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ARTICLE

Body composition, energy expenditure and physical activity

Is a vegan diet detrimental to endurance and muscle strength?

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Abstract

Background/objectives In the general population, there is a popular belief that a vegan diet may be associated with a lower exercise performance due to the lack of certain nutrients in vegan individuals. Thus, the purpose of the present study was to examine endurance and muscle strength differences between vegan and omnivore participants.

Subjects/methods We studied 56 healthy young lean physically active women (age: 25.6 ± 4.1 years; body mass index: 22 ± 1.9 kg/m^2). Participants were classified as vegan ($n = 28$) or omnivore ($n = 28$) based on their eating habits. All volunteers followed either a vegan or an omnivore diet for at least 2 years. Anthropometric measurements, body composition, estimated maximal oxygen consumption (VO_2 max), a submaximal endurance test (70% of VO_2 max), muscle strength (leg and chest press), and dietary factors were measured.

Results Both groups were comparable for physical activity levels, body mass index, percent body fat, lean body mass, and muscle strength. However, vegans had a significantly higher estimated VO_2 max (44.5 ± 5.2 vs. 41.6 ± 4.6 ml/kg/min; $p = 0.03$, respectively) and submaximal endurance time to exhaustion (12.2 ± 5.7 vs. 8.8 ± 3.0 min; $p = 0.007$, respectively) compared with omnivores.

Conclusions The results suggest that a vegan diet does not seem to be detrimental to endurance and muscle strength in healthy young lean women. In fact, our study showed that submaximal endurance might be better in vegans compared with omnivores. Therefore, these findings contradict the popular belief of the general population.

Introduction

Plant-based diets appear to be increasing in popularity since there is evidence to suggest that they could decrease the risk of cardiovascular diseases, diabetes, and all-cause mortality [1–3] as well as promote a healthier environment [4, 5]. Still, in the general population, there is a popular belief that a vegan diet may be associated with a lower exercise performance in vegan individuals due to the lack of certain nutrients such as protein, creatine, vitamin B_{12}, and vitamin D [6, 7].

Few studies have compared endurance and muscle strength performances between vegetarians/vegans and omnivores [8–11]. For example, the very first study compared young athletes who followed an omnivore diet with a heterogeneous group of vegetarians composed of lacto-ovo vegetarians, lacto vegetarians, and vegans for at least 2 years [8]. The results showed no differences in aerobic capacity (VO_2 max) and anaerobic performance as well as in hand grip strength between groups in both men and women. In another study, Nieman et al. [9] also observed no differences in VO_2 max in elderly women who either followed a vegetarian or omnivore diet. The study of Lynch et al. [10] compared young athletes who were either omnivores or a mixture of vegetarians composed of lacto-ovo vegetarians and vegans for at least 2 years. The authors reported higher VO_2 max levels in women vegetarians without any differences in the men vegetarian group when compared with omnivores. Furthermore, in the same study, peak torque using leg extensions was comparable between vegetarians and omnivores in both men and women. Finally, a recent study compared maximum power on an ergocycle in young recreational runners who were either vegans, lacto-ovo vegetarians or omnivores (duration of diets were between 0.5 to >3 years) [11]. No significant differences in maximum power were noted between all three groups in both women and men. In addition, no measurement of muscle strength was performed in that study.

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It should be noted that most of the previous studies that investigated a plant-based diet on physical performances mixed different types of vegetarians with vegans in the vegetarian group that may render findings and/or conclusions difficult to interpret. In addition, given that there is a growing trend for adopting a vegan diet [12, 13], the impact of a vegan diet only on exercise performance, however, is less clear. Thus, there is a need to conduct more research on this topic. Therefore, the purpose of the present study was to examine endurance and muscle strength differences between vegans and omnivores in a well-characterized population.

