.68	4.11 ± 0.80	4.07 ± 0.68	0.423	0.006
Men	3.85 ± 0.75	3.76 ± 0.61	4.04 ± 0.82	3.72 ± 0.73		
How satisfied are you with the conditions of your living place? [2]						
Women	4.13 ± 0.90	4.03 ± 0.94	4.21 ± 0.90	4.22 ± 0.75	0.861	0.001
Men	4.14 ± 0.91	3.91 ± 0.98	4.20 ± 0.96	4.26 ± 0.79		
How satisfied are you with your access to health services? [2]						
Women	4.19 ± 0.81	4.00 ± 0.85	4.39 ± 0.75	4.33 ± 0.68	0.403	0.007
Men	4.25 ± 0.75	4.18 ± 0.73	4.33 ± 0.70	4.21 ± 0.83		
How satisfied are you with your transport? [2]						
Women	4.25 ± 0.79	4.24 ± 0.69	4.25 ± 0.87	4.30 ± 0.87	0.073	0.019
Men	4.36 ± 0.77	4.03 ± 0.85	4.54 ± 0.66	4.42 ± 0.76		
How often do you have negative feelings such as blue mood, despair, anxiety, depression? [5]						
Women	3.80 ± 0.80	3.80 ± 0.82	3.65 ± 0.79	4.11 ± 0.70	0.109	0.016
Men	4.37 ± 0.65	4.39 ± 0.61	4.37 ± 0.68	4.35 ± 0.65		

Note. Results are presented as mean ± SD. 10 km – 10 Kilometer Control Group. HM – Half Marathon. M – Marathon. UM – Ultramarathon. p – p-value for ANOVA test. η^2 – effect size

[1] 1 = very poor, 2 = poor, 3 = neither poor nor good, 4 = good, 5 = very good

[2] 1 = very dissatisfied, 2 = dissatisfied, 3 = neither satisfied nor dissatisfied, 4 = satisfied, 5 = very satisfied

[3] 1 = not at all, 2 = a little, 3 = a moderate amount, 4 = very much, 5 = an extreme amount

[4] 1 = not at all, 2 = a little, 3 = moderately, 4 = mostly, 5 = completely

[5] 1 = never, 2 = seldom, 3 = quite often, 4 = very often, 5 = always

longer than men on average, researchers have found that women are more likely to report poorer health, suffer higher rates of morbidity, and use more health services than men [43, 44]. In terms of social relationship scores, there were no detectable differences between men and women, which contradicts results of previous studies [17, 18]. This can be explained by the fact that athletes usually have higher scores in this domain and thus any sex difference was eliminated [45]. In environment scores, there were no sex differences either. This finding is consistent with the results from other research [14].

Impact of the choice of the diet on quality of life

A second important finding was that diet choice does not affect the QOL-domains of physical health, psychological wellbeing, and social relationships for women or environment for men. However, our subjects showed that mean total domain scores are constantly high level (i.e. 16.99 on the 4–20 scale), mainly exceeding scores that have been generated for the general population in other studies (i.e. 15.70 [46] and 15.22 [47] on the 4–20 scale).

These findings confirmed our hypothesis that QOL of runners who adhere to a vegetarian or vegan diet is as good as the QOL of those who follow an omnivorous diet. Thus, they supported the notion that a vegetarian or vegan diet can be an appropriate and an equivalent alternative to an omnivorous diet.

The results are consistent with current research. Several studies have shown high QOL scores in vegetarians [13] and vegans [10, 48]. A reasonable explanation is the fact that a diet rich in fruit and vegetables leads to a higher degree of fitness and lower morbidity, and thus to a good health status [5, 7, 49]. It is beyond debate that a healthy body is an inevitable requirement for a healthy mind – and hence for a high perception of QOL [50]. The dictum 'Mens sana in corpore sano' – 'a healthy mind in a healthy body' – takes up this idea and also applies vice versa. This assumption has been supported by studies showing that vegetarians and vegans report low stress levels and good states of mood [21, 22].

Moreover, the high QOL scores can be explained by the personality profiles as well as moral concepts and personal beliefs of vegetarians and vegans. A current investigation shows that they tend to be more liberal, altruistic, universalistic, and empathic [48] and often deal intensively with moral and ethical concerns relating to animal treatment and conscious behavior towards the environment [49]. This could make them believe that they contribute to a sustainable relationship between mankind and environment [50], which could generate a higher life satisfaction.

However, we found a minor effect of diet on social relationships scores for men. This result can be explained again by men's self-perception or awareness of other men. The fact that men often still stick to traditional role concepts [41, 42] could lead them to consider male vegetarians or vegans as not being real men, since a real man has to eat meat [51]. This would evoke the impression of being isolated and excluded, consequently leading to a reduction in self-esteem and thus to lower life satisfaction. In addition, current literature reveals that vegetarians and vegans more often report that they neither live with a partner nor are married, respectively [52, 53]. This tendency could be identified in our sample as well. Since it is well known that having a girlfriend/boyfriend or wife/husband leads to a certain degree of life satisfaction [54] and, beyond that, prevents affective disorders such as depression [55], this fact could have caused lower scores as well.

Furthermore, our female subjects who adhered to an omnivorous diet had higher environment scores than the vegetarians/vegans. This finding was surprising because it was not consistent with existing literature. Since consumption of fruits and vegetables and thus vegetarianism/ veganism is regarded to be associated with a good socioeconomic background [56], we had expected that this would lead to high scores in financial resources, access to health and social care, and opportunities for acquiring new information and skills, which are the facets incorporated in the dimension environment. However, our subjects may have considered other facets in this dimension, for example, freedom, physical safety and physical environment, to be more important. As vegetarians and vegans usually have high demands concerning these topics, especially in the matter of physical environment [23, 57], this might have made them state lower satisfaction in this regard.

Impact of the race distance on quality of life

A third important finding was that our data did not show an interaction between race distance and physical health, psychological well-being and social relationships for women men.

In addition to the fact that mean QOL-scores of our subjects were consistently high, these results suggest that endurance running leads to a high degree of life satisfaction, regardless of the race distance. The findings are consistent with other research results [33, 58, 59]. There are various reasons which could explain this.

Similar to a well-balanced diet, physical activity in general, and endurance running in particular, are crucial factors which affect health. In this context, the 'healthy mind in a healthy body'-concept, which has already been mentioned before, could again provide an explanation [60, 61]. Research into endocrine responses to exercise has shown a positive correlation between endurance training and endorphin levels [62]. Since endorphins are regarded to be responsible for good mood and a reduction in sensation of pain [63], these changes lead to a lower level of perceived stress and thus to well-being. Similar tendencies can be found for stress and anxiety perception in athletes. Endurance running in particular leads to a higher resilience to stress and anxiety [64], a good sleep architecture [30], and an increased self-perception specifically in terms of a perceived internal and body competence [65]. As both the NURMI-Runners and the members of the 10-km control group derived high scores in the physical and psychological well-being dimensions, it appears likely that the previous explanation applies to both groups.

Besides health, sleep and body consciousness, motivational concerns and personality profiles of endurance runners are the basis for their high life satisfaction. Most athletes run voluntarily and therefore they are motivated by intrinsic reasons, such as self-esteem, self-discovery, improved fitness, life meaning or personal goal achievement and challenge [66]. Since endurance running challenges both body and mind to an extreme degree [67, 68], finishing a marathon shows that someone can achieve her/his goals and knows or even expands her/his personal limitations or abilities. In this context, the ability of 'self-conquest' is a crucial factor that contributes to the perception of extraordinary and wonderful feelings, leading to a certain degree of happiness and hence high QOL scores [12]. Furthermore, several authors have investigated the personality profiles of endurance athletes. They were described as task-oriented rather than ego-oriented, health and financially conscious [69], extroverted [70] and self-sufficient [71]. Moreover, they would have a certain degree of emotional intelligence [72]. These character traits are typically regarded to be positive and thus have positive effects on social relationships – one dimension of the QOL-domains. Since there were no detectable differences between the NURMI-Runners and the members of the 10-km control group in this regard, our findings suggest that these character traits apply to endurance runners of any distance and are not limited to one subgroup.

Furthermore, our data demonstrated a minor effect of the race distance on environment scores for women, where half-marathoners had higher counts than the members of the 10-km control group. Considering that the domain of environment was assessed using, among others, the categories financial resources, freedom and security, home environment, participation in leisure activities, and transport, the finding could be explained by the socioeconomic background of the related athletes. It has been reported that marathon runners tend to have an above average high socioeconomic status [2, 73]. Belonging to a high social class means having more financial resources, a better home environment and better access to transport.

Summarizing the effects of diet choice and race distance on QOL, it can be concluded that the dual approach of regular physical activity, i.e. endurance running, and conscious nutrition, i.e. a vegetarian/vegan diet, is a crucial factor in the derivation of the high QOL scores that were found in the subjects. Beyond that, these two factors are synergistic and thus mutually reinforcing [23], which increases their impact. Obviously, the positive effects of endurance running doesn't seem to depend on the race distance, as both of the NURMI-Runners and the 10-km controls showed high QOL scores. Further research is warranted to determine the optimal balance within the dual approach of physical activity such as endurance running linked to vegetarian or vegan nutrition, in order to achieve cumulative effects [23] for a high QOL.

Diet×race-distance-interaction and its impact on quality of life

A fourth important finding was that our data did not reveal a diet×race distance interaction concerning physical health, psychological wellbeing or social relationships for women or men.

Diet choice immediately before running or the composition of the personal diet might be influenced by the announced race distance [74, 75]. However, there is no evidence that the choice of diet in general has an effect on the preferred race distance and vice versa. Thus, an interference of one of the variables with the other affecting the influence on QoL would have been unexpected.

Nevertheless, a moderate diet×race distance interaction on the environment score was shown for men, although no interaction was found for women. This result could again be explained by the socioeconomic background of the runners. As has already been mentioned above, marathon runners tend to have above average levels of intelligence quotient (IQ) and a high socioeconomic status [2, 73]. High IQ scores [76, 77] and belonging to a high socioeconomic group is positively correlated with the ability to reflect critically about diet choice [78, 79]. In this way, an interaction between diet choice and race distance is possible.

Limitations and implications for future research

Some limitations of our study should be noted. The survey is based on self-report, meaning that the reliability of the data depends on the conscientiousness of our subjects. However, we minimized this effect by using questions to control for diet and race distance.

Moreover, the small sample size and the pre-selection of our subjects, due to the fact that only highly motivated runners took part, led to a lack of statistical representativeness, which might have affected our results. Nonetheless, the high intrinsic motivation of the participants would have led to an increase in the accuracy of their answers and hence to a higher quality of the generated data.

Practical applications

Since our survey is the first to investigate QOL in endurance runners adhering to a vegetarian or vegan diet, the results might be important for researchers involved in implementing individualized dietary strategies for athletes and thus may be used as reference for future studies. Moreover, our data may support recreational and professional runners as well as their coaches in finding an optimized nutrition strategy. Not only athletes but also non-runners and physicians might get a better insight into appropriate diets and more active lifestyles, and thus have a better basis for their choices for themselves, their families and even their patients. Beyond that, in the light of the aforementioned dual approach of regular physical activity integrated with vegetarian/vegan nutrition providing cumulative benefits for a high level of life satisfaction, the results might be used as a basis for public health and prevention programs for both children and adults.

Conclusion

In summary, our results reveal that the participants of our study, including the members of the 10-km control group as well as the NURMI-Runners, had a high QOL, regardless of the race distance or diet choice. These findings contribute to a broad body of evidence supporting the notion that adhering to a vegetarian or vegan diet can be an appropriate and equal alternative to an omnivorous diet. In combination with an active lifestyle, i.e. by performing regular endurance running, this dual approach can be one way to effectively and successfully achieve a high degree of life satisfaction.

Abbreviations

10 km: 10-Kilometer Control Group; DOM: Domain; EKSG: Ethics Board of St. Gallen, Switzerland; HM: Half Marathon; M: Marathon; NURMI : Nutrition and Running High Mileage; QOL: Quality of Life; SD: Standard Deviation; UM: Ultramarathon; WHOQOLBREF: World Health Organization Quality of Life Assessment - brief version (french: bref)

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Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available due to data security reasons but may be made available and provided by the principal investigator upon reasonable request. Subjects will receive a brief summary of the results of the NURMI Study if desired.

Authors' contributions

KW conceptualized, designed and developed the study design and the questionnaires together with BK and CL. PN performed data analysis. PB drafted the manuscript, TR helped in drafting the manuscript, and BK and KW critically reviewed it. Technical support was provided by GW and ChL. All authors read and approved the final manuscript.

Ethics approval and consent to participate

The study protocol is available online via https://link.springer.com/article/10.1186/s40064-016-2126-4 and was approved by the ethics board of St. Gallen, Switzerland on May 6, 2015 (EKSG 14/145).
The study is conducted in accordance with the ethical standards of the institutional review board, medical professional codex and the with the 1964 Helsinki declaration and its later amendments as of 1996 as well as Data Security Laws and good clinical practice guidelines.
Study participation is voluntary and can be cancelled at any time without provision of reasons and without negative consequences.
Informed consent was obtained from all individual participants included in the study considering the data collected, used and analyzed exclusively and only in the context of the NURMI Study.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Sex Differences in the Health Status of Endurance Runners: Results From the NURMI Study (Step 2)

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Abstract

Boldt, P, Knechtle, B, Nikolaidis, P, Lechleitner, C, Wirnitzer, G, Leitzmann, C, and Wirnitzer, K. Sex differences in the health status of endurance runners: results from the NURMI study (step 2). *J Strength Cond Res* XX(X): 000–000, 2018—Optimized endurance performance is closely linked to a good health status (HS), which is crucially affected by sex. Therefore, the purpose of this study was to investigate sex differences in the HS of endurance runners of different distances. A total of 281 female and male recreational runners completed an online survey. Health status included body mass, smoking habits, felt stress, chronic diseases, allergies, intolerances, medication intake, supplement intake, health-related food choice, enhancement substance use, and health care utilization. Data analysis was performed using the independent *t*-test and chi-squared test with Cohen's *d* and Cramer's phi (φ) to evaluate the magnitude of the differences and associations. There were 159 female and 122 male participants, with 173 runners meeting the inclusion criteria, among them 103 half-marathoners, and 70 marathoners and ultramarathoners, of which one hundred eight 10-km runners were defined as the control group. Statistical significance ($p < 0.05$) was determined for the following findings: there was a higher prevalence of hypothyroidism in women; the use of thyroid medication and the intake of hormones and supplements prescribed by a doctor were more common in women; men reported more often a decrease in body mass due to running training, and women reported more often choosing food to obtain phytochemicals. There was no statistically significant association ($p > 0.05$) between sex and body mass change because of a change in diet, smoking habits, felt stress, chronic diseases except hypothyroidism, allergies, food intolerances, intake of antihypertensives and cholesterol-lowering medication, intake of performance-enhancing substances, or health care utilization. Both female and male runners had a good HS with no difference between sexes. Based on the findings of this study, monitoring thyroid parameters and vitamin D levels is required in female athletes, whereas adequate body mass control strategies are needed for their male counterparts.

Key Words marathon, running, body mass control, hypothyroidism, vitamin D

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Introduction

Differences in running performance between women and men have been a matter of particular interest in scientific research for many years (3,6). Women used to run more slowly than men (34), but meanwhile the progression of world record running performances for women has improved at a faster rate than the world record for men during the same time frames (4). As endurance running challenges body and mind to an extremely high degree (7), a good health status (HS) and a strong mind are inevitable requirements for a good performance (10) for both women and men. A recent study highlighted the significance of a healthy and strong mind to good performance in endurance running. It revealed that faster runners had a better inhibitory control and showed superior ability to suppress processing of irrelevant information. Beyond that, their cognitive performance seemed to be less influenced by emotional stimuli, which enabled the runners to face the psychological demands of an endurance race (7,45). To be able to withstand the physical demands of an endurance race, such as a marathon, a good fitness level and a healthy body are required (3,36). A good HS and a strongmind contribute to improvements in endurance performance by positively affecting the most important performance-limiting factors, such as maximal oxygen consumption, musculoskeletal system, and body mass index (BMI) (4). Although sex has been identified as a crucial factor regarding health and health-related behavior in the general population (33), in the research in terms of the HS of athletes, in particular endurance runners, sex differences have often not been included.

Female runners are a specific population of athletes (10). Anatomical differences to men relating to height, body mass, body composition, and muscle mass not only cause differences in endurance performance between women and men but are also relevant to women's HS (10). As female endurance athletes have to change their body more from their natural body composition and shape than men to achieve a body mass that is optimal for endurance exercise performance, they are at a high risk of unintended body mass loss and disordered eating patterns (10). Concurrently, this increases the risk of macronutrient and micronutrient deficiencies such as low calcium and vitamin D levels (10), which are known to have severe consequences such as fractures due to osteoporosis or muscle weakness (32). Therefore, endurance-trained women need to know about dietary and training strategies that help to optimize body composition and to enhance performance (25). In particular, avoiding severe caloric energy restriction and being aware of nutrient deficits while critically monitoring training intensity and training volume is recommended (10,25). Nonetheless, female athletes' achievements in endurance sports, such as the impressive progression of world records in marathons (4), underpin women's ability to perform extraordinary well and to deliver superior results. Female marathoners improved their best times by 4% between 1985 and 2004, whereas men improved their records by only 1.8% (4). This remarkable progression of world records posed the question of whether women could even outrun men (34). However, current evidence suggests that the sex gap in running performance will probably never be closed (4,34).

Besides anatomical concerns, female athletes differ from male athletes in their markedly different physiological and hormonal profiles. For example, women possess fewer erythrocytes and less hemoglobin than men, which adversely affects the oxygen-carrying capacity of the blood (3,4). In addition, hormonal differences have a special significance for women's training routines, in particular due to effects of the menstrual cycle (3,10). Although current evidence suggests that endurance performance is not adversely affected, female athletes have to be especially aware of hormonal disorders, which are associated with vigorous exercise, such as menstrual irregularities and osteopenia (3). Differences in hormonal profiles between women and men also affect the prevalence of endocrine diseases. The most common endocrine diseases among female athletes are thyroid disorders, in particular hypothyroidism. The female predominance in the prevalence of hypothyroidism may be related to effects of female gonadal hormones and X chromosome inactivation on the thyroid gland and immune system (13). Untreated hypothyroidism can cause severe problems, such as fatigue or menstrual abnormalities, that could be unidentified performance-limiting factors (12,13). Therefore, hormone replacement, sufficient intake of iodine, and the early recognition of symptoms for a hormonal dysregulation have to be carefully considered when creating training and nutrition strategies for female athletes (12).

Male endurance runners have different physiological and psychological characteristics to women, which is why the comparability of athletic performance of female and male athletes is limited (3,4). For example, well-trained male endurance runners have a higher maximal aerobic capacity and a higher ratio of muscle mass to body mass than well-trained female athletes (3,4). More than this, it has been found that male athletes possess a high degree of mental toughness, which allows them to cope with stress during exercise and in everyday life (45). Other factors, such as genetics and sex-specific education (34,44), and sex hormones, in particular testosterone, play an important role in the genesis of these sex differences (3,34). Despite this, there are essential differences between female and male athletes regarding the prevalence of certain diseases, especially in terms of cardiovascular diseases (24,38). Men are more likely to be affected by cardiovascular diseases than women until women undergo the menopause. Afterward, prevalence rates are similar in both sexes (24). Because cardiovascular diseases are the leading cause of death in Europe and in the United States in both female and male elderly and young athletes (24,33,38,39), early recognition and treatment under special consideration of sex-specific characteristics, such as differences in the age of the manifestation of the disease, are critical to prevent death from myocardial infarction (24,38).

Likewise, clear sex differences in the prevalence of allergies, asthma, and other atopic diseases have been reported, whereby a male preponderance before puberty and a reversal of this sex preference after adolescence has been described (21). In light of this, it is noteworthy that in endurance runners, the prevalence of allergies, such as hay fever and high-performance asthma, is significantly higher than in the overall population in both sexes (36). This is attributed to the amount of time runners spend outdoors, which is associated with a drying of the airways and an increased exposure to airborne allergens (36). Knowledge of this topic can help athletes and their coaches to optimize training strategies by considering peak times of pollen levels or initiating an adequate therapy.