Methods

Participants

A total of 56 participants were recruited in this study between November 2018 and August 2019 using advertisement via emails and on social media websites as well as short presentations in classrooms at the Université du Québec à Montréal. Participants were included in the study if they met the following criteria: (1) female, (2) aged between 18–35 years old, (3) a body mass index between 18.5–24.9 kg/m^2, (4) primarily performed 150–200 min of aerobic physical activity/week (e.g., running, cycling), (5) no orthopedic limitations, (6) nonsmoker, and (7) low alcohol consumers (≤1 drink/day). Exclusion criteria were: (1) chronic diseases such as cardiovascular disease, diabetes and cancer and (2) being pregnant. Self-reported physical activity was determined using the following question: how many minutes of aerobic physical activity do you perform every week? It should be noted that that only young women were recruited in the present study because the prevalence of vegans has been shown to be significantly higher in women compared with men (75% vs. 25%, respectively) as well as higher in the age group of 18–30 years old compared with the age group of ≥65 years old (28.5% vs. 6.8%, respectively) [14]. Participants were classified as vegan ($n = 28$) or omnivore ($n = 28$) based on the diet of the participants. That is, omnivores had to consume meat at least three times a week, whereas vegans were defined by the consumption of only plant-based foods. All volunteers followed either a vegan or an omnivore diet for at least 2 years. Participants identified themselves as either vegan or omnivore during the recruitment process and their nutritional status was then confirmed during the analysis of their dietary journal. The study was conducted in accordance with the Declaration of Helsinki and all procedures were approved by the Ethics Committee of the Université du Québec à Montréal. All participants were fully informed about the nature, goal, procedures, and risks of the study, and gave their informed consent in writing.

Procedure

A phone interview was conducted to screen for the aforementioned inclusion/exclusion criteria. After screening, each participant was invited to the Department of Exercise Science at the Université du Québec à Montréal. Each participant was instructed to avoid eating and not to perform any physical activity 3–4 h before testing. Also, women were tested in the follicular phase of the menstrual cycle. Upon their arrival, the measurements were performed in the following order: (1) estimated VO_2 max, (2) upper body muscle strength (chest press), (3) lower body muscle strength (leg press), (4) anthropometric and body composition, and (5) a submaximal endurance test. Following the assessments, participants were given instructions to complete a 3-day dietary journal.

Estimated maximal oxygen consumption

A cycle ergometer (Lode Excalibur Sport, Groningen, The Netherlands) was used to evaluate maximal oxygen consumption (VO_2 max). The first stage began at 50 W for 2 min. Thereafter, there was a progressive increase in the level of intensity (25 W) every 2 min until voluntary exhaustion was reached. Participants were asked to maintain a speed between 70 and 80 rpm during the test. The estimated VO_2 max was calculated using the following validated prediction equation adjusted for body weight: VO_2 max (ml/kg/min) $= 10.8 \times (W/\text{body weight (kg)}) + 7$, where W is the maximal power output in watts achieved during the test [15]. Thereafter, we calculated peak maximal output, which takes into consideration the number of seconds in the final stage. Peak maximal output was calculated using the following validated prediction equation: peak maximal output (Watts) $= W_{\text{last}} + (t \times \Delta/T)$, where W_{last} is the last completed workload, t is the number of seconds in the final stage, Δ is the power increment in watts, and T is the duration in seconds of a complete stage [16].

Muscle strength

Muscular strength was assessed using two different weight machines, which included a leg press for lower body strength and a seated chest press for upper body strength from Atlantis Precision Series (Atlantis Inc. Laval, Canada). Muscle strength was measured using a one-repetition maximum (1-RM) technique. For the leg press, participants were aligned with the ball of their foot on the footplate of the machine at shoulder width so that their

knee angle approximated 90° of flexion. Keeping their back flat against the chair, participants were assisted to the starting position, which consisted of extended their legs outward. A complete repetition consisted of flexing the knees and slowly returning to a complete extension of the legs stopping before full knee extension. For the seated chess press, participants were properly seated so that their hands, once on the handles, were slightly below their shoulder height. Thereafter, participants were assisted to the starting position, which consisted of fully extended their arms outwards. To complete a repetition, elbows were flexed until they reached slightly behind the shoulders and then slowly returned to the starting position. Muscle strength testing started with the seated chest press and then the leg press. For each apparatus, participants were properly seated and adjusted. For all movements, the first set was used as a warm up of ten repetitions with a light initial load set by the training supervisor. Thereafter, the load was increased until maximal effort was achieved. The 1-RM was typically determined within five trials with a 4 min rest between each trial. Failure was defined as a lift falling short of the full range of motion. Muscular strength indices were calculated for both the leg press as well as the seated chest press and expressed as weight lifted in kg per kg of lean body mass.

Body composition

Total body weight, body fat percentage and lean body mass were measured using dual energy X-ray absorptiometry (General Electric Lunar Prodigy; standard mode; software version 12.30.008, Madison, WI, USA). Calibration was executed daily with a standard phantom prior to each test. Also, standing height (±0.1 cm) was measured using a wall stadiometer (Perspective Enterprises, MI, USA). Body mass index = body weight (kg)/height (m^2) was then calculated.

Submaximal endurance test

The submaximal endurance test was performed on a cycle ergometer (Lode Excalibur Sport, Groningen, The Netherlands). Intensity was set at 70% of their peak maximal power output in Watts, which was determined using the peak maximal power output value of their VO_2 max test. Participants were asked to pedal until voluntary exhaustion was achieved. Volunteers had to maintain a speed between 70 and 80 rpm during the test. Time in minutes was recorded.

Dietary intake

Food intake was assessed using a 3-day dietary journal. Participants were instructed to keep a record of food intake, including condiments and beverages during 3 days (2 weekdays and 1 weekend). Participants were asked to write as much information as possible about the foods they ate (i.e., brand names, percentage of carbohydrates, fats and proteins, how the food was cooked, use of supplements, etc.). No portion-size estimation measurement aid was given to the participants, however, they were asked to use the usual tools to estimate their portion sizes (i.e., teaspoon/tablespoon/cup in ml or ounces) and, if possible, weigh their portions. On their return, each food record was reviewed by a dietitian to verify the precision of the information written and to complete missing information. Furthermore, based on their dietary journal, the dietitian confirmed if the participants were either vegan or omnivore. No participant misidentified herself as either a vegan or an omnivore. Dietary analyses were completed using the ESHA food processor nutrition analysis software (version 7.9; ESHA Research, Salem, OR, USA) to determine the 3-day average of total energy intake as well as macronutrients and micronutrients.

Statistical analysis

The data are expressed as the mean ± standard deviation. We first verified the normality of the distribution of variables with the kurtosis test and found that all body composition and exercise performance tests variables were normally distributed (indices between −2 and 2). Then, an independent *t*-test was performed to compare vegan and omnivore individuals. Marginal estimates of submaximal endurance test values adjusted for estimated VO_2 max or age were calculated with ANCOVA (Univariate general linear model). Pearson's correlations were also performed to examine the relationship between age with body composition and exercise performance tests. We estimated that to detect a medium to large effect size with 80% power at an alpha error of 0.05, a sample of 26 participants in each group would be sufficient. Statistical analysis was performed using IBM SPSS Statistics for Windows, Version 24 (IBM Corp., Armonk, NY, USA). Statistical significance was set at $p \le 0.05$.

Results

The vegan group had been on a vegan diet for an average of 4.0 ± 2.6 years, whereas participants in the omnivore group were omnivores during their entire life.

Body composition characteristics of the participants are presented in Table 1. Both groups were comparable for total body weight, body mass index, total fat percentage, and total lean body mass. Also, age was significantly higher in vegans compared with omnivores ($p = 0.009$).