Further relevant sex differences have been found regarding health-related behavior by highlighting the fundamentally different attitudes of women and men in this regard (2,23,30). Women are more likely to make use of health care services and report poorer health than men (2), although they live, on average, 5 to 6 years longer than their male counterparts (23). Meanwhile, to date, there have been no hints of a direct correlation between health care utilization and a higher life expectancy in women (2,23). This apparent contradiction between mortality and (felt) morbidity is often termed "gender paradox" (23) and has significant economic, sociological, and medical implications. In particular, it causes an enormous financial burden for pension and health care systems (2). Meanwhile, men are more susceptible to risk-taking behaviors such as drug use, smoking, and the consumption of performance-enhancing substances (23,44). It is therefore not surprising that women are known to be more health conscious than men (31,37). In particular, women's health consciousness is underlined in their attitudes toward food choice, where they have been identified as higher consumers of fruits, vegetables, and other wholesome foods than their male counterparts (37). Being aware of these sex-specific characteristics regarding health-related behavior can help both athletes and their physicians in the assessment of health concerns of female and male athletes.

To date, little is known about sex differences in the HS of endurance runners. Most studies deal with either female or male participants or they do not classify their subjects by sex (19). Beyond that, most studies refer to athletes in general, with little data referring to endurance runners particularly. A well-founded comparison of characteristics in health concerns between female and male endurance runners is missing. Such knowledge would be of practical value for coaches, athletes, and their physicians to optimize training and treatment strategies according to sex-related health characteristics.

Therefore, the aim of this study was to determine sex differences in the HS between female and male endurance runners. Based on findings from the general population (33) and results from studies investigating either female or male athletes (3,10), we hypothesized that there are essential differences between female and male endurance runners.

Methods

Experimental Approach to the Problem

The study was designed to determine sex differences in the HS of female and male endurance runners. Data were collected in the context of the Nutrition and Running High Mileage (NURMI)-Study that was conducted after a cross-sectional design. The participants completed a detailed online survey. Health was determined using the following variables: body mass (current body mass, body mass change, and reasons for body mass change), smoking habits (current smoking and former smoking), perceived stress, chronic diseases (heart disease requiring treatment, state after heart attack, cancer, diabetes mellitus types 1 and 2, hyperthyroidism, and hypothyroidism), allergies/intolerances, regular medication intake (for thyroid, for high blood pressure, for cholesterol, and for hormones), dietary supplement intake, motives for food choice, food choice to avoid certain ingredients/products (refined sugar, sweetener, fat in general, saturated fats, cholesterol, products made with white flour, sweets and confectionery, nibbles, alcohol, and caffeine), food choice to obtain certain valuable ingredients (vitamins, minerals/trace elements, antioxidants, phytochemicals, and fiber), use of enhancement substances in daily life (performance boost and to cope with stress), and health care utilization (frequency of doctor consultations and frequency of use of check-ups/routine health checks).

Subjects

A total of 281 endurance runners (159 women and 122 men) with a mean age of 37.7 ± 10.5 years (mean ± *SD*) in women and 42.8 ± 11.1 years in men were included in the study. Their countries of origin were Germany ($n = 200$), Switzerland ($n = 14$), Austria ($n = 50$), and some others ($n = 17$; Belgium, Brazil, Canada, Italy, Luxemburg, the Netherlands, Poland, Spain, and United Kingdom).

Regarding dietary subgroups, 123 subjects followed an omnivorous diet and 158 adhered to a vegetarian/vegan diet. In terms of race distances, there were 173 NURMI-Runners (103 half-marathoners and 70 marathoners/ultramarathoners) and 108 members of the 10-km control group.

A total of 108 highly motivated runners provided valuable data by giving numerous accurate and useful answers. However, they had not successfully participated in either a half-marathon or marathon, but only in a 10-km race. To avoid an irreversible loss of these valuable data sets, those who met all inclusion criteria, but had identified a 10-km race as their running event, were kept as the control group. Throughout this article, they are called "10-km control group," whereas those who met the inclusion criteria to the full extent are referred to as "NURMI-Runners."

Characteristics of the subjects are presented in Table 1. Subjects were recruited mainly through social media, websites of the organizers of marathon events, online running communities, email lists, runners' magazines as well as magazines for health, vegetarian and vegan nutrition and lifestyle, sports and nutrition fairs, and through personal contacts. The study protocol (42) was approved by the ethics board of St. Gallen, Switzerland, on May 6, 2015 (EKSG 14/145). The trial registration number is ISRCTN73074080.

Procedures

Participants were classified into 2 dietary groups: omnivorous (commonly known as Western diet, no dietary restrictions); diet and vegetarian (no meat)/vegan (no products from animal sources, such as meat, fish, milk and dairy products, eggs, and honey) (28). Moreover, they were

Table 1. Anthropometric and demographic characteristics of the subjects displayed by sex.*†

	Total	Women	Men	p	CI
No. of subjects (%)	281 (100%)	159 (56.58%)	122 (43.42%)		
Age (y)	40.00 ± 11.00	37.7 ± 10.5	42.8 ± 11.1	<0.001‡	2.49–7.61
Race distance (%)					
Control group				<0.001‡	
10 km	108 (38.43%)	75 (47.17%)	33 (27.05%)		
NURMI-Runners					
Half-marathon	103 (36.65%)	57 (35.85%)	46 (37.70%)		
Marathon/ultramarathon	70 (24.91%)	27 (16.98%)	43 (35.25%)		
Body mass (kg)		59.77 ± 8.03	73.25 ± 8.29	<0.001‡	11.56–15.41
Height (m)		1.67 ± 0.06	1.79 ± 0.07	<0.001‡	0.10–0.13
BMI_{CALC} ($kg \cdot m^{-2}$)		21.38 ± 2.51	22.89 ± 2.19	<0.001‡	0.95–2.08
Academic qualification (%)					
No qualification	1 (<1%)	1 (<1%)	0 (<1%)	0.409	
Upper secondary education/technical qualification/GCSE or equivalent	94 (33.45%)	47 (29.56%)	47 (38.52%)		
A levels or equivalent	62 (22.06%)	35 (22.01%)	27 (22.13%)		
University degree/higher degree (i.e., Doctorate)	96 (34.16%)	58 (36.48%)	38 (31.15%)		
No answer	28 (9.96%)	18 (11.32%)	10 (8.2%)		
Marital status (%)					
Divorced/separated	16 (5.69%)	10 (6.29%)	6 (4.92%)	0.012‡	
Married/living with partner	190 (67.62%)	96 (60.38%)	94 (77.05%)		
Single	75 (26.69%)	53 (33.33%)	22 (18.03%)		
Country of residence (%)					
Austria	50 (17.79%)	19 (11.95%)	31 (25.41%)	0.021‡	
Germany	200 (71.17%)	124 (77.99%)	76 (62.30%)		
Switzerland	14 (4.98%)	7 (4.40%)	7 (5.74%)		
Other	17 (6.05%)	9 (5.66%)	8 (6.56%)		
Diet (%)					
Vegetarian/vegan	158 (56.23%)	101 (63.52%)	57 (46.72%)	0.005‡	
Omnivorous	123 (43.77%)	58 (36.48%)	65 (53.28%)		

*CI = 95% confidence interval of differences between groups; 10 km = 10-km control group; BMI_{CALC} = body mass index (calculated); p = p value for difference between groups.
†Results are presented as mean ± *SD*.
‡Significant difference.

categorized into 3 race distances: 10-km control group, half-marathon, and marathon/ultramarathon (longer than the marathon distance).

For successful participation in the study, the following 4 inclusion criteria were required: (a) written informed consent, (b) at least 18 years of age, (c) questionnaire completed, and (d) successful participation in a running event of either half-marathon or marathon distance in the past 2 years.

Participants completed a detailed online survey that was available on www.nurmi-study.com from February 1, 2015, to December 31, 2015. It was provided in German and English. The survey started with a written description of the procedure. After having been informed about the benefits and risks of the investigation, the participants gave their informed consent to take part in the study. Afterward, they completed the questionnaires that included questions relating to their physical and psychological health. Incomplete, inconsistent, and conflicting data sets were excluded from the data analysis. A total of 317 endurance runners completed our survey. However, after data clearance, 281 runners with complete data sets were included for descriptive statistical analysis.

Statistical Analyses

The statistical software SPSS v.23.0 (IBM, Chicago, IL, USA) and GraphPad Prism v.7.0 (GraphPad Software, San Diego, CA, USA) performed all statistical analyses. All data were tested for normality using the Kolmogorov-Smirnov test and visual inspection of normal Q-Q plots. Data analysis was performed using ANOVA. An independent *t*-test was used to study sex differences in age, body mass, height, and BMI. Cohen's d evaluated the magnitude of these differences (i.e., $d < 0.20$, trivial; $d = 0.20$–0.49, small; $d = 0.50$–0.80, medium; and $d > 0.80$, large). Chi-square (χ^2) examined the association among sex, nutrition group, race distance, and health variables. Cramer's phi (φ) evaluated the magnitude of these associations according to the following criteria: $\varphi < 0.3$ was considered as a small, $\varphi = 0.3$–0.5 as a medium, and $\varphi > 0.5$ as a large effect. The level of statistical significance was set at $p \leq 0.05$.

Results

Results are presented in Table 2. Statistical analysis and evaluation can be found below.

Hypothyroidism

A small sex × prevalence effect of hypothyroidism was found ($\chi^2 = 8.515$, $p = 0.014$, $\varphi = 0.174$) with a higher prevalence in women than in men in the NURMI-Runners and in the 10-km control group.

Medication for the Thyroid

Sex had a small effect on the intake of medication for the thyroid ($\chi^2 = 7.756$, $p = 0.021$, $\varphi = 0.166$) with a female predominance in both subgroups.

Intake of Hormones

Moreover, there was a moderate association between sex and the intake of hormones ($\chi^2 = 35.628$, $p < 0.001$, $\varphi = 0.356$), as only women stated consumption in both the NURMI-Runners and the 10-km control group.

Supplement Intake

There was a small association between sex and supplement intake prescribed by a doctor ($\chi^2 = 8.554$, $p = 0.014$, $\varphi = 0.174$), where mainly women reported intake in both subgroups.

Body Mass Decrease Due to Running Training

Sex had a small effect on the direction the body mass changed due to running training ($\chi^2 = 9.444$, $p = 0.024$, $\varphi = 0.183$), with relatively more men than women stating that their body mass decreased. This applied to both the NURMI-Runners and the 10-km control group.

Phytochemicals

There was a small effect of sex on food choice to obtain phytochemicals ($\chi^2 = 8.739$, $p = 0.013$, $\varphi = 0.176$), as women were more likely to report doing so in both the NURMI-Runners and the 10-km control group.

Body Mass Change

In both subgroups, there was no association between sex and whether the body mass changed as a result of change in diet ($\chi^2 = 0.757$, $p = 0.685$, $\varphi = 0.052$), running training ($\chi^2 = 1.379$, $p = 0.502$, $\varphi = 0.070$), and the direction that it changed due to diet ($\chi^2 = 3.455$, $p = 0.327$, $\varphi = 0.111$).

Smoking Habits

No association between sex and whether they did currently smoke ($\chi^2 = 5.503$, $p = 0.064$, $\varphi = 0.140$) or whether they ever smoked ($\chi^2 = 2.957$, $p = 0.228$, $\varphi = 0.103$) was observed, either in the NURMI-Runners or in the 10-km control group.

Stress

No association of sex with feeling pressure or stress was shown ($\chi^2 = 3.538$, $p = 0.171$, $\varphi = 0.112$), either in the NURMI-Runners or in the 10-km control group.

Chronic Diseases

Sex did not associate with heart disease requiring treatment ($\chi^2 = 1.596$, $p = 0.450$, $\varphi = 0.075$), heart attack ($\chi^2 = 1.596$, $p = 0.450$, $\varphi = 0.075$), cancer ($\chi^2 = 0.347$, $p = 0.741$, $\varphi = 0.035$), diabetes mellitus type 1 ($\chi^2 = 2.888$, $p = 0.236$, $\varphi = 0.101$), diabetes mellitus type 2 ($\chi^2 = 0.344$, $p = 0.842$, $\varphi = 0.035$), and hyperthyroidism ($\chi^2 = 0.347$, $p = 0.841$, $\varphi = 0.035$) in both the NURMI-Runners and the 10-km control group.

Allergies and Food Intolerances

There was no association between sex and the occurrence of allergies ($\chi^2 = 1.094$, $p = 0.579$, $\varphi = 0.062$) and food intolerances ($\chi^2 = 5.082$, $p = 0.079$, $\varphi = 0.134$) in the NURMI-Runners and in the 10-km control group.

Intake of Antihypertensives and Cholesterol-Lowering Medication

Sex did not associate with the intake of medication for high blood pressure ($\chi^2 = 2.267$, $p = 0.322$, $\varphi = 0.090$) and cholesterol and other blood serum lipid values ($\chi^2 = 2.888$, $p = 0.236$, $\varphi = 0.101$). These results applied to both the NURMI-Runners and the 10-km control group.

Food Choice and Intake of Performance-Enhancing Substances

There was no effect of sex on whether food or ingredients are chosen because they are healthy ($\chi^2 = 1.651$, $p = 0.438$, $\varphi = 0.077$), health promoting ($\chi^2 = 0.317$, $p = 0.853$, $\varphi = 0.034$), or good for maintaining health ($\chi^2 = 0.887$, $p = 0.642$, $\varphi = 0.056$), either among the NURMI-Runners or among the members of the 10-km control group.

Moreover, there was no correlation between sex and whether food or ingredients are chosen to avoid refined sugar ($\chi^2 = 5.032$, $p = 0.081$, $\varphi = 0.134$), sweetener ($\chi^2 = 0.316$, $p = 0.854$, $\varphi = 0.034$), fat in general ($\chi^2 = 1.287$, $p = 0.526$, $\varphi = 0.068$), saturated fats ($\chi^2 = 1.171$, $p = 0.557$, $\varphi = 0.065$), cholesterol ($\chi^2 = 0.536$, $p = 0.765$, $\varphi = 0.044$), products made with white flour ($\chi^2 = 2.450$, $p = 0.294$, $\varphi = 0.093$), sweets and confectionery ($\chi^2 = 1.913$, $p = 0.384$, $\varphi = 0.083$), nibbles ($\chi^2 = 3.637$, $p = 0.162$, $\varphi = 0.114$), alcohol ($\chi^2 = 0.973$, $p = 0.615$, $\varphi = 0.059$), and caffeine or other stimulants ($\chi^2 = 2.205$, $p = 0.332$, $\varphi = 0.089$) in any of the subgroups.

In addition, sex did not associate with whether food or ingredients are chosen because they are high in vitamins

Table 2. Health status dimensions of the NURMI-Runners and the 10-km control group displayed by sex.*

	NURMI-Runners		10-km control group		
	Women, n (%)	Men, n (%)	Women, n (%)	Men, n (%)	*p*
Body mass change due to a change in diet					
Increase	4 (4.76)	0 (0.00)	1 (1.33)	1 (3.03)	0.327
Stable	9 (10.71)	5 (5.62)	2 (2.67)	2 (6.06)	
Decrease	23 (27.38)	39 (43.82)	34 (45.33)	15 (45.45)	
Body mass change due to a change in running training					
Increase	3 (3.57)	0 (0.00)	3 (4.00)	0 (0.00)	0.024†
Stable	8 (9.52)	4 (4.49)	7 (9.33)	3 (9.09)	
Decrease	42 (50.00)	53 (59.55)	29 (38.67)	19 (57.58)	
Smoking habits					
Nonsmokers	75 (77.32)	79 (68.70)	65 (69.15)	27 (65.85)	0.064
Ex-smokers	22 (22.68)	36 (31.30)	29 (30.85)	14 (34.15)	0.228
Stress perception					
Yes	25 (29.76)	21 (23.60)	31 (41.33)	11 (33.33)	0.171
No	50 (59.52)	60 (67.42)	34 (45.33)	18 (54.55)	
Prevalence of chronic diseases					
Heart disease	0 (0.00)	1 (1.12)	0 (0.00)	0 (0.00)	0.450
Heart attack	0 (0.00)	1 (1.12)	0 (0.00)	0 (0.00)	0.450
Cancer	0 (0.00)	1 (1.12)	3 (4.00)	1 (3.03)	0.741
Diabetes mellitus 1	0 (0.00)	2 (2.25)	0 (0.00)	0 (0.00)	0.236
Diabetes mellitus 2	1 (1.19)	0 (0.00)	0 (0.00)	1 (3.03)	0.842
Hyperthyroidism	1 (1.19)	2 (2.25)	2 (2.67)	0 (0.00)	0.841
Hypothyroidism	9 (10.71)	1 (1.12)	4 (5.33)	0 (0.00)	0.014†
Prevalence of hypersensitivity reactions					
Allergies	15 (17.86)	20 (22.47)	20 (26.67)	13 (39.39)	0.579
Intolerances	12 (14.29)	3 (3.37)	11 (14.67)	5 (15.15)	0.079
Medication intake					
Indication					
Thyroid disease	10 (11.90)	3 (3.37)	7 (9.33)	0 (0.00)	0.021†
Hypertension	1 (1.19)	5 (5.62)	2 (2.67)	1 (3.03)	0.322
Cholesterol level	0 (0.00)	1 (1.12)	0 (0.00)	1 (3.03)	0.236
Hormones	17 (20.24)	0 (0.00)	21 (28.00)	0 (0.00)	<0.001†
Motivation for food choice					
Healthy	51 (60.71)	63 (70.79)	44 (58.67)	19 (57.58)	0.438
Health promoting	61 (72.62)	67 (75.28)	57 (76.00)	26 (78.79)	0.853
Maintaining health	65 (77.38)	74 (83.15)	61 (81.33)	28 (84.85)	0.642
Undesired ingredients in food choice					
Refined sugar	51 (60.71)	49 (55.06)	50 (66.67)	16 (48.48)	0.081
Sweetener	52 (61.90)	59 (66.29)	52 (69.33)	23 (69.70)	0.854
Fat in general	34 (40.48)	29 (32.58)	32 (42.67)	16 (48.48)	0.526
Saturated fats	43 (51.19)	48 (53.93)	44 (58.67)	14 (42.42)	0.557
Cholesterol	29 (34.52)	40 (44.94)	33 (44.00)	12 (36.36)	0.765
White flour	49 (58.33)	48 (53.93)	51 (68.00)	21 (63.64)	0.294
Sweets	48 (57.14)	46 (51.69)	48 (64.00)	21 (63.64)	0.384
Nibbles	48 (57.14)	42 (47.19)	49 (65.33)	22 (66.67)	0.162
Alcohol	41 (48.81)	41 (46.07)	40 (53.33)	17 (51.52)	0.615
Caffeine	29 (34.52)	22 (24.72)	26 (34.67)	12 (36.36)	0.332
Desired ingredients in food choice					
Vitamins	61 (72.62)	66 (74.16)	55 (73.33)	21 (63.64)	0.641
Minerals/trace elements	54 (64.29)	60 (67.42)	51 (68.00)	19 (57.58)	0.728
Antioxidants	41 (48.81)	40 (44.94)	39 (52.00)	11 (33.33)	0.203
Phytochemicals	37 (44.05)	32 (35.96)	41 (54.67)	9 (27.27)	0.013†
Fiber	56 (66.67)	54 (60.67)	50 (66.67)	17 (51.52)	0.133
Supplement intake					
Intention					

Health promotion	12 (14.29)	2 (2.25)	6 (8.00)	1 (3.03)	0.014†
Performance increase	15 (17.86)	12 (13.48)	5 (6.67)	3 (9.09)	0.953
Cope with stress	5 (5.95)	8 (8.99)	2 (2.67)	2 (6.06)	0.475
Frequency of medical consultations					
Never	20 (23.81)	20 (22.47)	21 (28.00)	13 (39.39)	0.214
Once a year	19 (22.62)	33 (37.08)	15 (20.00)	6 (18.18)	
Every 6 months	17 (20.24)	14 (15.73)	12 (16.00)	7 (21.21)	
Every 3 months	5 (5.95)	7 (7.87)	7 (9.33)	3 (9.09)	
Every 2 months	7 (8.33)	5 (5.62)	5 (6.67)	0 (0.00)	
Once a month	5 (5.95)	14 (15.73)	6 (8.00)	4 (12.12)	
Frequency of regular health check-ups					
Once a year	34 (40.48)	24 (26.97)	22 (29.33)	7 (21.21)	0.078
Twice a year	8 (9.52)	3 (3.37)	7 (9.33)	6 (18.18)	
Other	5 (5.95)	14 (15.73)	6 (8.00)	4 (12.12)	

*p = p value for difference among groups.
†Significant difference.

($\chi^2 = 0.888$, $p = 0.641$, $\varphi = 0.056$), minerals/trace elements ($\chi^2 = 0.636$, $p = 0.728$, $\varphi = 0.048$), antioxidants ($\chi^2 = 3.192$, $p = 0.203$, $\varphi = 0.107$), and fiber ($\chi^2 = 4.042$, $p = 0.133$, $\varphi = 0.120$). These results were found in both the NURMI-Runners and the 10-km control group.