Exercise performance characteristics of the participants are shown in Table 2. Estimated VO_2 max was significantly higher in the vegan group compared with the omnivore group ($p = 0.03$). In addition, there was a tendency for lower upper body muscle strength values (chest press) in vegans ($p = 0.06$). No differences were observed for physical activity and in lower body muscle strength (leg press) between both groups. Furthermore, we observed that vegans had significantly higher submaximal endurance test values than omnivores (12.2 ± 5.7 vs. 8.8 ± 3.0 min, $p = 0.007$, respectively). When statistically controlling for VO_2 max levels, significant differences in submaximal endurance between the groups persisted (vegans: 11.7 ± 4.3 vs. omnivores: 9.3 ± 4.3 min; $p = 0.049$). It should be noted that age was not significantly correlated with VO_2 max, submaximal endurance and the muscle strength indices. In addition, when statistically controlling for age, significant differences between vegans and omnivores for VO_2 max levels and submaximal endurance persisted.

Table 3 shows the dietary profile of the participants. We found that carbohydrate, dietary fiber, vitamin C, iron, and magnesium intake were significantly higher in vegans compared with omnivores. We also noted that protein, leucine, alanine, fat percentage, saturated fat, vitamin D, vitamin B_{12}, and vitamin D intake were significantly lower in the vegan group compared with the omnivore group. Both groups were similar for total energy intake, fat and sodium.

Table 1 Body composition characteristics of the participants.

Variables	Vegans ($n = 28$)	Omnivores ($n = 28$)	p value
Age (years)	27.1 ± 3.7	24.2 ± 4.1	0.009
Height (m)	1.66 ± 0.5	1.64 ± 0.6	0.2
Total body weight (kg)	59.9 ± 5.8	60.4 ± 6.7	0.8
Body mass index (kg/m^2)	21.7 ± 2.1	22.3 ± 1.8	0.3
Total body fat (%)	26.9 ± 6.9	28.0 ± 6.9	0.6
Total lean body mass (kg)	41.8 ± 3.5	41.5 ± 4.3	0.8

Values are mean ± SD.

Discussion

The purpose of the present study was to compare differences in endurance and muscle strength between vegans and omnivores. The main finding of our study shows that a vegan diet does not appear to be detrimental to endurance and muscle strength in young physically active women. In fact, we even observed significantly higher levels of VO_2 max in the vegan group compared with omnivores. Our results are similar with the findings of the study of Lynch et al. [10] who also reported greater VO_2 max levels, albeit, in a young group of mixed vegetarian women. However, two other studies observed no differences in VO_2 max levels between vegetarians and omnivores [8, 9]. In addition, we are the first study, to our knowledge, to show that a vegan diet may be associated with a better submaximal endurance performance, which is independent of VO_2 max levels. One potential mechanism that could explain the greater level of endurance performance in vegans may be a higher amount of carbohydrate intake. Evidence has suggested that greater carbohydrate intake may be associated with a better endurance performance [17] and this could be due to higher muscle glycogen storage [18]. It should be noted that, in the present study, carbohydrate intake was significantly higher in vegans compared with omnivores, which is in line with previous research showing that vegetarians/vegans consume higher amounts of carbohydrate [9–11]. Other potential mechanisms that may explain the better endurance performance in vegans could be due to favorable oxidative stress and inflammation profiles [19].

Furthermore, no significant differences were noted for upper (chest press) and lower (leg press) body muscle strength between groups, which is in line with a previous study who also showed no differences in peak torque using leg extensions [10]. Finally, no differences in body mass index and body composition were observed between both groups in the present study. Similar results were shown in the study of Nebl et al. [11] in vegans, however, the study

Table 2 Exercise performance characteristics of the participants.

Variables	Vegans ($n = 28$)	Omnivores ($n = 28$)	p value
Physical activity (min/week)	196.3 ± 41.4	196.8 ± 34.4	0.9
Estimated VO_2 max (ml/kg/min)	44.5 ± 5.2	41.6 ± 4.6	0.03
Submaximal endurance (min)	12.2 ± 5.7	8.8 ± 3.0	0.007
Muscle strength indices			
Leg press (kg/kg LBM)	2.4 ± 0.4	2.5 ± 0.5	0.5
Chest press (kg/kg LBM)	1.3 ± 0.2	1.4 ± 0.3	0.06

Values are mean ± SD; LBM: lean body mass.