Sex did not associate with the consumption of performance-enhancing substances in everyday life, at work, or while doing sport ($\chi^2 = 0.336$, $p = 0.953$, $\varphi = 0.035$), as well as with the intake of anything to cope with stress ($\chi^2 = 2.503$, $p = 0.475$, $\varphi = 0.094$) in both subgroups.

Health Care Utilization

No association between sex and the frequency of doctor consultations ($\chi^2 = 9.569$, $p = 0.214$, $\varphi = 0.185$), the use of regular check-ups and routine health checks ($\chi^2 = 1.171$, $p = 0.557$, $\varphi = 0.065$), and the frequency of the use of regular check-ups and routine health checks ($\chi^2 = 6.818$, $p = 0.078$, $\varphi = 0.156$) was observed. These results were found in both the NURMI-Runners and the 10-km control group.

Discussion

The aim of the study was to investigate the HS of endurance runners and to compare female and male athletes regarding potential sex differences in body mass change, smoking habits, stress perception, the prevalence of chronic diseases, the prevalence of allergies and food intolerances, medication intake, supplement intake, food choice, consumption of performance-enhancing substances, and health care utilization. The findings of this study support the hypothesis that there are essential differences between the HS of women and men.

We found a clear predominance of women in the prevalence of hypothyroidism in both the NURMI-Runners and the 10-km control group. This observation was consistent with the previous scientific literature (13,27).

Hypothyroidism is a disease where the thyroid gland does not generate enough thyroid hormone. It is one of the most common endocrine disorders among women. Symptoms of hypothyroidism can be fatigue, body mass gain, alteration in cognition, infertility, and menstrual abnormalities. The most common causes of hypothyroidism are iodine deficiency, Hashimoto's thyroiditis, and iatrogenic causes, such as the intake of certain medication, i.e., amiodarone, thyroid surgery, and radiotherapy (13). In particular for endurance runners, subclinical hypothyroidism, where free thyroxine (fT4) is normal and thyroid-stimulating hormone is increased, can be an unidentified performance-limiting factor, so an adequate therapy is a crucial factor for training and success (12).

Likely explanations for the clear female predominance in the prevalence of hypothyroidism are the effects of the sex hormones testosterone and estrogen, and direct influences of genes on the sex chromosomes. Besides, there are supposed to be some immunologic differences between women and men, which are not yet entirely clear (12,13). A relationship between vigorous exercise, such as endurance running, and hypothyroidism in women could not be proven, although the findings of this study and the results from other investigations have suggested this relationship (27).

Women were more likely than men to take medication for the thyroid in both the NURMI-Runners and the 10-km control group. This result was consistent with the previous literature (13) and was not surprising, as it was found that women were more likely than men to report to suffer from hypothyroidism. Because untreated hypothyroidism can have severe consequences, such as fatigue, body mass gain, alteration in cognition, infertility, and menstrual abnormalities (13), early recognition and starting with a therapy is crucial. The standard treatment is a monotherapy with levothyroxine. The dose has to be adjusted to the patient's age, BMI, the presence of other diseases, and special life events, such as pregnancy. Levels of thyroid-stimulating hormone should be evaluated at least every 12 months and within 4–8 weeks after initiation or alteration of the dosage of levothyroxine. Meanwhile, patients have to be informed of the necessity of sticking to the therapy, and knowledge about potential complications and symptoms of hypothyroidism has to be provided (13).

In this study, women only reported intake of other hormones and hormone preparations such as medication for the thyroid. In light of the fact that more than 100 million women worldwide use contraceptive pills (5) or other interventions to avoid unintended pregnancies, it could be expected that this effect would be displayed in the sample of this study as well. This assumption is supported by the fact that there is some evidence that the intake of oral contraceptives has beneficial effects for female endurance runners that improve performance (10). It has been found that intake of oral contraceptives reduces menstrual blood loss by about 60% and therefore entails a lower need for iron (10). Beyond that, it has been demonstrated that oral contraceptives improve lipid and carbohydrate metabolism as well as glycogen storage and utilization during prolonged submaximal exercise (10). However, the findings are based on few studies and no effect has been found on other factors that affect performance, such as hemoglobin, growth hormone, ventilation, lactate, and maximal heart rate (10). Therefore, these findings need to be interpreted with caution.

There was a predominance of women observed to take supplements prescribed by a doctor in both the NURMI-Runners and the 10-km control group. The most common supplement was vitamin D. Vitamin D is crucial for bone health and for nonskeletal benefits, such as immune and muscle functions, as well as for athletic performance. The most important factor for optimal vitamin D levels is sun exposure, whereas dietary habits and supplementation are secondary variables (10). Vitamin D deficiency is very common among female endurance athletes and can be an unidentified performance-limiting factor (10). However, the background why male athletes are affected more seldom is still unknown. The hypothesis that the physiological postmenopausal hormone response in women is the reason can only be one part of the explanation, as mean age of our subjects was 37.7 ± 10.5 years (Table 1). Most women undergo the menopause between the ages of 40 and 50 years (32).

Sex had a small effect on the direction the body mass changed due to running training. The majority of the female and male subjects reported a body mass decrease, whereby men reported more often a body mass change than women. These results could be found in both the NURMI-Runners and the 10-km control group.

A body mass decrease due to running training has been reported in other studies as well in both sexes (35). The most plausible explanation is a higher metabolic rate and thus a reduction of body fat in addition to a gain of muscle mass (35). It was observed that differences in the hormonal and appetite responses to physical activity led to greater body fat loss in men compared with women. This male predominance is linked to physiological effects of sex hormones, ghrelin, insulin, and leptin (16). Furthermore, differences between women and men in terms of relative muscle mass, skeletal muscle contractile, and metabolism are supposed to increase fat metabolism in men (16). Because endurance running is a high-energy–consuming sport, the creation of adequate dietary and training strategies under special consideration of body mass control is needed (25). In particular, female athletes have to be aware of excessive body mass loss and disordered eating patterns (10). As a low BMI is associated with good running performance by contributing to a better running economy (4,25,34), it is sometimes believed that the lower the BMI, the better the performance will be. This misinterpretation may make athletes adhere to excessive body fat reduction strategies, which cause an immoderate decrease in body mass and could end up in disordered eating patterns (10). Avoiding severe energy restriction, monitoring protein intake and protein timing and quality, spreading meals and snacks throughout the day, eating breakfast, eating after exercise, and being aware of nutrient deficits while adhering to moderate training volumes can all be part of an optimal training and dietary strategy (25). In this way, the best body mass for optimal performance can be generated while a good HS is maintained (25).

As the mean BMI of the runners of this study was within the normal range in both women and men, there were no data indicating that the subjects were at risk of disordered eating patterns. However, according to the results of this study, male endurance runners have to be aware of excessive body mass loss due to running training, which underpins the significance of reasonable training and body mass control strategies.

Female subjects of both the NURMI-Runners and the 10-km control group reported more often choosing their food to obtain phytochemicals. Phytochemicals are chemical compounds that are usually produced by plants as repellents to pests and sunlight as well as growth regulators. In humans, they are supposed to have beneficial health effects, such as a reduced risk of cardiovascular and other diseases (20). The difference between women and men can be explained by differences in nutritional knowledge. Women tend to be better informed in terms of nutritional concerns and therefore they usually know better about the effects of special ingredients, such as phytochemicals (37).

There was no major association between the sex and body mass change due to a change in diet in either the NURMI-Runners or the 10-km control group. In this context, previous scientific literature has revealed that men reduced their body mass faster and to a greater extent due to a change in dietary habits when compared with women (40). The discrepancy between the findings of this study and the body of evidence can be explained by the motivations of the participants that made them change dietary habits. Change of dietary habits means both changes within a certain kind of diet, such as a reduction in the amount of consumed food to reduce calories, and a shift from one kind of diet to another, such as from omnivorous dietary patterns to vegetarian kinds of diet. In most studies comparing body mass changes, both female and male subjects who had the intention of reducing their body mass were included (16,40). However, subjects of this study mainly reported other reasons than body mass loss for changing their dietary habits, such as animal welfare or personal well-being. Therefore, existing sex differences in the amount of, and time needed for, body weight reduction might have been compensated for by other aspects than change in diet, eg. training volume (both extent and intensity).

Smoking habits were not associated with sex in both subgroups. Moreover, it was shown that smoking prevalence was low among both female and male subjects, and the majority of those subjects who had previously smoked had successfully stopped smoking. These findings were mostly in line with scientific evidence. It has been reported that the prevalence of smokers usually is quite low among endurance runners with no difference between women and men (26). However, a study by Linke et al. (22) identified women as being less likely to successfully quit smoking in cessation trials because of their tendency to smoke to help prevent or alleviate negative mood, depression, and postcessation body mass gain. Nonetheless, this sex difference could not be found in this study. This might be attributed to a bias due to the low overall number of smokers and ex-smokers in the sample of this study, so that any difference was not evident. Moreover, adhering to regular physical exercise, such as endurance running, can be one promising way of preventing people from smoking or even of helping stopping smoking by causing a reduction of cessation-related mood symptoms and a decrease in cigarette craving and withdrawal symptoms among temporarily abstinent smokers (22). Marti et al. supported this notion by showing a positive association between smoking quitters and running activity in terms of weekly training mileage (26). These findings provide a reasonable explanation for the low overall smoking rates in the sample of this study. In addition, the effects of endurance running regarding smoking and smoking cessation might have compensated for a potential sex difference in this regard.

There was no association between the sex and stress or feeling pressure in either the NURMI-Runners or the 10-km control group. These findings contradicted previous scientific literature (8,45). It has been shown that women, in general, report both greater exposure to and appraisal of stressful events than males (8). Moreover, it has been reported that male endurance athletes possess a slightly higher degree of mental toughness than their female counterparts, which allows them to better cope with stress during exercise and in everyday life (45). Several explanations have been found, such as social desirability of the stated feelings, differences in the interpretation of environmental demands, sex-specific education, and existing sex inequality at work (8,45). However, differences seem to be marginal and, overall, female endurance athletes also show a high degree of high mental toughness (45). However, the majority of our female and male participants reported low stress levels. This finding can be explained by the fact that endurance running enhances personal well-being and fitness, 2 crucial factors that help with coping with stress (15,45).

In terms of chronic diseases, sex showed no association with heart disease requiring treatment, state after heart attack, cancer, diabetes mellitus types 1 and 2, and hyperthyroidism in both the NURMI-Runners and the 10-km control group. In addition, there was a low overall prevalence of these diseases among our subjects. These findings were not consistent with the previous literature, as other authors observed clear sex differences in this area (4,9,27,38). A male predominance in the prevalence of heart diseases and diabetes mellitus 1 and 2 was found (4,38), whereas women were more likely to report to suffer from thyroid diseases (9,27). Beyond that, men generally seem to be more susceptible to cancer (11), although this assumption does not apply to all types of cancer because there is huge variety of sex-associated factors in different cancer entities.

These low prevalence rates and the absence of sex differences can be partially explained by the rather low mean age of the participants (37.7 ± 10.5 years in women and 42.8 ± 11.1 years in men). Diabetes mellitus type 2 occurs mainly in women and men who are older than 40 years, and cardiovascular disease is usually diagnosed in women older than 55 years and men older than 45 years (18,38). The incidence for the manifestation of most types of cancer normally reaches a maximum between 75 and 90 years old, whereby most incidence rates increase significantly after the age of about 45 years (17). Thus, most subjects had not yet reached the age, which is known to be critical in terms of the incidence of these diseases. In particular, the variable "age" is relevant for the manifestation of most types of cancer and might be the main reason why a male predominance in the susceptibility to cancer, which could have been expected based on other studies (11,17), was not confirmed in this study.

A further reason for the low prevalence among our subjects might be the protective effect of endurance running in terms of the occurrence of risk factors for certain diseases, such as impaired glucose tolerance, an early step in the genesis of diabetes mellitus type 2, and hypertriglyceridemia, which is an important risk factor for cardiovascular disease (4,14). Moreover, the fact that mainly healthy people adhere to endurance running might have biased prevalence. In particular, being an endurance runner with diabetes mellitus type 1 would be a great challenge because well-planned dietary and training strategies under special consideration of the insulin therapy would be needed (18).

In the study, there was no statistical correlation between the sex and allergies in both subgroups. Nevertheless, there was a slight male predominance, where 22.01% of the women and 27.05% of the men reported to have at least one allergy. This finding was consistent with the previous literature. In clinical studies, clear sex differences in prevalence exist in asthma and other atopic diseases with a male preponderance before puberty and a reversal of this sex preference after adolescence (21). Beyond that, it has been reported that allergies and hay fever (25%), and exercise-induced asthma (13%) are more common in endurance athletes, compared with 7–8% of people from the overall population, which is in line with the findings of this study. The high susceptibility of endurance runners to allergies, hay fever, and exercise-induced asthma is usually attributed to the amount of time runners spend outdoors. This is associated with a drying of the airways and an increased exposure to airborne allergens (36).

Although there was no effect of the sex on the prevalence of food intolerances, 14.47% of the women and 6.57% of the men stated that they had a food intolerance. Previous literature has not provided clear data regarding sex differences. One study found a slightly higher prevalence of women (4.2% vs. 2.9% in men) in terms of all food intolerances (1). Nonetheless, Miall et al. (29) demonstrated that athletes in general are supposed to be more susceptible to symptoms of food sensitivities. Constant training challenges the bowel to an extreme degree and endurance running, in particular, might lead to gastrointestinal complaints. Hence, the ability to cope with additional gastrointestinal stress by food intolerances is limited (29).

Sex did not associate with the intake of medication for high blood pressure and cholesterol and other blood serum lipid values, although there was a slight male predominance. Overall, intake rates were low. These results applied to both the NURMI-Runners and the 10-km control group, and were in line with both previous research (19,24,39) and other findings from this study.

Some risk factors for arterial hypertension are sex, a lack of physical activity, smoking, and obesity (39). It was shown that men are more often affected than women until the age of 50–60 years, but after the age of about 60 years, women and men are affected similarly. This sex difference is attributed to effects of the sex hormone estrogen, as it disappears after menopause (24). Because the mean age of the subjects of this study was 37.7 ± 10.5 years in women and 42.8 ± 11.1 years in men, a male predominance regarding the intake of hypertensives could be expected. Despite this, according to the variables mentioned above, subjects of this study had an advantageous risk profile regarding arterial hypertension. First, they were endurance runners, so their lifestyle included regular physical exercise. Second, there were only a few smokers among them. Third, the mean BMI was 21.38 ± 2.51 in women and 22.89 ± 2.19 in men, which is within the normal range and therefore indicates a good body mass/height ratio. Based on these data, it was not surprising that overall intake rates of antihypertensives were low among the subjects.

Lipoproteins are macromolecular complexes that consist of proteins, cholesterol, triglycerides, and phospholipids. They play an important role in human metabolism because they serve as transporters for hydrophobic lipids in the blood. According to their density in ultracentrifugation, they can be classified into different fractions: chylomicrons, very low density lipoproteins, intermediate-density lipoproteins, low-density lipoproteins, and high-density lipoproteins (HDLs) (14). In particular, HDL is known to be a protective factor against cardiovascular disorders (19,24,39). Lipoprotein levels and profiles depend on genetics, lifestyle factors such as smoking habits, body mass, and the presence of certain chronic diseases such as diabetes mellitus type 2 (39). According to these variables, which are similar to the risk factors for hypertension, the subjects of this study appeared to have favorable risk profiles. The profiles were characterized by regular physical exercise, not smoking, a body mass within the normal range, and the absence of severe diseases such as diabetes mellitus type 2. It was found that endurance exercise in particular favorably affects triglyceride and HDL levels in both women and men (19,39). This effect was mainly attributed to an increase in lipids metabolism during prolonged endurance exercise training (19,39). These findings suggest that most subjects had advantageous blood lipid profiles and therefore the number of those who needed to take cholesterol-lowering medication was low.

When comparing women and men regarding blood lipoproteins, women usually have better profiles than men, which are mainly characterized by higher levels of HDL. This sex difference is known to be one of the main reasons for a reduced risk of cardiovascular disease in premenopausal women. The mechanisms behind this difference are still unknown, although an involvement of estrogen is conceivable (24). Despite this, the unfavorable blood lipoprotein profiles of men are a reasonable explanation for the male predominance in this study regarding the intake of cholesterol-lowering medication.

The absence of sex differences in terms of the choice of food and certain ingredients to avoid detrimental or to benefit from advantageous effects on health was not consistent with the previous scientific literature. Several studies have detected women preferring food with health-promoting effects. They usually state that they choose their food in favor of fruit, fiber, and vegetables, while limiting the consumption of salt or high-fat foods (37). This has been explained by women's greater body mass control involvement and their stronger beliefs in healthy eating (37). This underlines the fact that women are particularly health conscious (37). Beyond that, women's health consciousness seems to affect their attitude toward the consumption of performance-enhancing substances because male endurance athletes have been detected as being more susceptible to the intake of ergogenic aids (41). The same applies to the consumption of energy drinks and caffeine as "performance-enhancement" substances for everyday life, where male athletes usually report higher intakes (44). In addition to the fact that men are known to be less health conscious than women, a further explanation might be that the consumption of performance-enhancing substances seems to be more acceptable among male athletes compared with female athletes (44). However, the data from this study did not support this notion. Because subjects were aware of potential disadvantages and detrimental effects, overall intake of performance-enhancing substances was low. Furthermore, the subjects seemed to perform naturally and thus can be considered as "real" athletes who work hard for their success and to maintain their health. This was in line with other findings from this study that characterized the participants as conscientious and well informed regarding their health. More than this, it seems that the beneficial effects of endurance running, such as a reduction in perceived stress, a high degree of life satisfaction, and certain degree of stress resilience (15) compensated for any desire to consume substances to cope with stress in both female and male subjects.

There was no effect of sex on the frequency of doctor consultations, the use of regular check-ups and routine health checks, and the frequency of the use of regular check-ups and routine health observed, either in the NURMI-Runners or in the 10-km control group. These findings were not in line with the previous scientific literature. According to the "gender-paradox" theory, there is higher morbidity among women, although mortality is lower compared with men (23). Consequently, women make more often use of health care services, although they have a higher life expectancy and live, on average, 5–6 years longer than their male counterparts (23,43) (p 387). However, to date, there have been no hints of an association between a higher life expectancy of women and the amount of health care utilization (2,23). Reasonable explanations for the high amount of health care utilization by women might rather be sex differences in the subjective HS (2), objective sex differences in the HS, such as higher rates of death from myocardial infarction in men (24), less inhibitions in women in seeking health care, and biases in the provision of care to female and male patients (30). In addition, a high degree of health consciousness, which is usually attributed to women rather than to men (31,37), might also explain sex differences in the use of health care services. Moreover, because most health care services are used in the past year of life, higher age-specific mortality rates among men affect the use of health care services at the end of life (30). Nevertheless, expenditures for health care are similar for male and female subjects after differences in reproductive biology and higher age-specific mortality rates among men have been accounted for (30). However, the "gender paradox" could not be found in the subjects of this study. Overall, most of the subjects reported seeing a doctor usually once a year, mainly for routine check-ups. This finding suggested that the subjects seem to care about their health and have a certain degree of health consciousness, which applied to both the female and male participants. Moreover, one of the most important reasons for higher rates in health care use among women is higher morbidity among women (2). Because morbidity among both female and male subjects of this study was low, this was supposed to be a factor that compensated for the "gender paradox."

Practical Applications

To enhance endurance running performance, an overall good HS is important because it physiologically and psychologically challenges the body and mind to an extremely high degree. Being aware of the health implications caused by sex differences may support recreational and professional runners as well as their coaches in creating sustainable training and competition strategies. Female endurance runners and their coaches have to be aware of hypothyroidism and vitamin D deficiency. This necessitates regular medical supervision to be able to initiate early and rapid diagnosis and start treatment when deficiencies are identified. Well-balanced iodine and hormone levels are the basis for thyroid function, whereas sun exposure is needed to maintain vitamin D levels. Male endurance athletes are at risk of unintended body mass loss due to running training, which requires the creation of adequate dietary and training strategies under special consideration of body mass control. Avoiding severe caloric energy restriction, spreading meals and snacks throughout the day, and being aware of nutrient deficits while adhering to moderate training volumes can be part of the strategy. In this way, the ideal body mass for optimal performance can be generated.