Table 3 Dietary profile of the participants.

Variables	Vegans ($n = 28$)	Omnivores ($n = 28$)	p value
Total energy intake (kJ)	8691 ± 2694	7973 ± 2764	0.3
Carbohydrate (g)	303.4 ± 90.5	225.4 ± 123.2	0.009
Carbohydrate (% energy)	58.8 ± 6.5	45.6 ± 12.0	<0.001
Dietary fiber (g)	41.2 ± 15.5	21.8 ± 8.3	<0.001
Protein (g)	66.2 ± 19.2	86.4 ± 26.5	0.002
Protein (g/kg body weight)	1.11 ± 0.32	1.45 ± 0.49	0.004
Leucine (g)	2.5 ± 1.32	4.8 ± 2.0	<0.001
Alanine (g)	1.6 ± 0.8	3.1 ± 1.4	<0.001
Protein (% energy)	13.1 ± 2.8	19.2 ± 5.9	<0.001
Fat (g)	71.1 ± 32.6	75.0 ± 24.7	0.6
Fat (% energy)	30.3 ± 7.0	36.1 ± 8.7	0.009
Saturated fat (g)	13.1 ± 7.6	22.8 ± 8.0	<0.001
Saturated fat (% energy)	5.5 ± 2.0	11.1 ± 3.5	<0.001
Vitamin B_{12} (mcg)	1.24 ± 1.8	3.7 ± 2.2	<0.001
Vitamin C (mg)	182.9 ± 96.8	121.7 ± 71.0	0.009
Vitamin D (IU)	69.1 ± 113.2	122.3 ± 69.2	0.04
Iron (mg)	21.4 ± 10.1	13.4 ± 4.8	<0.001
Magnesium (mg)	424.7 ± 163.1	293.1 ± 116.7	0.001
Sodium (mg)	3592.2 ± 4797.8	2577.9 ± 1301.4	0.3

Values are mean ± SD.

of Hanne et al. [8] reported higher percent body fat in vegetarian women and the study of Lynch et al. [10] found that vegetarian women had significantly lower lean body mass. Therefore, further research may be needed to untangle the discrepancies in the findings of body composition between vegetarians/vegans and omnivores.

Indeed, our results may be useful for clinical and practical purposes. It is important to educate healthcare professionals such as nutritionists and kinesiologists regarding the role of a vegan diet on exercise performance. That is, healthcare professionals should not discourage a vegan diet and may even want to consider it as an option during the implementation of an exercise training program. Indeed, it should be noted that our study was only composed of young healthy lean physically active women. Therefore, our findings are limited to this population. Another limitation was that aerobic physical activity was measured using a single question. Nonetheless, these findings should be considered preliminary, but they may stimulate interest for additional research on the impact of a vegan diet on exercise performance in different populations.

In conclusion, the results of the present study indicate that a vegan diet does not seem to be detrimental to endurance and muscle strength in healthy young lean physically active women. This suggests that following a vegan diet for long term (≥2 years) may be adequately supportive to maintain muscle strength and could even be more effective for endurance performance as shown by a better submaximal endurance performance compared with omnivores. Accordingly, these findings contradict the popular belief of the general population.