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Health Status of Female and Male Vegetarian and Vegan Endurance Runners Compared to Omnivores—Results from the NURMI Study (Step 2)

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Abstract: Health effects of vegetarian and vegan diets are well known. However, data is sparse in terms of their appropriateness for the special nutritional demands of endurance runners. Therefore, the aim of this study was to investigate the health status of vegetarian (VER) and vegan endurance runners (VGR) and compare it to omnivorous endurance runners (OR). A total of 245 female and male recreational runners completed an online survey. Health status was assessed by measuring health-related indicators (body weight, mental health, chronic diseases, and hypersensitivity reactions, medication intake) and health-related behavior (smoking habits, supplement intake, food choice, healthcare utilization). Data analysis was performed by using non-parametric ANOVA and MANOVA. There were 109 OR, 45 VER and 91 VGR. Significant differences ($p < 0.05$) were determined for the following findings: (i) body weight for VER and VGR was less than for OR, (ii) VGR had highest *food choice* scores, and (iii) VGR reported the lowest prevalences of allergies. There was no association ($p > 0.05$) between diet and mental health, medication intake, smoking habits, supplement intake, and healthcare utilization. These findings support the notion that adhering to vegetarian kinds of diet, in particular to a vegan diet, is associated with a good health status and, thus, at least an equal alternative to an omnivorous diet for endurance runners.

Keywords: vegetarian; vegan; half-marathon; marathon; running; health conscious; recreational athlete

1. Introduction

During an endurance event, such as a marathon running, body and mind are challenged to an extremely high degree. Athletes are exposed to several physiological and psychological challenges, in particular with regard to energy metabolism, body temperature and fluid balance [1–3]. A study by Hausswirth and Lehénaff highlighted the importance of fat metabolism, since an increase in free fatty acids and glycerol at the end of long-distance races crucially affects running economy and, thus, performance when the athlete is almost at the finish line [3]. Further important parameters with regard to running economy are maximal oxygen consumption, lactate-threshold, and metabolic efficacy [2]. Moreover, completing a long-distance race is a psychological challenge which requires favorable character traits, such as inhibitory control, the ability not only to inhibit motor response, but also to suppress processing of irrelevant information, and the ability to protect cognitive performance so that it is less influenced by emotional stimuli [1]. In order to meet all these requirements, a good health status and a strong mind are necessary and will contribute to good exercise performance [1,2].

An essential requirement for a good health status is the choice of an appropriate, healthy, and sustainable diet [4,5]. As endurance running is known as a kind of sport with high energy expenditure and, thus, consumption, an endurance athlete's need for vitamins, trace elements and other valuable food ingredients besides macronutrient requirements is very high [4]. Therefore, a well-balanced energy turnover is crucial [4], resulting in the creation of a well-planned and reasonable nutrition strategy [5]. Current evidence suggests that one strategy could be adhering to a meatless diet rich in vegetables and fruits, such as a vegetarian kind of diet [6–8] (pp. 419–437). Vegetarian kind of diet is an umbrella term which subsumes four main dietary patterns: lacto-ovo-vegetarian, lacto-vegetarian, ovo-vegetarian, and vegan. Lacto-ovo vegetarians consume dairy products and eggs but no meat, poultry or seafood. Lacto-vegetarians eat dairy products but avoid eggs, meat, poultry, and seafood. Ovo-vegetarians eat eggs, but no dairy products, meat, poultry, or seafood. A vegan diet is characterized by the rejection of all products from animal sources, such as meat, fish/shellfish, milk and dairy products, eggs, and honey. A dietary pattern without any restriction is referred to as an omnivorous kind of diet [7].

Healthy vegetarian kinds of diet usually include complex carbohydrates, fiber, fruits, vegetables, and antioxidants [9]. Although potentially lower in some nutrients, such as zinc and vitamin B12 [9], carefully planned vegetarian kinds of diet meet or even exceed the nutritional requirements of athletes, in particular with regard to the intake of proteins, fatty acids and iron [6–8] (pp. 419–437). More than this, vegetarian kinds of diet are known to have further beneficial effects on health than just energy intake, in particular in terms of body weight control [10,11], the prevention of diabetes mellitus type 2 [12,13], ischemic heart disease [11,14], and protection against depression [15]. In addition, a vegetarian diet has been found to reduce the risk for some types of cancer, such as colon and prostate cancer [9,16]. Despite immediate health-related effects due to the consumption of healthy foods, being a vegetarian or vegan is often associated with a healthy lifestyle characterized by the avoidance of adverse health behavior, such as smoking and alcohol consumption, a high level of physical activity, and time for relaxation [8] (p. 393).

To date, little is known about the health status and health-related behavior of vegetarian and vegan endurance runners [17,18]. Most researchers have not classified their subjects by dietary subgroup [19]. Beyond that, these studies usually dealt with athletes in general, so that data in terms of endurance runners is sparse. A well-founded comparison of health characteristics between vegetarian, vegan and omnivorous endurance runners is lacking. Specific knowledge about the interconnectedness of diet choice and health could provide a better basis for athletes and their coaches, physicians, and nutritionists/dietitians, in order to optimize training and treatment strategies.

The aim of the study, therefore, was to investigate the health status of endurance runners and to compare athletes who adhere to a vegetarian or vegan diet to those who follow an omnivorous diet. Since a good state of health of non-active vegetarians and vegans is sound and compares favorably to that of omnivores [8] (p. 411), it was hypothesized that vegetarian and vegan endurance runners would have a better health status than omnivorous endurance runners.

2. Materials and Methods

2.1. Study Protocol and Ethics Approval

The study protocol [20] was approved by the ethics board of St. Gallen, Switzerland on 6 May 2015 (EKSG 14/145). The trial registration number is ISRCTN73074080.

2.2. Participants

The NURMI (Nutrition and Running High Mileage) Study was conducted in three steps following a cross-sectional design. Endurance runners, mainly from German-speaking countries including Germany, Austria, and Switzerland, were recruited. In addition, people from around the world were addressed. Participants were contacted mainly via social media, websites of the organizers of marathon events, online running communities, email lists, and runners' magazines, as well as via magazines for health, vegetarian, and/or vegan nutrition and lifestyle, sports fairs, trade fairs on vegetarian and vegan nutrition and lifestyle, and through personal contacts. The characteristics of the subjects are presented in Table 1.

Table 1. Anthropometric and demographic characteristics of the subjects displayed by diet group.

		Omnivorous	Vegetarian	Vegan
Number of Subjects		100% (109)	100% (45)	100% (91)
Sex	Female	47% (51)	58% (26)	70% (64)
	Male	53% (58)	42% (19)	30% (27)
Age (years) (median)		43 (IQR 18)	39 (IQR 16)	37 (IQR 15)
Body Weight (kg) (median)		68 (IQR 16.7)	62 (IQR 11.3)	64 (IQR 10)
BMI_{CALC} (kg/m^2)	≤18.49	4% (4)	7% (3)	9% (8)
	18.50–24.99	80% (87)	87% (39)	82% (75)
	≥25–29.99	17% (18)	7% (3)	9% (8)
Race Distance	10 km	34% (37)	33% (15)	43% (39)
	Half-marathon	36% (39)	44% (20)	33% (30)
	Marathon/Ultramarathon	30% (33)	22% (10)	24% (22)
Academic Qualification	No Qualification	0% (0)	0% (0)	1% (1)
	Upper Secondary Education/Technical Qualification/GCSE or Equivalent	38% (41)	38% (17)	27% (25)
	A Levels or Equivalent	24% (26)	16% (7)	22% (20)
	University Degree/Higher Degree (i.e., doctorate)	30% (33)	38% (17)	36% (33)
	No Answer	8% (9)	9% (4)	13% (12)
Marital Status	Divorced/Separated	3% (3)	4% (2)	11% (10)
	Married/Living with Partner	75% (82)	58% (26)	62% (56)
	Single	22% (24)	38% (17)	27% (25)
Country of Residence	Austria	21% (23)	18% (8)	14% (13)
	Germany	70% (76)	76% (34)	74% (67)
	Switzerland	7% (8)	4% (2)	3% (3)
	Other	2% (2)	2% (1)	9% (8)
Motive for Diet Choice	Health, wellbeing	81% (21)	85% (28)	90% (79)
	Sporting performance	54% (14)	33% (11)	59% (52)
	Food scandals	15% (4)	55% (18)	32% (28)
	Animal welfare	46% (12)	79% (26)	90% (79)
	Ecological aspects	50% (13)	76% (25)	83% (73)
	Social aspects	35% (9)	55% (18)	57% (50)
	Economic aspects	8% (2)	12% (4)	22% (19)
	Religion/spirituality	0% (0)	12% (4)	7% (6)
	Custom/tradition	15% (4)	0% (0)	2% (2)
	Taste/enjoyment	42% (11)	33% (11)	44% (39)
	No specific reason	4% (1)	0% (0)	0% (0)

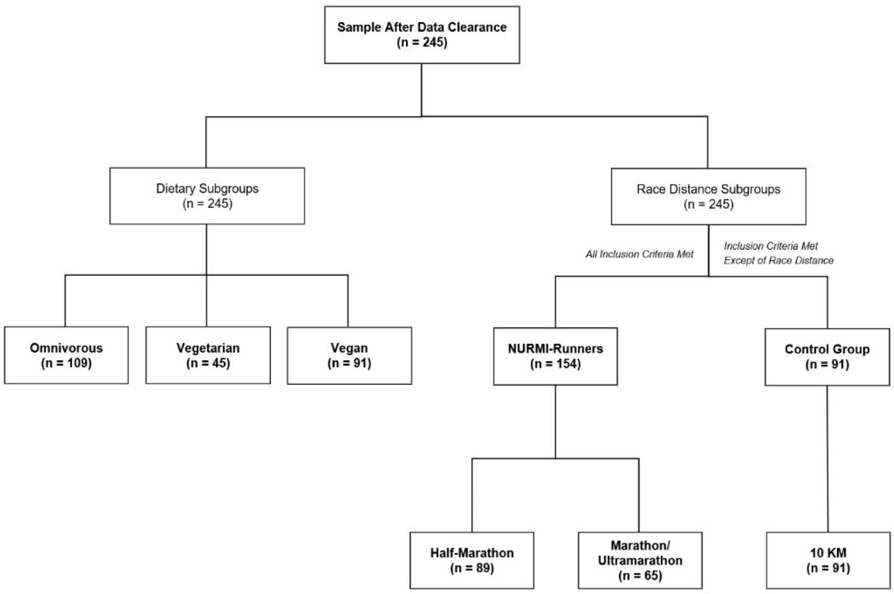
10 km = 10-km control group. BMI_{CALC} = Body Mass Index (calculated). IQR = interquartile range.

2.3. Procedures

2.3.1. Experimental Approach

Participants completed an online survey within the NURMI Study Step 2, which was available in German and English at www.nurmi-study.com from 1 February 2015 to 31 December 2015. Prior to completing the questionnaires on physical and psychological health, participants were provided with a written description of the procedures and gave their informed consent to take part in the study.

For successful participation in the study, the following inclusion criteria were required: (1) written informed consent, (2) at least 18 years of age, (3) completed questionnaire, (4) successful participation in a running event of at least half-marathon distance in the past two years. Participants were classified into three dietary subgroups (Scheme 1): omnivorous (commonly known as Western diet, no dietary restrictions) diet; vegetarian (no meat); and vegan (no products from animal sources) [7]. In addition, they were categorized according to race distance: 10-km, half-marathon, and marathon/ultramarathon. Marathoners and ultramarathoners were pooled together since the marathon distance is included in an ultramarathon. A total of 91 highly-motivated runners provided accurate and useful answers with plenty of high-quality data. However, they had not successfully participated in either a half-marathon or marathon, but rather in a 10-km race. In order to avoid an irreversible loss of these valuable datasets, those who met all inclusion criteria but named a 10-km race as their running event were kept as the control group.



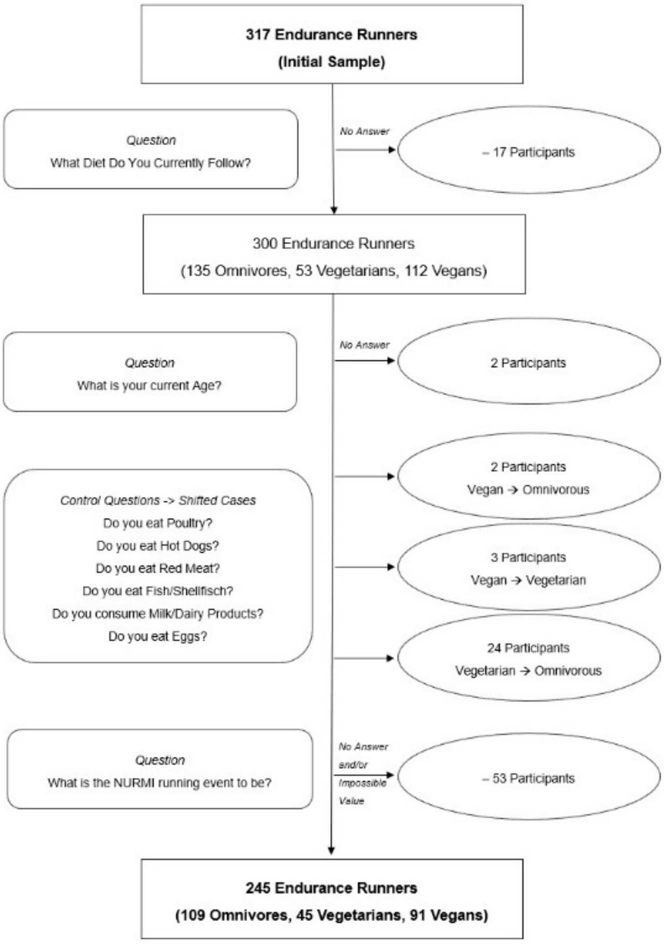
Scheme 1. Categorization of participants.

According to the WHO [21,22] the goal for individuals should be to maintain a BMI in the range 18.5–24.9 kg/m^2 (BMI$_{NORM}$) in order to achieve optimum health. They point to an increased risk of co-morbidities for a BMI 25.0–29.9 kg/m^2, and moderate to severe risk of co-morbidities for a BMI > 30 kg/m^2 [21,22]. Therefore, the calculated Body Mass Index (BMI$_{CALC}$) was classified into three categories of body weight-to-height ratio (kg/m^2): $\leq$ 18.49 < BMI$_{NORM}$: 18.50–24.99 kg/m^2 $\geq$ 25. Since the BMI of active runners could be below BMI$_{NORM}$ [23], but in addition people with a higher BMI might start running in order to achieve and maintain a stable, healthy body weight, participants with BMI < 30 were included. BMI has been shown to be a significant performance-determining parameter for speed improvement in running over various distances, with a continuous increase in BMI from 19.57 (1.29) kg/m^2 in marathoners to 23.3 (1.67) kg/m^2 over the 100 m distance [24]. An optimal BMI for high running pace, reported for the best performers over 10 km and marathon distance, was found to be between 19–20 kg/m^2.

2.3.2. Data Clearance

In order to control for measures of (1) diet and (2) running, two groups of control questions were included, each within different sections of the survey. In order to control for a minimal status of health linked to a minimum level of fitness and to further enhance the reliability of datasets, the BMI approach following the WHO [21,22] was used. With a BMI ≥ 30 other health-protecting and/or weight loss strategies than running would be necessary to safely reduce body weight. Therefore, three participants with a BMI ≥ 30 were excluded from the data analysis.

A total of 317 endurance runners completed the survey. Incomplete, inconsistent, and conflicting datasets were excluded from the data analysis. After data clearance a total of 245 runners with complete datasets were included for descriptive statistical analysis (Scheme 2).



Scheme 2. Flow chart of participants' enrollment.

2.4. Measures

Health status (latent variable) was derived by using both the two clusters 'Health-related Indicators' and 'Health-related Behavior'. Each cluster pooled four dimensions, with each defined by specific items based on manifest measures. An overview of the variables is presented in Table 2.

The following health-related indicators described health outcomes: (1) body weight/BMI, (2) mental health (stress perception), (3) chronic diseases and hypersensitivity reactions: prevalence of chronic diseases (heart disease, state after heart attack, cancer), prevalence of metabolic diseases (diabetes mellitus 1, diabetes mellitus 2, hyperthyroidism, hypothyroidism), prevalence of hypersensitivity reactions (allergies, intolerances), and (4) medication intake (for thyroid disease, for hypertension, for cholesterol level, for contraception).

Table 2. Overview of the variables in order to derive health status of endurance runners.

Cluster	Dimension	Indicator	Item	Measure
Health-related Indicators	**Body weight**/BMI	BMI_{calc} [1]	Your current body weight (kg)? Your height (m)?	Body weight (kg) Height (m)
	Mental health	Stress perception	Are you under pressure and/or are you suffering from stress?	Yes No
	Chronic diseases and hypersensitivity reactions	Cardiovascular diseases and Cancer	Are you currently suffering from the following chronic diseases or their direct consequences?	Heart disease requiring treatment Heart attack Cancer (now or in the past)?
		Metabolic diseases	Are you currently suffering from one of the following metabolic disease(s)?	Diabetes mellitus type 1 Diabetes mellitus type 2 Hyperthyroidism Hypothyroidism
		Hypersensitivity reactions	Are you currently suffering from ...?	Allergies Intolerances
	Medication intake		Do you take medicaments regularly (every day), for example, ...?	Thyroid High blood pressure Cholesterol and/or other blood serum lipid values contraceptive pill
Health-related Behavior	**Smoking habits**	Current consumption of cigarettes	Do you currently smoke?	Yes No
		Former consumption of cigarettes	Have you ever smoked?	Yes No
	Supplement intake	Substance intake for medical reasons	Do you take supplements prescribed by a doctor regularly (everyday)?	Yes No
		Intake of Performance enhancement substance	Do you take anything to boost your performance in your daily life, at work or while doing sport (e.g., energy drinks)?	Yes, regularly every day Yes, occasionally No
		Substance intake for stress coping	Do you take anything to help you cope with stress in your daily life, at work or while doing sport?	Yes, regularly every day Yes, occasionally No
	Food choice	Motivation for food choice	Do you choose ingredients and food on the basis Of the following (e.g., in view of the disease mentioned above or other illnesses)?	Healthy (e.g., if you are ill) Health-promoting (e.g., to prevent ill-health) Good for maintaining health (e.g., wholefoods)

Table 2. *Cont.*

Cluster	Dimension	Indicator	Item	Measure
		Avoided ingredients	Do you choose food in order to avoid particular ingredients or nutrients (e.g., in view of the diseases mentioned above or other illnesses or effects on health)?	Refined sugar Sweetener Fat in general Saturated fats Cholesterol Products made with white flour Sweet things (e.g., Jelly beans, chocolate drops, cream cakes) Nibbles (e.g., crisps, salted peanuts) Alcohol Caffeine or other stimulants (e.g., in coffee or energy drinks)
		Desired ingredients	Do you choose food because of particular valuable ingredients or nutrients (e.g., to prevent the diseases mentioned above or other illnesses or effects on health)?	Vitamins Minerals/trace elements Antioxidants Phytochemicals Fiber Other
	Healthcare utilization	Frequency of doctor consultations	How often have you seen a doctor in the last 12 months (except dentist and for routine check-ups)?	Never Once a month Every 2 months Every 3 months (four times a year) Every 6 months (twice a year) Once a year
		Utilization of regular health check-ups	Do you go for regular check-ups or routine health checks?	Yes No

[1] BMI_{CALC} = Body Mass Index calculated.

The following variables of health-related behavior described health outcomes: (1) smoking habits (current and former smoking), (2) supplement intake (supplements prescribed by a doctor, supplements for performance enhancement, supplements to cope with stress), (3) food choice (motivation, desired ingredients, avoided ingredients), and (4) healthcare utilization (regular check-ups). Resulting from this, eight domain scores (body weight/BMI, mental health, chronic diseases, and hypersensitivity reactions, medication intake, smoking, supplement intake, food choice, healthcare utilization) were derived, which generated scores between 0 and 1. Low scores indicate detrimental health effects, while higher scores indicate beneficial health effects (given as mean scores plus standard deviation, and percentage (%)).

2.5. Statistical Analysis

The statistical software R version 3.5.0 Core Team 2018 (R Foundation for Statistical Computing, Vienna, Austria) performed all statistical analyses. Exploratory analysis was performed by descriptive statistics (median and interquartile range (IQR)). Significant differences between dietary subgroups and domain scores to describe health status were calculated by using a non-parametric ANOVA. Chi-square test and Kruskal-Wallis test were used to examine the association between dietary subgroups and domain scores with nominal scale variables, and Wilcoxon test and Kruskal-Wallis test (ordinal and metric scale) approximated by using the F distributions.

Statistical modeling. State of health as the latent variable was derived by manifest variables (e.g., body weight, cancer, smoking, etc.). In order to scale the health status displayed by measures, items and dimensions, a heuristic index between 0 and 1 was defined (equivalence in all items). To test the statistical hypothesis considering significant differences between dietary subgroups, race distance and sex for each dimension a MANOVA was performed to define health status. The assumptions of the ANOVA were verified by residual analysis.

The level of statistical significance was set at $p \leq 0.05$.

3. Results

A total of 317 endurance runners completed the survey, of whom 245 (141 women and 104 men) remained after data clearance with a mean age of 39 (IQR 17) years, from Germany (n = 177), Switzerland (n = 13), Austria (n = 44) and from other countries (n = 11; Belgium, Brazil, Canada, Italy, Luxemburg, Netherlands, Poland, Spain, UK).

A total of 109 participants followed an omnivorous diet, 45 reported to adhere to a vegetarian diet, and 91 to a vegan diet. In addition, there were a total of 91 10-km runners, 89 half-marathoners, and 65 marathoners/ultramarathoners.

3.1. Cluster 'Health-Related Indicators'

3.1.1. Dimension of Body Weight/BMI

There was a significant difference in body weight between dietary subgroups ($F_{(2, 242)} = 6.86$, $p = 0.001$), with vegetarians and vegans showing lower body weight than omnivores. However, there was no difference in the health-related item BMI between dietary subgroups ($\chi^2_{(4)} = 6.08$, $p = 0.193$) (Table 3). Moreover, vegans had the highest counts for the health-related indicator *body weight/BMI* (0.69 (0.40), $F_{(2, 242)} = 0.41$, $p = 0.662$) (Figure 1a).

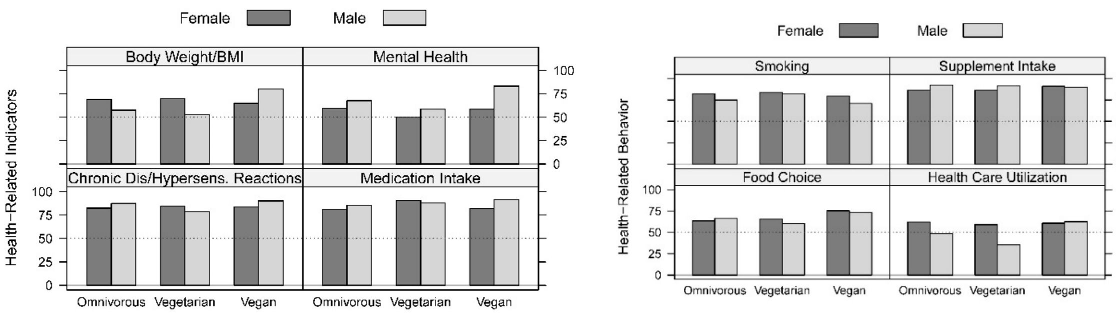
3.1.2. Dimension of Mental Health

There was no significant association between diet group and stress perception ($\chi^2_{(2)} = 1.78$, $p = 0.412$) (Table 3). However, vegans had the highest score with regard to *mental health* (0.66 (0.48), $F_{(2, 219)} = 0.88$, $p = 0.415$) (Figure 1a).

Table 3. Descriptive results and ANOVA of the 'Health-Related Indicators' cluster.

Dimension	Omnivorous	Vegetarian	Vegan	Statistics
Body Weight/BMI				
Body Weight (kg) (median)	68.00 (IQR 16.70)	62.00 (IQR 11.30)	64.00 (IQR 10.00)	$F_{(2, 242)} = 6.86$, $p = 0.001$
BMI_{CALC}				$\chi^2_{(4)} = 6.08$, $p = 0.193$
≤18.49	4% (4)	7% (3)	9% (8)	
18.50–24.99	80% (87)	87% (39)	82% (75)	
≥25–29.99	17% (18)	7% (3)	9% (8)	
Mental Health				$\chi^2_{(2)} = 1.78$, $p = 0.412$
Stress Perception				
Yes	36% (35)	46% (18)	34% (29)	
No	64% (63)	54% (21)	66% (56)	
Chronic Diseases and Hypersensitivity Reactions				
Prevalence of Chronic Diseases				$\chi^2_{(4)} = 2.88$, $p = 0.578$
Heart Disease	1% (1)			
Heart Attack				
Cancer			1% (1)	
No Diseases	99% (97)	100% (39)	99% (84)	
Prevalence of Metabolic Diseases				$\chi^2_{(10)} = 7.14$, $p = 0.713$
Diabetes Mellitus 1	1% (1)	3% (1)		
Diabetes Mellitus 2	2% (2)			
Hyperthyroidism	1% (1)	3% (1)	1% (1)	
Hypothyroidism	5% (5)	3% (1)	8% (7)	
Other Diseases	1% (1)		1% (1)	
No Diseases	90% (88)	92% (36)	89% (76)	
Prevalence of Hypersensitivity Reactions				$\chi^2_{(4)} = 12.87$, $p = 0.012$
Allergies	32% (31)	36% (14)	20% (17)	
Intolerances	1% (1)	10% (4)	12% (10)	
No Reactions	67% (66)	54% (21)	68% (58)	
Medication Intake (regularly)				$\chi^2_{(6)} = 7.58$, $p = 0.271$
Thyroid Disease	6% (6)	8% (3)	11% (9)	
Hypertension	5% (5)	3% (1)		
Cholesterol Level				
Other Medication	5% (5)		5% (4)	
No Medication	84% (82)	90% (35)	85% (72)	
Contraceptives	12% (12)	10% (4)	15% (13)	$\chi^2_{(2)} = 0.70$, $p = 0.704$

BMI_{CALC} = Body Mass Index (calculated). IQR = interquartile range.



(**a**) 'Health-Related Indicators' (**b**) 'Health-Related Behavior'

Figure 1. Indices of both clusters 'Health-Related Indicators' and 'Health-Related Behavior' of female and male endurance runners, displayed by dietary subgroups (as percentage, %). Low scores indicate detrimental health effects, high scores indicate beneficial health effects.

3.1.3. Dimension of Chronic Diseases and Hypersensitivity Reactions

There was no significant association between diet and the prevalence of cardiovascular diseases and cancer ($\chi^2_{(4)} = 2.88$, $p = 0.578$), and even between diet and prevalence of metabolic diseases ($\chi^2_{(10)} = 7.14$, $p = 0.713$). However, there was a significant difference between the prevalence of hypersensitivity reactions and diet ($\chi^2_{(4)} = 12.87$, $p = 0.012$), where vegan endurance runners stated least often that they had at least one allergy. In addition, omnivores reported having a food intolerance least often (Table 3). Omnivorous, vegan, and vegetarian runners scored similarly with regard to the health-related indicator *chronic diseases and hypersensitivity reactions* (respectively, 0.85 (0.20), 0.82 (0.20), and 0.85 (0.18), $F_{(2, 219)} = 0.58$, $p = 0.562$) (Figure 1a).

3.1.4. Dimension of Medication Intake

There was no significant association between medication intake and dietary subgroup ($\chi^2_{(6)} = 7.58$, $p = 0.271$) (Table 3). Furthermore, there was no significant effect diet on the use of contraceptives ($\chi^2_{(2)} = 0.70$, $p = 0.704$). However, vegetarians had the highest scores with regard to medication intake, even though all dietary subgroups had similar scores (respectively, 0.84 (0.37), 0.90 (0.31), and 0.85 (0.36), $F_{(2, 219)} = 0.41$, $p = 0.663$) (Figure 1a).

3.2. Cluster 'Health-Related Behavior'

3.2.1. Dimension of Smoking Habits

Diet and current or former smoking were not significantly associated ($\chi^2_{(4)} = 8.96$, $p = 0.062$) (Table 4). Vegetarians showed the best health-related behavior with regard to *smoking habits* (0.83 (0.29), $F_{(2, 219)} = 1.30$, $p = 0.275$) (Figure 1b).

Table 4. Descriptive results and ANOVA of the 'Health-Related Behavior' cluster.

Dimension	Omnivorous	Vegetarian	Vegan	Statistics
Smoking Habits				$\chi^2_{(4)} = 8.96$, $p = 0.062$
Non-Smoker	58% (57)	72% (28)	54% (46)	
Ex-Smoker	40% (39)	23% (9)	46% (39)	
Smoker	2% (2)	5% (2)		
Supplement Intake				
prescribed by doctor	8% (8)	10% (4)	6% (5)	$\chi^2_{(2)} = 0.79$, $p = 0.675$
to boost your performance (occasionally)	10% (10)	21% (8)	11% (9)	$\chi^2_{(4)} = 4.09$, $p = 0.394$
to boost your performance (regularly)	3% (3)	0 % (0)	2% (2)	
to cope with stress (occasionally)	5% (5)	5% (2)	8% (7)	$\chi^2_{(4)} = 1.79$, $p = 0.774$
to cope with stress (regularly)	2% (2)		2% (2)	
Food Choice				
Motivation				
because it is healthy	67% (66)	74% (29)	75% (64)	$\chi^2_{(2)} = 1.59$, $p = 0.452$
because it is health-promoting	81% (79)	79% (31)	88% (75)	$\chi^2_{(2)} = 2.41$, $p = 0.300$
because it is good for maintaining health	85% (83)	92% (36)	95% (81)	$\chi^2_{(2)} = 5.99$, $p = 0.050$
Avoided Ingredients				
Refined Sugar	62% (61)	56% (22)	73% (62)	$\chi^2_{(2)} = 3.95$, $p = 0.138$
Sweetener	74% (73)	59% (23)	80% (68)	$\chi^2_{(2)} = 6.16$, $p = 0.046$
Fat in General	39% (38)	46% (18)	49% (42)	$\chi^2_{(2)} = 2.17$, $p = 0.339$
Saturated Fats	53% (52)	46% (18)	72% (61)	$\chi^2_{(2)} = 9.82$, $p = 0.007$
Cholesterol	34% (33)	31% (12)	65% (55)	$\chi^2_{(2)} = 21.60$, $p < 0.001$
White Flour	64% (63)	59% (23)	74% (63)	$\chi^2_{(2)} = 3.42$, $p = 0.181$
Sweets	58% (57)	62% (24)	69% (59)	$\chi^2_{(2)} = 2.52$, $p = 0.284$
Nibbles	62% (61)	59% (23)	62% (53)	$\chi^2_{(2)} = 0.15$, $p = 0.928$
Alcohol	55% (54)	51% (20)	56% (48)	$\chi^2_{(2)} = 0.29$, $p = 0.864$
Caffeine	26% (25)	36% (14)	46% (39)	$\chi^2_{(2)} = 8.30$, $p = 0.016$
Desired Ingredients				
Vitamins	81% (79)	72% (28)	86% (73)	$\chi^2_{(2)} = 3.48$, $p = 0.175$
Minerals/Trace Elements	70% (69)	72% (28)	75% (64)	$\chi^2_{(2)} = 0.56$, $p = 0.757$
Antioxidants	47% (46)	44% (17)	60% (51)	$\chi^2_{(2)} = 4.25$, $p = 0.119$
Phytochemicals	42% (41)	31% (12)	59% (50)	$\chi^2_{(2)} = 9.93$, $p = 0.007$
Fiber	68% (67)	62% (24)	75% (64)	$\chi^2_{(2)} = 2.58$, $p = 0.276$
Health Care Utilization				
Regular check-ups or routine health checks	54% (53)	49% (19)	61% (52)	$\chi^2_{(2)} = 1.91$, $p = 0.385$

3.2.2. Dimension of Supplement Intake

There was no significant association between diet and supplement intake prescribed by a doctor ($\chi^2_{(2)} = 0.79$, $p = 0.675$), the consumption of performance-enhancing substances ($\chi^2_{(4)} = 4.09$, $p = 0.394$) or the intake of substances to cope with stress ($\chi^2_{(4)} = 1.79$, $p = 0.774$) (Table 4). Vegans showed the best health-related behavior with regard to *supplement intake* (0.91 (0.19), $F_{(2, 219)} = 0.35$, $p = 0.708$) (Figure 1b).

3.2.3. Dimension of Food Choice

There was no significant association between diet and food choice (i) because it is healthy ($\chi^2_{(2)} = 1.59$, $p = 0.452$) and health-promoting ($\chi^2_{(2)} = 2.41$, $p = 0.300$); or (ii) in order to obtain vitamins ($\chi^2_{(2)} = 3.48$, $p = 0.175$), minerals/trace elements ($\chi^2_{(2)} = 0.56$, $p = 0.757$), antioxidants ($\chi^2_{(2)} = 4.25$, $p = 0.119$) and fiber ($\chi^2_{(2)} = 2.58$, $p = 0.276$) (Table 4). Moreover, there was no significant association between diet and the avoidance of the following ingredients (Table 4): refined sugar ($\chi^2_{(2)} = 3.95$, $p = 0.138$), fat in general ($\chi^2_{(2)} = 2.17$, $p = 0.339$), white flour ($\chi^2_{(2)} = 3.42$, $p = 0.181$), sweets ($\chi^2_{(2)} = 2.52$, $p = 0.284$), nibbles ($\chi^2_{(2)} = 0.15$, $p = 0.928$), and alcohol ($\chi^2_{(2)} = 0.29$, $p = 0.864$).

However, there was a significant effect of diet on *food choice,* both (i) because it is good for maintaining health ($\chi^2_{(2)} = 5.99$, $p = 0.050$), with vegetarians and vegans reporting doing so more often; and (ii) in order to obtain phytochemicals ($\chi^2_{(2)} = 9.93$, $p = 0.007$), with vegans reporting doing so more often. Moreover, there was a significant association between diet and the avoidance of the following ingredients (Table 4): sweetener ($\chi^2_{(2)} = 6.16$, $p = 0.046$), saturated fats ($\chi^2_{(2)} = 9.82$, $p = 0.007$), cholesterol ($\chi^2_{(2)} = 21.60$, $p < 0.001$), and caffeine ($\chi^2_{(2)} = 8.30$, $p = 0.016$). Vegans were more likely to report considering avoiding these ingredients in their food choice than vegetarians and omnivores.

Vegan athletes had the highest scores in *food choice* compared to the other dietary subgroups (0.75 (0.20), $F_{(2, 219)} = 6.76$, $p = 0.001$) (Figure 1b).

3.2.4. Dimension of Healthcare Utilization

There was no significant association between the use of regular health check-ups and diet ($\chi^2_{(2)} = 1.91$, $p = 0.385$) (Table 4). Vegan athletes had the highest scores with regard to *healthcare utilization* (0.61 (0.49), $F_{(2, 219)} = 0.95$, $p = 0.389$) (Figure 1b).

3.3. Results of the MANOVA

The findings of the MANOVA considering state of health are presented in Table 5, indicating significant differences ($p < 0.05$) for the following results: (i) race distance (F = 3.39, Df = 2, $p = 0.036$) and sex (F = 4.06, Df = 1, $p = 0.045$) had an effect on *mental health*, (ii) race distance had an impact on *chronic diseases* and *hypersensitivity reactions* (F = 3.27, Df = 2, $p = 0.040$), (iii) an association between sex and *smoking habits* (F = 4.22, Df = 1, $p = 0.041$), and (iv) an association between *food choice* and diet (F = 6.10, Df = 2, $p = 0.003$), with vegans having the highest scores (0.75).

Table 5. Results of the MANOVA considering health status.

Cluster	Dimension	Subgroup	F	Df	*p*
Health-related Indicators	**Body weight/BMI**	Diet	0.75	2	0.475
		Race Distance	0.49	2	0.613
		Sex	0.62	1	0.432
	Mental health	Diet	0.91	2	0.402
		Race Distance	3.39	2	0.036
		Sex	4.06	1	0.045
	Chronic diseases and hypersensitivity reactions	Diet	0.49	2	0.611
		Race Distance	3.27	2	0.040
		Sex	0.77	1	0.381
	Medication intake	Diet	0.41	2	0.665
		Race Distance	0.15	2	0.859
		Sex	1.06	1	0.304

Table 5. *Cont.*

Cluster	Dimension	Subgroup	F	Df	*p*
Health-related Behavior	**Smoking habits**	Diet	0.80	2	0.451
		Race Distance	1.78	2	0.172
		Sex	4.22	1	0.041
	Supplement intake	Diet	0.14	2	0.866
		Race Distance	0.93	2	0.395
		Sex	1.91	1	0.168
	Food choice	Diet	6.10	2	0.003
		Race Distance	1.11	2	0.331
		Sex	0.08	1	0.779
	Healthcare utilization	Diet	0.96	2	0.385
		Race Distance	1.52	2	0.222
		Sex	2.14	1	0.145

F = F-value. Df = Degrees of freedom. *p* = *p*-value for difference among groups.

However, the overall health status derived from all dimensions showed differences between race distances with statistical trend (F = 1.83, Df = 2, p = 0.71), but no significant differences were found for either diet or sex.

4. Discussion

This study intended to investigate the health status of vegetarian and vegan endurance runners and to compare it to omnivorous athletes, regarding potential differences in body weight, smoking habits, stress perception, the prevalence of chronic and metabolic diseases, the prevalence of allergies and food intolerances, medication and supplement intake, food choice, consumption of performance-enhancing substances, and healthcare utilization. In terms of assessing the state of health of endurance runners, it is generally accepted, that body weight, BMI and smoking behavior were known to affect running performance.

The main findings were: (i) vegetarians and vegans weighed significantly less than omnivores, (ii) vegans had the highest *food choice* scores, (iii) vegans reported choosing food because it is good for maintaining health more often, (iv) vegans reported avoiding sweeteners, saturated fats, cholesterol, and caffeine when choosing food more often, (v) vegans reported choosing food in order to obtain phytochemicals more often, and (vi) vegans reported the lowest prevalence of allergies.

4.1. Body Weight and BMI

A first important finding was that both vegetarians and vegans had lower body weight (62.00 kg (IQR 11.30) and 64.00 (IQR 10.00) kg, respectively) than omnivores (68.00 kg (IQR 16.70). At the same time, the majority of all participants had a BMI which was within the normal range of 18.50–24.99 kg/m^2 (80 % in omnivores vs. 87 % in vegetarians vs. 82 % in vegans) [21,22,24], with vegans having the best *body weight/BMI* health scores.

BMI is a relevant parameter, since it is associated with an increased risk for diseases, such as cardiovascular diseases, if it is higher than BMI_{NORM}, and with a couple of other disorders, such as anorexia nervosa, if it is below BMI_{NORM} [21,22]. In addition, it is a key factor with regard to running performance [24]. However, careful use and interpretation of the BMI is required. For example, the BMI of active runners could be below the normal range without being pathological [23].

In the light of this, the findings of the present study were in line with previous literature, where vegetarians and vegans also had lower BMI than meat-eaters [25–27]. Spencer et al. [28] attributed these differences in body weight and BMI mainly to differences in macronutrient intake between vegetarians, vegans, and omnivores. High protein and low fiber intakes were the factors most strongly associated with increasing BMI. Considering the fact that running speed and endurance performance are significantly associated with body mass and BMI [24], vegetarian kinds of diet are known to be a good basis for body weight control strategies for endurance athletes [7,16,29]. Meanwhile, athletes, as well as their coaches, have to be particularly aware of unintended body weight loss [30], which is why regular monitoring of body weight is recommended [27]. Beyond athletic concerns, vegetarian, but in particular vegan, dietary patterns are known as to be useful for body weight control for people who suffer from obesity and diabetes mellitus type 2 and hypercholesterinemia [12,13].

4.2. Vegetarians' and Vegans' Attitudes Towards Food Choice

While only the dimension *food choice* showed significant differences between dietary subgroups, overall the vegan dietary subgroup displayed the highest health scores from all dimensions (except for *medication intake*) and contributed to runners' good state of health, ranging from 61%–91%.

A main result was that vegans showed the highest score (75%) in endurance runners in the dimension *food choice* to contribute most beneficially to the overall state of health. This means that they reported choosing food ingredients because they are good for maintaining health. This finding was consistent with available scientific literature.

Studies of vegetarians and vegans have identified a range of motivations for dietary choices [8] (p. 395), although personal health and animal welfare were predominant motives [31–33] (pp. 24–28). It has also been shown that vegetarians and vegans usually have healthier lifestyles than omnivores [8,34] (p. 393). Their healthy lifestyle is characterized by the avoidance of adverse health behaviors, such as smoking and alcohol consumption, a high level of physical activity, and time for relaxation. Moreover, vegetarians and vegans are usually well-educated, have a certain degree of intellectual curiosity, and are open to new experiences [8] (p. 393). These findings match the results from the present study and support the characterization of vegetarians, but vegans in particular, as being health-conscious. However, all participants, meaning vegetarian, vegan, and omnivorous endurance runners, reported health-reasons as being important for food and ingredients choice. This supports the notion that athletes in general are health-conscious [35], but vegan athletes are supposed to be those who care most about this specific health-related strategy [8] (p. 393).