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Author contributions ADK and GHB designed the research; MALD and MG conducted the research; MALD, MG, and GHB analyzed the data; GHB and ADK wrote the first draft of the paper; GHB, ADK, MG, and MALD contributed to the writing of the paper; ADK had primary responsibility for the design, writing, and final content. All authors read and approved the final paper.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Orlich MJ, Singh PN, Sabate J, Jaceldo-Siegl K, Fan J, Knutsen S, et al. Vegetarian dietary patterns and mortality in Adventist Health Study 2. JAMA Intern Med. 2013;173:1230–8.
2. Kim H, Caulfield LE, Garcia-Larsen V, Steffen LM, Coresh J, Rebholz CM. Plant-based diets are associated with a lower risk of incident cardiovascular disease, cardiovascular disease mortality, and all-cause mortality in a general population of middle-aged adults. J Am Heart Assoc. 2019;8:e012865.
3. Qian F, Liu G, Hu FB, Bhupathiraju SN, Sun Q. Association between plant-based dietary patterns and risk of type 2 diabetes: a systematic review and meta-analysis. JAMA Intern Med. 2019;179:1335–44.
4. Pimentel D, Pimentel M. Sustainability of meat-based and plant-based diets and the environment. Am J Clin Nutr. 2003;78:660S–3S.
5. Masset G, Vieux F, Verger EO, Soler LG, Touazi D, Darmon N. Reducing energy intake and energy density for a sustainable diet: a study based on self-selected diets in French adults. Am J Clin Nutr. 2014;99:1460–9.
6. Fields H, Ruddy B, Wallace MR, Shah A, Millstine D, Marks L. How to monitor and advise vegans to ensure adequate nutrient intake. J Am Osteopath Assoc. 2016;116:96–9.
7. Solis MY, Artioli GG, Otaduy MCG, Leite CDC, Arruda W, Veiga RR, et al. Effect of age, diet, and tissue type on PCr response to creatine supplementation. J Appl Physiol. 1985;2017:407–14.
8. Hanne N, Dlin R, Rotstein A. Physical fitness, anthropometric and metabolic parameters in vegetarian athletes. J Sports Med Phys Fit. 1986;26:180–5.

9. Nieman DC, Sherman KM, Arabatzis K, Underwood BC, Barbosa JC, Johnson M, et al. Hematological, anthropometric, and metabolic comparisons between vegetarian and nonvegetarian elderly women. Int J Sports Med. 1989;10:243–51.
10. Lynch HM, Wharton CM, Johnston CS. Cardiorespiratory fitness and peak torque differences between vegetarian and omnivore endurance athletes: a cross-sectional study. Nutrients. 2016;8:E726.
11. Nebl J, Haufe S, Eigendorf J, Wasserfurth P, Tegtbur U, Hahn A. Exercise capacity of vegan, lacto-ovo-vegetarian and omnivorous recreational runners. J Int Soc Sports Nutr. 2019;16:23.
12. Janssen M, Busch C, Rodiger M, Hamm U. Motives of consumers following a vegan diet and their attitudes towards animal agriculture. Appetite. 2016;105:643–51.
13. Melina V, Craig W, Levin S. Position of the academy of nutrition and dietetics: vegetarian diets. J Acad Nutr Diet. 2016;116:1970–80.
14. Alles B, Baudry J, Mejean C, Touvier M, Peneau S, Hercberg S, et al. Comparison of sociodemographic and nutritional characteristics between self-reported vegetarians, vegans, and meat-eaters from the nutrinet-sante study. Nutrients. 2017;9:E1023.
15. Thompson PD, Arena R, Riebe D, Pescatello LS, American College of Sports Medicine ACSM's new preparticipation health screening recommendations from ACSM's guidelines for exercise testing and prescription, ninth edition. Curr Sports Med Rep. 2013;12:215–7.
16. Lounana J, Campion F, Noakes TD, Medelli J. Relationship between %HRmax, %HR reserve, %VO2max, and %VO2 reserve in elite cyclists. Med Sci Sports Exerc. 2007;39:350–7.
17. Jacobs KA, Sherman WM. The efficacy of carbohydrate supplementation and chronic high- carbohydrate diets for improving endurance performance. Int J Sport Nutr. 1999;9:92–115.
18. Hearris MA, Hammond KM, Fell JM, Morton JP. Regulation of muscle glycogen metabolism during exercise: implications for endurance performance and training adaptations. Nutrients. 2018;10:E298.
19. Barnard ND, Goldman DM, Loomis JF, Kahleova H, Levin SM, Neabore S, et al. Plant-based diets for cardiovascular safety and performance in endurance sports. Nutrients. 2019;11:E130.