However, there was no significant major effect of dietary subgroups on whether food or ingredients had been chosen because they were healthy or health-promoting, even though there was a slight predominance of vegetarian and vegan runners. This was not entirely in line with current scientific evidence, as it has been shown that vegetarians and vegans are usually more health-conscious than omnivores [33,34,36]. Notwithstanding this, the contradiction might be explained by the composition of the sample. As all participants were endurance runners, who are known to be health-conscious compared to non-active people of the general population [35], the predominance of vegetarians and vegans might have been compensated for in this regard. Furthermore, the survey was based on self-reporting, so the definition of what is healthy or health-promoting in terms of food ingredients would depend on individual definitions based on personal suggestions and beliefs. Therefore, the results might have been biased to a certain degree. However, as the majority of all runners reported considering health aspects when choosing food, the findings support the characterization of the participants as being health-conscious.

A further main result was that vegan participants reported choosing food ingredients in order to avoid cholesterol, caffeine, sweetener and saturated fats more often. This finding was in line with the literature as well [37] and supports the fact that vegans in particular are supposed to be health-conscious.

Even though caffeine and cholesterol do not have detrimental health effects or may even have beneficial health implications if they are consumed conscientiously [38,39], cholesterol, in particular, is believed to be a crucial factor in the genesis of cardiovascular diseases [39]. Cholesterol is known to be an important risk factor for cardiovascular disease due to the induction of the elevation of LDL levels. It has also been found that HDL levels, which protect against cardiovascular diseases, increase after cholesterol consumption, so moderate consumption has been recommended in some studies [39].

However, to date the interactions between cholesterol intake and LDL and HDL blood levels have not been revealed completely [40]. With regard to caffeine, moderate consumption can increase physical and mental performance, while excessive intake can induce abuse or dependence [39]. Thus, it seems likely that both substances can be consumed moderately without any severe harm. However, being aware of potential detrimental side effects and therefore conscientious consumption is recommended.

Consumption of a high number of saturated fats is associated with cardiovascular diseases, such as stroke, myocardial infarction, and hypertension [8] (p. 414). Since vegan diets are characterized by a low percentage of saturated fats and a high percentage of omega-3 and omega-6 fatty acids [41], adhering to a plant-based diet can be a good way to improve cardiovascular health.

Health-effects of artificial sweeteners are controversial. While a couple of these products, such as aspartame, have previously received a generally recognized status as being safe from the United States Food and Drug Administration, there is also evidence for detrimental effects, such as the manifestation of glucose intolerance, weight gain and triggering of migraine in susceptible individuals [42]). Moreover, carcinogen effects could not be ruled out yet [43]. Overall, avoiding these agents appears to be advisable, so that the fact that the vegan endurance runners of our sample reported avoiding ingestion of sweeteners characterized them as being particularly health-conscious once again.

In addition to the avoidance of harmful substances, such as cholesterol and saturated fats, vegans reported choosing food in order to obtain phytochemicals. This finding supports the fact that vegan athletes are particularly health-conscious, since the consumption of phytochemical-rich foods is an important benefit of any plant-based diet in that it might help to mitigate the effects of excess inflammation and to promote recovery from training [41].

4.3. Allergies and Food Intolerances

There was a significant association between the prevalence of hypersensitivity reactions and diet, whereby vegan endurance runners reported least often that they had at least one allergy (20% in vegans vs. 32% in omnivores and 36% in vegetarians). Among those vegan endurance runners, 10-km runners had the lowest prevalence of allergies. At the same time, omnivores reported having a food intolerance least often (1% in omnivores vs. 10% in vegetarians and 12% in vegans).

Current evidence is sparse in this regard. One study has detected higher allergy rates among vegetarians [44], whereas others found a protective effect of a diet rich in fruits and vegetables on the occurrence of allergic asthma [45] and food allergies [46,47]. However, a relatively high incidence of allergies in a sample of endurance runners is not unexpected. It is well known that endurance athletes are more likely to have allergies (prevalence up to 13%) than people from the general population (prevalence 7% to 8%) [48]. This is usually attributed to the amount of time runners spend outdoors, which is supposed to be associated with a drying of the airways and an increased exposure to airborne allergens [49]. In the light of this, the finding that the vegan 10-km runners reported the lowest prevalence of allergies appears to be plausible because they usually have to cope with smaller training volumes (daily and weekly mileage) to successfully compete over shorter race distances. As a consequence, these runners do not spent as much time outdoors as long-distance runners, such as half-marathoners and (ultra-)marathoners.

Regarding food intolerances, the current literature does not provide clear data in this regard. One study indicated that a vegan diet might beneficially affect the intestinal flora, which seems to lower the risk of irritable bowel disease [47], whereas another study identified a long-term vegetarian diet as being the reason for the occurrence of irritable bowel disease [50]. However, endurance athletes, in general, are supposed to be more susceptible to symptoms of food sensitivities, which can be similar to those of irritable bowel disease. Constant training challenges the bowel to an extreme degree and endurance running, in particular, might cause gastrointestinal complaints. Thus, the ability to cope with additional gastrointestinal stress induced by food intolerances would be reduced [51].

4.4. Stress Perception

There was no significant difference found between vegetarians, vegans, and omnivores in reported stress and perceived pressure. *Mental health* scores were high, regardless of diet choice. However, vegan endurance runners had the highest scores for *mental health*. These findings were in line with previous studies, which showed that both endurance running [52,53] and adhering to a vegan dietary pattern caused good mood states [54]. Certain characteristics of vegans, such as a high degree of health-awareness [8] (p. 393), and the beneficial effects of endurance running, such as relaxation due to physical activity and an increase in stress resilience [52,53], appear to be the key factors in this regard.

In the light of this, finding the optimal dose of endurance running appears to be relevant, since too little exercise does not lead to a reduction in stress, whilst too much exercise might even increase stress levels [52]. According to the findings of the present study, half-marathon running appears to be a good way to cope with stress. These findings (unpublished data from our laboratory) are discussed in detail elsewhere [55]. Moreover, among the participants of the present study, there was a slight male predominance among those runners who reported as not suffering from stress. This was in line with previous research where it was reported that male endurance athletes possess a slightly higher degree of mental toughness than their female counterparts, allowing them to cope better with stress during exercise and in everyday life [56].

4.5. Chronic Diseases

There was no significant differences between the dietary subgroups when considering heart disease requiring treatment, state after heart attack, cancer, diabetes mellitus type 1 and 2, hypothyroidism and hyperthyroidism. In addition, there was a low overall incidence of these diseases among our participants. The only exceptions seemed to be apparently higher rates of cancer and hypothyroidism among vegetarians and vegans, which could be explained by a statistical bias.

There were five females who had suffered from breast cancer. Three of them had decided to change their dietary habits in favor of a vegetarian kind of diet after diagnosis of cancer, which skewed the results. The higher prevalence of hypothyroidism could be explained by the female predominance among the vegetarian and vegan subjects, as it is well known that eight times as many women suffer from thyroid diseases in general, and in particular from hypothyroidism, than men [57].

The fact that there was no association between diet and the prevalence rates of chronic diseases partially contradicts the body of evidence. Adhering to a vegetarian or vegan diet is usually associated with a lower incidence of diabetes mellitus type 2 [7,12,13], hypothyroidism (Tonstad et al. 2013 [58]), coronary artery disease [11,14], depression [54] and obesity [11] compared to an omnivorous diet. However, this effect might be compensated for by the fact that all our subjects were endurance athletes, who are usually supposed to be health-conscious, especially compared to non-active people of the general population [35]. Furthermore, the mean age of our participants was quite low (43.00 $\pm$ 18.00 in omnivores, 39.00 $\pm$ 16.00 in vegetarians, and 37.00 $\pm$ 15.00 in vegans), so that it can be assumed that the peak age for the manifestation of most diseases had not been reached yet. Furthermore, the fact that people who suffer from severe diseases usually do not become endurance runners might have led to a certain decrease in prevalence rates as well.

4.6. Medication Intake

There was no significant association found between the intake of medication with diet. All subgroups had similar *medication intake* scores. As there was a low prevalence of chronic diseases among our subjects, it was not surprising that there was also a low number of athletes who had to take any medication on a regular basis. The only exceptions were the intake of hormones and medication for the thyroid. The relatively high number of athletes who take hormones could be explained by the use of contraceptive pills or other interventions among the female runners. With regard to thyroid medication, the relatively high incidence rates of hypothyroidism among the female subjects (8%) explains the number of subjects who were taking thyroid medication.

4.7. Smoking Habits

There was no significant association between diet and current or former smoking. Yet, a low rate of smokers in vegetarian, vegan and omnivorous runners was observed. Vegetarians had the best scores considering *smoking habits*. These findings were in line with previous research, which also showed low numbers of smokers among vegetarians and vegans [59,60]. Although the low rates among endurance runners could be explained by undesired performance limitations due to smoking [59], vegetarians and vegans are often particularly health-conscious and therefore the number of smokers would be quite low among them [8,60] (p. 393). In addition, we found that women were more likely to be non-smokers compared to men, which was in line with previous research [61]. Nonetheless, in the past years, the number of female smokers has increased, which is particularly displayed in the prevalence of smoking associated diseases, such as lung cancer [61].

4.8. Supplement Intake

The finding that percentages of supplement intake were similar in all diet groups is consistent with current evidence. At the same time, vegans had the highest *supplement intake* scores. These findings are in line with previous research which showed that vegetarian kinds of diet are not lacking in critical micronutrients and macronutrients, per se, but rather that nutrient deficits can occur in any kind of diet [62]. Plant-based diets, such as a vegan dietary pattern, are not worse in terms of daily nutrient intake than omnivorous kinds of diet [63]. A recent study showed that an omnivorous diet does not meet the required amount of intake of six nutrients on average (calcium, folate, magnesium, iron, copper, vitamin E), whereas in vegetarian diets the amount of the daily intake of three nutrients is too low on average (calcium, zinc, vitamin B12) [9]. Another study has even revealed higher diet quality scores in vegetarian runners than in non-vegetarian runners [17]. Thus, supplementation of certain nutrients can be recommended for omnivores, vegetarians, and vegans alike [63]. More than this, these findings underpinned the fact that vegans are particularly health-conscious, which has been confirmed in other studies as well [8,60] (p. 393).

The most frequently taken supplement mentioned by the participants was vitamin D. Vitamin D deficiency is usually not associated with a vegetarian or vegan diet [64], but is a common problem in the general population [65] and in particular among endurance runners. It was found that there is a very large difference between necessary and real intake in athletes, regardless of whether they adhere to a vegetarian, vegan, or omnivorous diet [66]. Thus, all endurance athletes have to be aware of vitamin D levels, irrespective of their dietary patterns.

4.9. Enhancement Substances

There was no significant association between dietary subgroups and the consumption of enhancement substances or anything to cope with stress. Vegans reported the lowest use of enhancement substances. As there was a low overall number of subjects who reported using such substances (n = 32 for the consumption of enhancement substances, n = 18 for the consumption of substances to cope with stress) it could be expected that the number among the dietary subgroups would be quite low as well. It is noteworthy that these findings contradicted a previous study by Wilson [18] who found that 40% of male marathon finishers reported the recent use of performance-enhancing supplements. However, since our subjects did (almost) not report using such substances, they are probably aware of the detrimental effects of substances to increase performance and would, therefore, have avoided intake. This applies especially to the vegan participants, who are known to be particularly health-conscious [8] (p. 393).

4.10. Healthcare Utilization

Vegans had the highest scores in *healthcare utilization*, although scores were similar for all dietary subgroups. Scientific data is sparse in this regard. In one study a higher need for healthcare has been found among vegetarians [44]. However, since our results showed a good state of health in vegan, vegetarian and omnivorous endurance runners, there seems to be no need for frequent doctor consultations. Furthermore, physical activity, such as endurance running, prevents diseases which could require consulting a doctor more frequently [52]. However, about half of the participants (54% in omnivores, 49% in vegetarians, and 61% in vegans) reported making use of routine health checks. Considering that the mean age of our participants was around 40 years, this was an encouraging result, as most health checks for the early recognition and treatment of severe diseases in Europe are recommended for people who are aged 40 years and older [67].

4.11. Limitations and Implications for Future Research

Some limitations of the study should be noted. The survey was based on self-reporting. Thus, the reliability of the data depended on the conscientiousness of the participants. However, this effect was controlled for diet, participation in running events and race distance by using control questions, each separated from the respective main question and included in different sections of the questionnaire. In addition, the small sample size and the pre-selection of the participants due to the fact that mainly highly motivated runners took part led to a lack of statistical representativeness which might have affected the results. Nonetheless, the high intrinsic motivation of the participants would also have led to an increase in the accuracy of their answers and thus to a high quality of the generated data. Moreover, it was striking that most subjects came from Germany (n = 177). This imbalance in the composition of the sample may have several causes. First, Germany has a population of 82 million, making it the largest German-speaking country [68]. As the core area of the present study were German-speaking countries, this predominance is displayed in the sample of the present study. Second, Germany has large vegetarian and vegan populations [69]. Since a couple of subjects were addressed via trade fairs on vegetarian and vegan nutrition and lifestyle, it was likely that the number of German participants would increase. Third, some of the largest running events, such as the Berlin Marathon [70], take place in Germany. Together, this might have led to an increase in German participants.

Nevertheless, the data contributes to the growing scientific interest in and research on vegetarianism and veganism as it relates to sports and exercise and can be taken as one step towards creating a broad body of evidence in this regard. Future studies should be performed on large randomized samples in order to improve statistical representativeness. Furthermore, measurement of the health status could be elaborated by including additional parameters, such as energy metabolism and fluid balance regulation. Thereby, the data generated from the participants' self-report could be specified.

5. Conclusions

In summary, the findings revealed that all endurance runners had a good health status, regardless of the diet choice. At the same time, vegan athletes appeared to be extraordinarily health-conscious, in particular due to their food choice habits. These findings support the notion that adhering to vegetarian kinds of diet, but in particular to a vegan dietary pattern, is compatible with ambitious endurance running and can be an appropriate, at least equal and healthy alternative to an omnivorous diet for athletes.

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VegMed 2018
Medicine and Plant-based Nutrition

ABSTRACTS

Editors
Christian Kessler;
Andreas Michalsen,
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Das Modell des «Veganen Tellers» dient dabei als Grundlage, da es die Lebensmittelauswahl eines Tages veranschaulicht. Weitere Fragen die beantwortet werden, sind:

- Welcher Esstyp bin ich?
- Wie gestalte ich meine Mahlzeiten?
- Worauf sollte ich beim Einkauf achten?

Disclosure: none declared

NR. 39

Pflanzenbasierte Ernährung und Gesundheit aus wirtschaftlichen Gesichtspunkten

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Ausgangspunkt für Innovationen sind oftmals «Life-Needs», zentrale Bedürfnisse der Menschen, die befriedigt werden sollen. Krankheiten gehören zu den elementaren Herausforderungen und es werden Milliarden-Budgets zur Heilung und Entwicklung von Medikamenten bereitgestellt. Ernährung wird verstärkt als Ursache einer Vielzahl von Krankheiten identifiziert. Mit dem Buch «How not to Die» hat Dr. Michael Greger ein weltweit beachtetes Werk geschrieben, welches die 15 häufigsten Todesursachen der westlichen Welt behandelt. Es werden Krankheiten wie Krebs, Diabetes, Herzerkrankungen, Bluthochdruck etc. diskutiert und anhand von wissenschaftlichen Studien betrachtet.
Der Vergleich von konventioneller Medizin und «alternativen» Ansätzen stellt daher ein sehr großes Feld für Forschung und Entwicklung dar, in der Hoffnung das neue innovative Konzepte, die auf Ernährung und Bewegung abzielen, deutlich größere Effekte und zugleich wirtschaftlich sinnvollere Ansätze hervorbringen und so das Leiden vieler Betroffener lindern oder die Krankheit sogar komplett stoppen können.
Im Rahmen der Innovationsforschung von Prof. Wirsam werden alternative und konventionelle Behandlungsmethoden aus betriebs- und volkswirtschaftlicher Perspektive betrachtet und anhand von Fallstudien (analog zu «How not to die» 15 häufigste Todesursachen) miteinander verglichen. Erkenntnisse und Einblicke in aktuelle Entwicklungen, neuen Behandlungsmethoden, zukünftigen Chancen werden in den jeweiligen Themenblöcken angeboten.

Disclosure: none declared

NR. 40

Soulfood – Nahrung für die Seele, ein MuM-Workshop

Seifert, P. und Team

Medizin und Menschlichkeit e.V., Berlin, Germany

In dem vielfach durch unser MuM Team erprobten Workshop wollen wir Wege aufzeigen, wie unsere Bedürfnisse nach Stille, Kommunikation, Gehört werden, Wertschätzung und Authentizität auf einfache Weise erfüllt werden können. Wir werden in Einzelarbeit Räume für die Begegnung mit sich selbst und in Kleingruppenarbeit die Begegnung mit anderen eröffnen, wir werden schweigen und nach innen horchen und wir werden teilen und zuhören. In unserer Erfahrung eröffnet dies ein Feld der Achtsamkeit und menschlichen Verbindung welches über den Workshop hinaus wirkt.

Disclosure: none declared

NR. 41

Intermittent fasting and plant-based nutrition – a longevity concept?

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Experimental research in the last decades has consistently shown that caloric restriction, periodic and intermittent fasting extends the life span of organisms and delays the onset of most age-associated chronic diseases. Distinct mechanisms behind these phenomena have been described, among them reduced mitochondrial oxidative damage, increase of autophagy, the production of ketones, hormetic stress responses and the reduction of IGF-1, insulin and leptin as known promotors of age-associated metabolic disease. Notably relevant parts of these mechanisms can also be elicited by minimizing the intake of animal protein and refined sugars as fructose and glucose. Therefore a wholesome plant-based diet might be a complementary way for maximizing health promoting effects of caloric restriction and fasting. Current ongoing clinical trials investigate the effects of vegan fasting-mimicking diets in different indications as hypertension, diabetes, and cancer.

Disclosure: none declared

Research Sessions

NR. 42

Health status of vegetarian/vegan and omnivorous endurance runners – results from the NURMI-Study (Step 2)

[1]Boldt, P.; [2]Knechtle, B.; [3]Nikolaidis, P.; [4]Lechtleitner, C.; [5]Wirnitzer, G.; [6]Leitzmann, C.; [7]Wirnitzer, KW.

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Purpose: Since endurance running challenges body and mind to an extremely high degree, a good health status (HS) is inevitable. As the choice of an appropriate diet is a crucial factor in terms of health, the aim of the study was to investigate the HS of vegetarian/vegan endurance runners (VR) and compare it to omnivorous endurance runners (OR).
Methods: 281 recreational runners (159 women, 122 men) completed an online survey. We approached the HS using the dimensions "weight", "smoking", "perceived stress", "chronic diseases", "allergies/intolerances", "regularly medication/supplement intake", "health-related food choice", "enhancement substance use" and "healthcare utilization". Data analysis was performed by using analysis of variance and Chi-squared-test.
Results: There were 123 OR and 158 VR. 173 participants were classified as NURMI-Runners [103 half-marathoners (HM), 70 marathoners/ultramarathoners (FM)], 108 subjects were categorized as 10-km control group.
In neither dimension a remarkable difference between VR and OR was observed. Women reported more likely than men intake of hormones, mainly due to hypothyroidism and contraception. VR stated to choose food and to avoid certain ingredients (i.e. caffeine and cholesterol) for health reasons more often than OR. HM reported lowest stress levels and most rarely a weight loss due to a change in diet. FM stated lowest hormone intake.

Conclusions: Our results revealed that the endurance runners of our sample had a good HS, regardless of the race distance or diet choice. This demonstrated that adhering to both a vegetarian or vegan diet can be an appropriate and equal alternative to an omnivorous diet.

Disclosure: none declared

NR. 43

Consumer acceptance of behavioral interventions towards plant-based choices in foodservice

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Purpose: To evaluate the acceptability of behavioral interventions towards plant-based choices in foodservice by a sample of adolescents and older adults from DK, FR, IT and UK.
Methods: Cross-sectional study with 377 adolescents aged 12–19 years and 349 older adults aged 65+ who were part of VeggiEAT Project. VeggiEAT aimed to increase vegetables consumption across the lifespan in institutional foodservice. Participants reported their attitudes towards ten hypothetical interventions aimed at plant-based choices. Means and Standard deviation (SD) by age group were calculated for each intervention.
Results: The most acceptable intervention for adolescents is the provision of a green salad with lunch (mean 3.38; SD 1.32). For older adults, the highest-rated intervention was the use of posters by foodservice providers with simple and easy tips on how they could eat more vegetables (mean 3.59; SD 1.22). The use of posters showing happy adolescents eating vegetables and sad adolescents eating unhealthy was the less acceptable for this age group (mean 2.35; SD 1.25). For older adults, the less acceptable was a competition hold by foodservice providers where the winner would be the one with the largest vegetable intake (mean 2.38; SD 1.18).
Conclusions: Provision of a by default serving of vegetables and use of posters with easy tips towards plant-based consumption could be acceptable for EU adolescents and older consumers respectively. Interventions targeting self-image or competitions should be avoided for promotion of plant-based eating for EU adolescents and older consumers respectively.

Disclosure: none declared

NR. 44

Plant-based vs. animal-based protein and their impact on blood pressure in older consumers: a systematic review

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Purpose: Systematic Review of the effects of animal vs. plant protein consumption on the development of cardiovascular disease factors in older consumers.
Methods: Systematic Review, including randomized control trials, cohort studies and observational studies. Three databases were used for article identification (PubMed, Ovid Medline and Web of Science). Keywords used were "plant protein", "animal protein", "cardiovascular diseases" and "elderly". Main inclusion criteria were participants 60+ years old and articles published between 2000–2017.
Results: In total 297 articles were identified, of which only two met the inclusion criteria, one long term (15y), the other short term (6y) follow-up. BMI changes were not significant in either study. After 15 y regular consumption of plant proteins systolic (–2,64 mm/Hg) and diastolic (–1,75 mm/Hg) blood pressure (BP) levels decrease significantly. In the 6 months follow-up study plant protein consumption led to a drop in systolic (–8,70 mm/Hg) and diastolic (-6,50 mm/Hg) BP, whereas animal protein led to a modest decrease in systolic (-2,00 mm/Hg) and a modest increase in diastolic (+1,20 mm/Hg) BP.
Conclusions: Consumption of plant protein leads to a significant decrease in BP levels, suggesting that plant proteins are beneficial in preventing CVD, particularly in the short term. Since the reviewed studies were not fully comparable, it cannot be concluded that animal and plant proteins effect CVD factors differently in elderly. Another finding is that studies comparing health effects of plant vs. animal proteins are scarce. Hence new studies are needed focusing on different protein sources and their health benefit.

Disclosure: none declared

NR. 45

Impact of elimination or reduction of dietary animal proteins on cancer progression and survival – a pilot study

[1]Aspalter, R.; [1]Bacsics, A.; [1]Dobner, T.; [1]Fuchs, S.; [1]Wolf, V.; [1]Demanega, M.; [1]Ricker, A.; [1]Seitz, J.; [1]Ritter, A.C.; [1]Greiner, T.; [2]Wagner, K-H.

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Purpose: Animal fat and protein have been shown to influence tumor development and progression. The aim of this pilot-study was to investigate tumor outcome in a cohort of cancer patients with a wide range in intake of animal derived foods and to find a first estimate of the effect size.
Methods: In this prospective pilot-cohort study cancer patients were recruited online. They choose their dietary pattern for the duration of 6 months and had to complete three questionnaires (0, 3 and 6 months) about cancer history, treatment, cancer- and therapy related symptoms, comorbidities and diet.
Results: Out of 99 completers, 39 followed an omnivore, 26 a semivegetarian or vegetarian and 34 a semivegan or vegan diet. Mean intake of protein rich animal food ranged from 0.0 to 3.4 ± 2.2 servings/day. Vegan and semivegan patients had significantly more remissions compared to omnivores (33% versus 5%, p = 0.004) after 6 months. They also had less neuropathy and constipation. Meat, total meat (including processed meat), dairy and fish consumption correlated inversely with remissions, whereas vegetable intake was inversely related to cancer progression. None of the safety parameters (BMI, Karnofsky performance score, laboratory parameters) indicated any disadvantage for the vegetarian or vegan groups.
Conclusions: Reducing animal foods, especially animal proteins, was save and improved tumor prognosis in a population of mixed cancer patients, who already lived healthy. The novel finding, that particular food groups are differentially linked to tumor outcome, may lead to more differentiated nutritional advice for cancer patients.

Disclosure: none declared

NR. 46

Nutritional status of the spanish vegetarian population: Veggunn study

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Purpose: Vegetarian diets are increasingly becoming popular in Spain. appropriately planned vegetarian, including vegan, diets are healthful, nutritionally adequate, and may provide health benefits for the prevention and treatment of certain diseases. There are no scientific data on the nutritional status of vegetarian/vegan Spanish adults or on the relationship between their lifestyle habits and analytical biomarkers of health. Here we present the methodology of an ambitious research project with the aim of knowing the nutritional status of vegetarians, including vegans, using biochemical, anthropometric, dietary and health status markers.

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Medicine and Vegetarian Nutrition

ABSTRACTS

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the active form of vitamin B12. The HTC assay is believed to be more accurate in presenting the real vitamin B12 status in the human body.
In this presentation a case study is shown with a miss diagnosis by various medical doctors and as a result a severe vitamin B12 deficiency. The recovery of a severe B12 deficiency needs a careful guidance with personalised integrative care and may take several years to rebalance the body.

NO. 36

The NURMI Study: Methodology and First Results of the Prevalence of Vegetarians and Vegans in Running Events

Wirnitzer, K. C.[1]; Leitzmann, C.[2]; Knechtle, B.[3]; Nikolaidis, P.[4]; Wirnitzer, G.[5]; Lechleitner, C.[6]; Seyfart, T.[7]; Boldt, P.[8]

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Purpose: Considering the growing background numbers of vegetarians and vegans, the number of vegetarian and vegan runners is likely to rise, too. Therefore, the main goal of the Nutrition and Running High Mileage (NURMI) Study was to establish a broad body of scientific evidence on the endurance performance of vegetarian but especially vegan runners.
Methods: The NURMI Study was conducted following a cross-sectional design. Step 1 determines epidemiological aspects of endurance runners. Step 2 depicts dietary habits and running history from eligible participants (at least finishing a half-marathon). Step 3 displays data after a running event. Data collection (1/10/2014 to 31/12/2015) was accomplished using standardized questionaires. Analysis will be performed using SPSS software package (SPSS Inc., Chicago, IL, USA). All data derived from the statistical methods will be given in mean ± standard deviation.
Results: Data collected built a basic sample size of 3,163 runners (1,779 or 56.2% women; 1,384 or 43.8% men) predominently from German-speaking countries (Austria, Germany, Switzerland: n = 2,788) with lower numbers from the rest of Europe (n = 375). The overall prevalence of omnivorous, vegetarians and vegans in running events was 1,434 (45.3%), 665 (21.0%) and 1,065 (33.7%), respectively. Vegan runners were found to be significantly ($p < 0.001$) younger and leaner (age: 35.2 ± 10.2 y; body weight: 65.3 ± 10.4 kg; BMI: 21.9 ± 2.5 kg.m-2) compared to vegetarians and omnivores (age: 36.2 ± 11.0 vs. 39.2 ± 11.1 y; body weight: 65.0 ± 10.5 vs. 69.0 ± 10.9 kg; BMI: 21.8 ± 2.4 vs. 22.7 ± 2.5 kg.m-2).
Conclusions: Since scientific data about endurance athletes following a vegetarian but particularly a vegan diet are limited, the NURMI Study is the first study to assess this issue considering a bigger sample size. Therefore, the results will provide new information and a major contribution by adding knowledge to overcome the lack of data on the prevalence and exercise performance of vegetarian but especially vegan runners in endurance events.

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5 Wirnitzer K, Seyfart T, Leitzmann C, Keller M, Wirnitzer G, Lechleitner C, Rüst C, Rosemann T, Knechtle B (2016). Study Protocol. Prevalence in running events and running performance of endurance runners following a vegetarian or vegan diet compared to non- vegetarian endurance runners: The NURMI Study. Currently under review (Springer Link).

NO. 37

Impact of Elimination or Reduction of Dietary Animal Proteins on Cancer Progression and Survival

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Background: There is evidence that the incidence of cancer is low in vegan populations but currently there is little data available on the effect of a pure plant-based diet on the progression of diagnosed cancer.
Hypothesis: A reduction or total elimination of animal protein from the diet can positively influence the course of an existing cancer disease and – in addition to oncological standard therapies – increase the remission rate. We expect a higher effect the lower the consumption of animal protein.
Purpose of the pilot study:

1. To test the hypothesis that elimination/reduction of dietary animal proteins leads to an improved tumor prognosis. Tumor behavior (numbers and percentage of tumor remissions) at 6 months was chosen as primary end point in the respective diet forms (omnivore/lacto-ovo vegetarian/vegan)
2. To estimate the effect size and thus to enable sample size calculations in further studies
3. To test the feasibility of the different diets especially of a vegan diet, in cancer patients
4. To test the tolerance of different diets and to proof that a vegan diet does not lead to a deterioration of health, tumor progression or malnutrition
5. To test the online portal as a study platform (technical aspects, sequence of displayed questionnaires)
6. To test the validity of self reported and online-generated data

The concept of this ongoing pilot study and first experiences with its setting as a patient driven online-study are presented.

NO. 38

Fasting Protects Against Experimental Colitis and Commensal Microbial Gut Dysbiosis

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Inflammatory Bowel Disease (IBD) is an auto-inflammatory disease of the gastro-intestinal system with unknown aetiology. Many studies suggest that an imbalance in the interplay between diet, the gut microbiota and the intestinal epithelial barrier contribute to the pathogenesis of the disease. Our Western diet dramatically alters the makeup of our gut microbiota, which can in turn, lead to weakened gut barriers and microbial dysbiosis. This is characterized by loss of beneficial microbes and an increase in potentially pathogenic bacteria. Inflammation results when these bacteria interact with an impaired epithelial surface or leak across the epithelial barrier and stimulate the underlying immune cells.
Experiments from our lab demonstrate that fasting greatly reduces inflammation in two models of experimental colitis: A 48 hour fast ameliorates Dextran Sulfate Sodium (DSS)-induced colitis and leads to a significant decrease in IL-1β, IL-6 and TNFα expression in the colon along with changes in the make-up of the gut microbiota of C57BL/6 mice. In experiments using a mouse model of Salmonella typhimurium induced cecitis, we found that – following streptomycin pre-treatment – a 48h fast completely protects C57Bl/6 mice from the expected pathogen-induced intestinal damage. Preliminary data show that fasting alters the resident microbiota, and increases microbiota-based colonization resistance thereby preventing S. typhimurium from infecting the intestine and triggering inflammation. We therefore conclude that fasting beneficially modulates the gut microbiota and shapes host-microbe interaction in a way that promotes resistance to exogenous stressors and prevents microbial dysbiosis and inflammation.

Wirnitzer *et al. SpringerPlus (2016) 5:458*
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STUDY PROTOCOL

Open Access

Prevalence in running events and running performance of endurance runners following a vegetarian or vegan diet compared to non-vegetarian endurance runners: the NURMI Study

Katharina Wirnitzer[1], Tom Seyfart[2], Claus Leitzmann[3], Markus Keller[4], Gerold Wirnitzer[5], Christoph Lechleitner[6], Christoph Alexander Rüst[7], Thomas Rosemann[7] and Beat Knechtle[8*]

Abstract

Background: Beneficial and detrimental effects of various vegetarian and vegan diets on the health status are well known. Considering the growing background numbers of vegetarians and vegans, the number of vegetarian and vegan runners is likely to rise, too. Therefore, the Nutrition and Running High Mileage (NURMI) Study was designed as a comparative study to investigate the prevalence of omnivores, vegetarians, and vegans in running events and to detect potential differences in running performance comparing these three subgroups.

Methods/design: The NURMI Study will be conducted in three steps following a cross-sectional design. Step 1 will determine epidemiological aspects of endurance runners (any distance) using a short standardized questionnaire. Step 2 will investigate dietary habits and running history from eligible participants (capable of running a half-marathon at least) using an extended standardized questionnaire. Step 3 will collect data after a running event on finishing time and final ranking as well as a post-race rating of perceived exertion, mood status, nutrient and fluid intake during the race.

Discussion: Our study will provide a major contribution to overcome the lack of data on the prevalence and running performance of vegetarian and vegan runners in endurance running events. We estimate the prevalence of vegetarians and vegans participating in a running event to be less compared to the respective proportion of vegetarians and vegans to the general population. Furthermore we will validate the subject's self-assessment of their respective diet. This comparative study may identify possible effects of dietary behavior on running performance und may detect possible differences between the respective subgroups: omnivorous, vegetarian and vegan runners.

Trial registration Current controlled trials, ISRCTN73074080

Keywords: Diet, Nutrition, Running performance, Marathon, Endurance running, Vegetarian

Background

The Academy of Nutrition and Dietetics (formerly the American Dietetic Association) publishes position papers to vegetarian diets since 1980. The position paper of 2009 states that well-planned vegetarian diets, including total vegetarian or vegan diets, are appropriate for individuals during all stages of the lifecycle, including pregnancy, lactation, infancy, childhood, and adolescence, and for athletes (Craig and Mangels 2009).

The current position paper states that well-designed vegetarian diets, that may include fortified foods or

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supplements, meet current nutrient recommendations and are appropriate for all stages of the life cycle, including pregnancy, lactation, infancy, childhood, and adolescence (Cullum-Dugan and Pawlak 2015).

Numerous reputable studies (e.g. EPIC Oxford, Adventist health Study 1&2, and GEICO Study) described distinct advantages of vegetarian or vegan diets compared to diets containing meat and other foods of animal origin (Appleby et al. 1999; Davey et al. 2003; Le and Sabaté 2014; Mishra et al. 2013; Tonstad et al. 2013).

Health related benefits of vegetarian diets range from lower mortality from all-causes (Li 2014; Orlich et al. 2013) to lower body weight (BW), Body-Mass-Index (BMI) (Williams 1997), blood pressure (Yang et al. 2011), risk of obesity, and incidence of type 2 diabetes (Chiu et al. 2014; Zhang et al. 2010), as well as an enhanced antioxidant status capable of reducing exercise-induced oxidative stress (Kim et al. 2012; Trapp et al. 2010). Generally, the health of vegetarians is sound and compares favorably with that of the non-vegetarians (Appleby et al. 1999; Deriemaeker et al. 2011). As for all kinds of nutrition schemes, the health of vegans depends on their knowledge of how to compose and appropriately supplement their diet (Gilsing et al. 2010; Key et al. 2006; Le and Sabaté 2014; Obersby et al. 2013).

Since vegetarians consume widely divergent diets, a differentiation between various types of vegetarian diets is necessary. Many misunderstandings concerning vegetarianism are due to scientific data from studies without this differentiation. In the past, vegetarian or vegan diets have been described as being deficient in several nutrients including vitamin B_{12} (Gilsing et al. 2010; Obersby et al. 2013) iron, zinc, calcium, omega-3 fatty acids and iodine (Key et al. 2006). Numerous studies have demonstrated that the observed deficiencies are usually due to poor meal planning (Leitzmann 2005).

Although there has been some concern about protein intake for vegetarian and vegan athletes, data indicate that all essential and non-essential amino acids can be supplied by plant food sources alone as long as a variety of foods are consumed and the energy intake is adequate (Nieman 1999). Furthermore well planned, varied, appropriately supplemented vegetarian and vegan diets high in nutrient density appear to successfully and effectively support parameters that influence athletic performance (Rodriguez et al. 2009), nutritional requirements, recovery and resistance to illness in athletes (Barr and Rideout 2004; Eisinger et al. 1994; Fuhrman and Ferreri 2010). Yet, some athletes, regardless of diet, may lack nutritional knowledge critical to preventing nutrition-related health problems. However, most athletes have positive attitudes toward nutrition and are receptive to nutritional counseling (Zawila et al. 2003).

Considering the growing background numbers of vegetarians and vegans (Stahler 2011; Vegetarierbund Deutschland 2015), we assume that the number counts of vegetarian and vegan runners is rising, too. Among Europeans, 5 % of the population are estimated vegetarian or vegan adding up to 37 million vegetarians and vegans overall (European Vegetarian Union 2015). Considering German speaking European countries (Austria, Germany, and Switzerland), 9 % of the Austrian population or 760,000 are estimated vegetarian and 80,000 vegan (Hnat 2015). In Germany 10 % of the population or 7.8 million are estimated vegetarian and 1.1 % or 900,000 vegan (Vegetarierbund Deutschland 2015). 5 % of the Swiss population is estimated vegetarian (Schweizerische Vereinigung für Vegetarismus 2015).

There are many vegetarian and vegan athletes especially in endurance and ultra-endurance disciplines such as Alan Murray and Janette Murray-Wakelin (marathon running) (Murray and Murray-Wakelin 2015), Michael Arnstein (marathon running) (Arnstein 2015), Fiona Oakes (marathon running), Vlad Ixel (ultra-marathon running), Scott Jurek (ultra-marathon running), Ruth Heidrich (triathlon) (Greatveganathletes.com 2015), Emil Voigt (Olympic track and field), Edwin Moses (Olympic track and field), Paavo Nurmi (Olympic track and field) (Finn 2015), Brendan Brazier (triathlon) (Braizer 2015), and Arnold Wiegand (ultra-triathlon) (Wiegand 2015).

Considering these and numerous other successful (ultra-) endurance athletes adhering to various vegetarian and vegan diets provides sufficient evidence that high-level endurance and ultra-endurance performance can be achieved by following a vegetarian or vegan diet. Therefore it is reasonable to conclude that a vegetarian or vegan diet is compatible with successful endurance and ultra-endurance performance. Yet the prevalence of vegetarians or vegans in endurance running events has not been investigated to date.

Scientific data about endurance and ultra-endurance athletes following a vegan diet is limited. Only two case reports describing vegan diet and athletic performance can actually be found in PubMed database (MEDLINE Database 2015). Wirnitzer and Kornexl (2014) described the successful implementation of a vegan diet during an 8-day mountain bike race of a female athlete. Leischik and Spelsberg (2014) investigated an ultra-endurance triathlete on a raw vegan diet, with reference to his ability to perform, cardiac status, and any symptoms of deficiency.

Since case reports are not adequate to draw any scientific conclusions to a larger population, the NURMI Study was designed as a comparative study with a large study population to investigate the prevalence in running events and to detect potential differences in running performance comparing three subgroups: omnivorous, vegetarian and vegan endurance runners.

The future results of the NURMI Study might be useful to develop adequate strategies on nutrition behavior and might help to design individualized interventions in order to meet the nutritional challenges of demanding endurance running races and the requirements of vegetarian and vegan endurance runners.

Trial objectives

1. The first and major goal of the NURMI Study is to compare endurance performance of vegetarian and vegan runners to non-vegetarian marathon runners and to determine potential differences/to identify possible correlations.
2. The second goal is to investigate the prevalence of vegetarian and vegan runners in endurance (half-marathon and marathon) events.
3. The third goal is to validate the subjects self-reports on his/her dietary behavior.

Methods

The NURMI Study was designed by an interdisciplinary team of primary care physicians, sports medicine specialists, sport scientists, and nutrition scientists. An overview of all components of the intervention is shown in Fig. 1.

Step 1 Epidemiological pre-study

Step 1 is composed of a short standardized online questionnaire for endurance and ultra-endurance runners (any distance and any level of performance) primarily in Austria, Germany and Switzerland. Data on sex, age, kind of diet, and running history and habits will be collected. We aim to approach as many runners as possible for this step since gathered data will be used to estimate the prevalence of vegetarians and vegans active in endurance running.

Step 2 The major NURMI Study questionnaire

Runners matching inclusion criteria of the respective subgroups (capable of running a half-marathon etc./see "Subjects" section) complete an extended questionnaire on health status, specific dietary habits (details of consumption of specific foods or food groups), running history (i.e. preferred running distance, finished races overall and number of completed races in the last 2 years, preparation for a specific event, average distance and training load per day/week, etc.) and exercise induced diet (i.e. during training, racing or a day of rest, nutritional strategy on race day, etc.) as well as quality of life and health-related behavior. Step 2 includes a short form of the Quality of Life questionnaire (QOL BREF 26) distributed by the World Health Organization.

Step 3 NURMI post-race testing

After individual finishing a race of at least half-marathon distance, runners complete a questionnaire on final

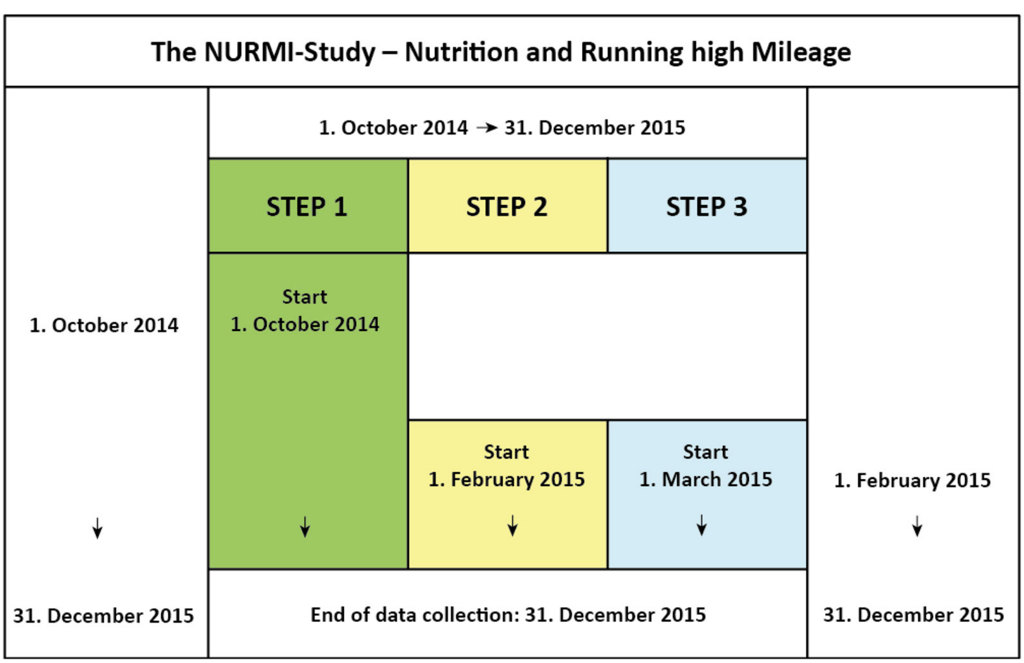

Fig. 1 Timescale of the NURMI Study

ranking, finishing time, energy and fluid intake, in race dietary strategy, and physical and mental perception. The rate of perceived exertion (RPE, overall, leg muscles and respiratory system) will be assessed by using the Borg Scale (Borg 1998).

Subjects

A large number of runners is planned to be enrolled in order to reach a sufficient number of subjects especially for Step 1. For Step 2 and 3 runners will need to meet the inclusion criteria. Runners participating in the NURMI Study will be recruited via advertisement by various channels such as directly at the websites of the organizers of marathon events, online running communities, and specific mailing-lists for runners, runners' magazines as well as magazines for health, vegetarian nutrition and lifestyle and personal communication. Additionally, information will also be provided by the official website (www.nurmi-study.com). Core region are German-speaking countries of Europe (Germany, Austria, Switzerland).

Inclusion criteria

For the epidemiological pre-study (Step 1) any subject active in running (any distance as well as any performance level) can participate. For successful participation in the main study (Step 2 and 3) a complete data set consisting of the following four items is required: written informed consent (1), at least 18 years of age (2), all NURMI questionnaires completed (3), successful participation in a running event of either half-marathon or marathon distance (4).

Description of measurements/methods/data collection

Questionnaires

All questionnaires are standardized, based on self-report, and will be conducted as online-surveys. Subjects can access www.nurmi-study.com and complete all questionnaires via encrypted interface.

Further measurements

Individual finishing time will be measured by the running events professional timing system and will be calculated as percentage of the overall winner's time.

Voluntary physical examination (optional)

Study participation does not involve any specific invasive type of intervention. Yet, we strongly advise the subjects to undergo a medical checkup including both a blood test and an incremental exercise test on a treadmill prior to the running event. Both can be conducted by a physician and analysed at a professional diagnostics laboratory at the runners hometown to determine critical micronutrient levels of iron, haemoglobin, serum ferritin, haematocrit, magnesium, serum vitamin B_{12}, holo transcobalamin, homocysteine and zinc, as well as to determine laboratory running performance. Participants will need to pay full cost for this voluntary laboratory testing, since it is optional. Subjects will be asked to measure body weight before and after the running event chosen for Step 3.

Outcomes

Primary outcomes

In addition to running performance (individual marathon finishing time of Step 3) adjusted to performance level the primary outcome is the prevalence of kinds of diets (omnivorous, vegetarian, vegan) among runners attending running events.

Secondary outcomes

Outcomes from Step 1 are: nationality, sex, age, body weight, height, calculated BMI, kind of diet, attended races in past 2 years, finished running distances, personal best time on each distance, number of planned events for 2014/2015, in-race food and fluid consumption, daily/weekly training frequency, daily/weekly training load, period of preparation for main event, and aim of race participation.

Outcomes from Step 2 are: years of running experience, motivation for running then and now, assisted training, years of race experience, training intensity, medium/long-term goal of racing, additional specific kinds of training, specific diet including supplements, specific training/diet prior to race, diet on day of rest/training/race, pre/in/post-race diet, specific gear, relevant medical measures, and quality of life and health-related behavior.

Outcomes from Step 3 are: Pre-race: body weight (including clothing and shoes). In-race: individual finishing time, individual runtime as % of overall winners time (calculated), ranking, calculated pace, temperature, wind, air pressure, humidity, sunlight. Post-race: body weight (including clothing and shoes), calculated weight loss, RPE (Borg) whole body/respiratory/legs, mental mood, fluid and nutrient intake including breakfast, and dietary strategy during race.

Strengths of the study

Since scientific data about endurance and ultra-endurance athletes following a vegan diet is limited the NURMI Study will be the first study to assess this issue considering a bigger sample size. The NURMI Study aims to provide a large data set comparing respective subgroups of omnivorous, vegetarian and vegan runners ranging from epidemiological aspects, dietary and training habits, in-race dietary consumption, and performance measurements. Large numbers of participants will allow to discriminate between and, identify associations with, different dietary patterns and level of training status as well as to detect differences in running performance between subgroups of omnivores, vegetarians and vegans. To make sure to assess fit runners only the NURMI Study focuses on runners who are at least capable of coping the half-marathon distance as the primary inclusion criteria.

Limitations of the study

Not all vegetarians and vegans participating in running events may be within the reach of the various recruitment methods. Due to various season, daytime and location of races, environment conditions (e.g. weather including sun or rain, temperature, relative humidity) will vary among the respective running events. Furthermore, our study shares with others the limitation of the cross-sectional design; therefore the present investigation allows no conclusion regarding causality. Prospective cohort studies are needed to confirm the associations between specific kinds of diet, health status and endurance performance to assess the causal direction and to develop recommendations for nutritional intake for vegetarian and vegan runners for training and racing.

Statistical methods

Analyses will be performed using commercially available software (IBM SPSS Statistics 23, SPSS Inc., Chicago, IL, USA). All data derived from the statistical methods will be given in mean ± standard deviation. Research shows that the most successful athletes in marathon and ultramarathon running events are frequently those who lose substantially more than 3–4 % BW during competition (Zouhal et al. 2011). Mean body weight of male recreational marathon runners is 73.9 ± 8.1 kg (Barandun et al. 2012) and 75.8 ± 8.6 kg (Friedrich et al. 2014) of male recreational half marathon runners. Mean body weight of female recreational runners is 59.1 ± 6.3 kg (Rüst et al. 2013) and 60.1 ± 7.8 kg (Friedrich et al. 2014) of female recreational half marathon runners. Expected body weight loss during a marathon race is 2.3 ± 2.2 % overall (Zouhal et al. 2011). For male recreational marathon runners we expect a 2.3 % weight loss from 73.9 to 72.2 kg, therefore a sample size of 179 runners is needed to reach 80 % power with two-sided test and alpha of 0.05. For female recreational marathon runners we expect a 2.3 % weight loss from 59.1 to 57.7 kg, therefore a sample size of 159 runners is needed to reach 80 % power with two-sided test and alpha of 0.05. Since body weight loss during a marathon is inversely related to race finishing time (Zouhal et al. 2011) we expect the fastest runners to lose the most relative body weight during competition. Multivariant regression analyses will be used the determine effects of kind of diet, sex, age, BMI, finished running distances, years of race experience, weekly training load, weekly training frequency, training intensity, in-race food and fluid consumption on individual finishing time (% of overall winners time, ranking, calculated pace). An analysis of variance will be performed to compare individual finishing time (% of overall winners time, ranking, calculated pace), sex, age, body weight, height, BMI, attended running events in past 2 years, finished running distances, personal best time on each distance, number of planned events for 2014/2015, daily/weekly training frequency, daily/weekly training load, period of preparation for main event, aim of race participation, years of running experience, motivation for running then and now, assisted training, years of race experience, training intensity, medium/long-term goal of racing, additional specific kinds of training, specific diet including supplements, specific training/diet prior to race, diet on day of rest/training/race, pre/in/post-race diet, in-race food and fluid consumption, specific gear, relevant medical measures, pre/post-race body weight (including clothing and shoes), calculated weight loss, in-race: nutritional strategy during race, fluid and nutrient intake including breakfast, mood status, and RPE (Borg) whole body/respiratory/legs, among the three subgroups created respective to diet.

Schedule of the study

Step 1 is accessible since October 1st 2014. Step 2 is accessible since February 1st 2015 and Step 3 is accessible since March 1st 2015. All questionnaires will be accessible through December 31st 2015. Analysis and interpretation will be taking place subsequently to the study.

Study centers

Data of all steps of the NURMI Study will be collected and analyzed in Austria. Core region are German-speaking countries of Europe (Germany, Austria, Switzerland).

Ethical principles

The study is conducted in accordance with medical professional codex and the Helsinki Declaration as of 1996 as well as Data Security Laws and good clinical practice guidelines. Study participation is voluntary and can be cancelled at any time without provision of reasons and without negative consequences.

The subject's written informed consent

Previous to study, subjects participating in the NURMI Study give written information about the content and extent of the planned procedure of the study. In case of study discontinuation, all data sets will be deleted.

Vote of the ethics committee

The study protocol was approved by the ethics board of St. Gallen, Switzerland on May 6, 2015 (EKSG 14/145).

Duties on the part of the investigators

The authors hereby confirm that ethical and scientific criteria as well as quality standards in terms of planning, study procedure, monitoring, analysis and documentation of the study will be fully observed and carried out in accordance with the protocol. All rights of the subjects will be respected and the results of the study will be handled correctly. The investigators are bound to conduct the study according to the study protocol and to report and document deviations to the ethics committee.

Evaluation of the risk–benefit ratio

All planned measurements are routine, justifiable and reasonable from a medical point of view. Study participation implicates no additional risk for the subject. Participation is voluntary and discontinuation will be possible at any time and without negative consequences. The study will be considered a contribution for endurance athletes, in particular endurance runners following some kind of vegetarian diet including the vegan diet. Moreover, the study aims to add knowledge to the currently very limited body of science considering the vegetarian but specifically the vegan endurance athlete. Furthermore the study could help to eliminate remaining concerns of coaches and runners and has the potential to show the adequacy of vegetarian and vegan diets on running performance as seen in professional runners.

Benefits for the subjects

Subjects will not be given any financial compensation. Subjects will receive a brief summary of the results of the NURMI Study if desired.

Data security

IT-team

All data are treated according to appropriate Federal Data Security Laws. The NURMI online surveys hosted on a dedicated virtual server, and run https-only, therefore all relevant data are transmitted SSL-encrypted. Access to the server as well as the file- and database-backups is restricted to the IT staff of the study team and the hosting provider (also a project partner). Security measurements include a local firewall on the server itself, regular security updates of the operating system and applications, no FTP access and no unencrypted access at all. SSH access is restricted to SSH key authentication, ruling out dictionary attacks, automatic detection of dictionary and other brute force attacks against SSH, with automatic locking of attacking clients' IP addresses, and basic intrusion detection regarding operating system and applications. Gathered data will be stored pseudo-anonymised. Each subject will be assigned an identification code (ID), which will be kept in a separate database. Questionnaire data and subject's registration data will be stored in different databases. ID linkage will allow us to assign questionnaire data to each subject's data set. All members of the research staff are bound to their professional obligation to discretion. Data will be used and analyzed exclusively and only in the context of the NURMI Study.

Trial status

All questionnaires are open and will be accessible through December 31st 2015.

Abbreviations

NURMI: Nutrition and Running High Mileage; BW: body weight; BMI: body mass index; RPE: rate of perceived exertion; IT: information technology; ID: identification code.

Authors' contributions

KW: principal investigator, study coordinator, conception and design, financial support, statistics and analysis, data collection and analysis, manuscript writing, critical revision and final approval of the manuscript. TS: manuscript writing, critical revision and final approval of the manuscript. CL and MK: conception and design, critical revision and final approval of the manuscript. GW and ChL: IT. CR and TR: Statistical analysis. BK: conception and design, statistics and analysis, data collection and analysis, manuscript writing, critical revision and final approval of the manuscript. All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

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and body composition were assessed by magnetic resonance imaging and dual energy X-ray absorptiometry, respectively. Physical fitness was also examined by hand grip strength (HGS) and the 20-m shuttle run (SR) test. Results After DCI, reductions of %BF (from 29.3±5.8% to 27.8±6.1%) and FM in DCI group were significantly larger than CONT group ($p<0.05$), whereas increases of total fat-free mass (FFM), HGS and the number of SR in DCI group were significantly larger than CONT group. HOMA-IR in DCI group was also significantly decreased compared to CONT group ($p<0.01$). Discussion It was found that the 10-week DCI for female HW Judo athletes significantly lowered %BF, FM and HOMA-IR with increasing FFM, muscle strength as well as cardiorespiratory fitness. Interestingly DCI group did not significantly decrease VF. Previous study showed that overweight men deceased larger VF than overweight women in calorie restriction with exercise (Redman, et al., 2007). Therefore, although DCI effectively reduces CMR for female HW Judo athletes, it may have less effect on reducing VF for female HW Judo athletes. Conclusion DCI for female HW Judo athletes reduced CMR without reducing their physical performance. References Despres JP, Lemieux I, Bergeron J, et al. (2008). Arterioscler Thromb Vascr Biol, 28:1039-49. Murata H, Oshima S, Torii S, et al. (2015). ECSS annual congress abstract, 320. Murata H, Takata K, Natsui H, et al. (2013). Jpn J Clin Sports Med, 24,623-31. Redman LM, Heilbronn LK, Martin CK. et al. (2007). J Clin Endocrinol Metab, 92, 865–72. Contact hiromura@toki.waseda.jp

PREVALENCE OF OMNIVORES, VEGETARIANS AND VEGANS IN RUNNING EVENTS: THE NURMI STUDY

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Introduction Considering the growing background numbers of vegetarians and vegans (Craig et al., 2009; Stahler, 2011), the number of vegetarian and vegan runners is likely to rise, too. Therefore, the aim of the Nutrition and Running High Mileage (NURMI) Study was to investigate the prevalence of omnivores, vegetarians, and vegans in running events in the first step. Methods The NURMI Study was conducted following a cross-sectional design. The present study determined epidemiological aspects of runners. Data collection (1/10/2014 to 31/12/2015) was accomplished using a standardized questionnaire. Analysis was performed using SPSS software package. All data derived from the statistical methods were presented as mean ± standard deviation. Results Data collected built a basic sample size of 3163 runners (1779 women: 56.2%; 1384 men: 43.8%) predominently from German-speaking countries (Austria, Germany, Switzerland: 2788) with lower numbers from the rest of Europe (375). The prevalence of omnivores, vegetarians and vegans in running events was 1434 (45.3%), 665 (21.0%) and 1065 (33.7%), respectively. An association between sex and diet was observed ($p<0.001$): the prevalence for female and male runners was 673 (37.8%) vs. 761 (55.0%) in omnivores, 431 (24.2%) vs. 234 (16.9%) in vegetarians, and 675 (37.9%) vs. 389 (28.1%) in vegans. Omnivorous runners were found to be older and heavier (age: 39.2±11.1 y; body weight: 69.0±10.9 kg; body mass index (BMI): 22.7±2.5 kg.m-2; $p<0.001$) compared to vegetarians and vegans (age: 36.2±11.0 vs. 35.2±10.2 y; body weight (BW): 65.0±10.5 vs. 65.3±10.4 kg; BMI: 21.8±2.4 vs. 21.9±2.5 kg.m-2; $p<0.001$). A sex-diet interaction was found on BW ($p=0.022$, n2=0.002) and BMI ($p<0.001$, n2=0.007). Discussion The main findings of the present study were (1) almost equal numbers of female omnivorous and vegan runners, whereas the major count of male runners were omnivores; and (2) omnivorous runners were older and heavier than non-omnivores in this study. However, beneficial and detrimental effects of vegetarian and vegan diets on the health status are well known (Cullum-Dugan et al., 2015). Since scientific data about endurance athletes following a vegetarian and particularly vegan diet is limited (Wirnitzer & Kornexl, 2014; Leischik & Spelsberg, 2014), the NURMI Study is the first to assess this issue considering a bigger sample size. Therefore, these results provide a major contribution by adding knowledge to overcome the lack of data on the prevalence and demographics of vegetarians and vegans in running events (Scheerder et al., 2015), and might be helpful as reference data for future studies. This further may help to augment the body of science on the limited data of vegan athletes in general (Fuhrmann & Ferreri, 2010). References Craig WJ, Mangels AR (2009). J Am Diet Assoc 109(7):1266-1282 Cullum-Dugan D, Pawlak R (2015). J Am Diet Assoc 115(5):801-810 Fuhrmann J, Ferreri DM (2010). Curr Sports Med Rep 9(4): 233-241

DIETARY HABITS AND SUPPLEMENT USE OF ELITE ADOLESCENT CYCLISTS

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Introduction Diet is key to health and athletic performance. Dietary intake of British Cycling Olympic Development Programme (ODP) athletes was assessed and compared in 1st and 2nd year cyclists. Supplement use of these athletes was also determined. Methods Forty adolescent cyclists, 25 male and 15 female (mean age 16.2 years) completed a Dietary Habits Questionnaire (DHQ) that included a Food Frequency Questionnaire (FFQ) and questions to assess monthly supplement use. Dietary analysis was conducted with a sample of 21 FFQ, using Microdiet™ software. Supplement use was calculated for all 40 participants. Energy and macronutrient intake was compared to UK dietary reference values (DRVs). Results ODP cyclists achieved DRVs for energy, carbohydrate and saturated fat (SF), but both males and females consumed more protein than recommended, exceeding DRV by 137.1g and 111.6g respectively (Z-3.180, $p=0.001$, n=13; Z-2.521, $p=0.012$, n=8). Dietary intake of 1st and 2nd year cyclists did not differ. Supplement use did not differ between 1st and 2nd year cyclists ($\chi2=0.231$, df=1, $p=0.631$) but were used at least once a week by 95% of ODP athletes. Average intake per rider per month was 78.2 items, although there were large range values of total monthly use per rider (0-272). Use was more prevalent in male athletes than females (96 vs. 49 items per month) ($\chi2=15.234$, df=1, $p<0.001$) and compared to other squads, the sprint athletes (TS) used significantly more (122 vs. 75 (Endurance), 24 (BMX), 77 (MTB)), ($\chi2=64.60$, df=3, $p<0.001$). The most popular supplements amongst the 40 athletes were protein/recovery drinks, multivitamins, fish oil/omega 3, vitamin C and carbohydrate (CHO) bars. Discussion Dietary intake appeared to be adequate, but further research is needed using DRVs specific to young athletes. Small improvements in dietary composition appeared in 2nd year athletes although these were not significant. 2nd year athletes consumed more of their total energy from CHO (+1.76%) and protein (+0.82%) and less from fat (-2.45%), suggesting nutrition education may have had a small impact. The high prevalence of supplement use found among these young athletes is consistent with previous findings from young UK athletes from other sports (Petróczi et al., 2008). However, these results are concerning as young athletes are advised against using supplements by the IOC (2011) due to the associated risks. Further research is needed in order to develop an athlete-specific, validated FFQ and also to determine reasons for supplement use. References IOC consensus statement on sports nutrition 2010. (2011). Journal of Sports Sciences, 29. S3-S4 Petróczi, A, Naughton, DP, Pearce, G, Bailey, R, Bloodworth, A, McNamee, MJ. (2008). Nutritional supplement use by elite young UK athletes: fallacies of advice regarding efficacy. JISSSN. 5(22), 1-24. Contact 1219939@chester.ac.uk