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Are there differences between strength-trained women following plant-based versus omnivorous diets? A pilot study examining anaerobic fitness, strength, body composition, and physical activity

Thesis Manuscript

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Abstract

Plant-based diets (PBD), consisting of both vegan and vegetarian diets, are being adopted more prevalently each year. While the health benefits and safety of the diet has been sufficiently proven, possible influences of PBDs on fitness and energy expenditure are less known. This cross-sectional study assessed differences in strength trained females for anaerobic capacity, strength and power, body composition, and energy intake/expenditure. Anaerobic power was assessed using a Wingate test and strength was assessed using isokinetic dynamometry in 12 individuals following a PBD and 8 following an omnivore (OMNI) diet. Body composition was assessed using the BodPod, food logs were recorded using ASA-24 and ActiHeart monitors tracked physical activity and energy expenditure. It was hypothesized that PBDs would have no significant negative effects on measures of strength, anaerobic power, body composition, or energy expenditure. It was also hypothesized that PBDs would show differences in dietary intake, specifically higher carbohydrate and lower fat intake. There were no significant differences in body composition between dietary groups (body fat %: 25.5 ± 5.8 % and 20.3 ± 6.6 % for PBD and OMNI respectively, $p > 0.05$). While carbohydrate intake was higher for PBD (272 ± 58 g and 195 ± 59 g, $p < 0.05$), overall energy intake did not significantly differ (1977 ± 456 kcals and 1780 ± 496 kcals for PBD and OMNI respectively, $p > 0.05$). Although there was a trend for greater moderate physical activity in PBD, overall there were no differences in physical activity levels (1.97 ± 0.34 and 1.74 ± 0.12 for PBD and OMNI respectively, $p > 0.05$). Peak (93.2 ± 23.4 ft·lbs^{-2} and 92.9 ± 20.7 ft·lbs^{-2} for PBD and OMNI respectively, $p > 0.05$) and mean (79.2 ± 23.0 ft·lbs^{-2} and 82.6 ± 18 ft·lbs^{-2} for PBD and OMNI respectively, $p > 0.05$) leg extension torque were not different between dietary groups. No differences were detected for peak (750 ± 168 W and 723 ± 171 W for PBD and OMNI respectively, $p > 0.05$) and mean (433 ± 76 W and 472 ± 81 W for PBD and OMNI respectively, $p > 0.05$) anaerobic power. Results show that PBDs have no negative influence on measures of body composition, energy intake/expenditure, and most importantly strength and anaerobic performance in strength-trained females.

1. Introduction

Each year, individuals are adopting plant-based diets (PBDs) for a variety of reasons (Borrione et al. 2009, Clarys et al. 2014, Craig 2009, Hever 2016, Venderely et al. 2006). PBDs are defined as diets restricted from meat, fish and poultry, and can be more specifically labeled (Appleby et al. 2016, Clarys et al. 2013). The specifications of PBDs include: lacto-ovo-vegetarian which includes dairy and eggs, lacto-vegetarian which includes dairy, ovo-vegetarian which includes eggs, and vegan which excludes all forms of animal products, meat, fish, poultry, eggs, and dairy (American Dietetic Association 2003, Appleby et al. 2016, Venderley et al. 2006). In 2012, a combined prevalence of 3% for vegans and vegetarians was reported (Ruby 2012); more recently, it was reported in 2015 that 5% and 2% of Americans reported being vegetarian and vegan, respectively (Appleby et al. 2015). Reasons for following a vegetarian or vegan diet include: ecological purposes, ethical motivations, economic drives, and the speculated or proven health benefits (Borrione et al. 2009).

PBDs have shown significantly lower intakes of total fat, saturated and mono-unsaturated fat, dietary cholesterol, dietary proteins, and sodium, as well as significantly higher dietary polyunsaturated fatty acids, dietary fiber, dietary iron, magnesium, boron, folate, antioxidant vitamins C and E, carotenoids, and phytochemicals, when compared to their omnivore (OMNI) counterparts (American Dietetic Association 2003, Clarys 2014, Fontana et al. 2007). PBDs were also proven to adhere more than OMNI diets to the Healthy Eating Index (HEI), a hypothesis-oriented approach that coincides with standards reviewed in the United States Department of Agriculture Food Guide Pyramid (Clarys et al. 2013). Ultimately the Academy of Nutrition and Dietetics and Dieticians of Canada have released position statements throughout the years supporting the idea that PBDs can healthily sustain individuals and provide sufficient amounts of all the required nutrients for any population of people (American Dietetic Association 2003, American Dietetic Association 2016).

While PBDs have been proven nutritionally adequate, there are still concerns from researchers and the general population about the adequacy of these diets, especially for athletic populations. This is an important consideration, as more athletes are adopting PBDs in order to maintain adequate carbohydrate intake and a desired body weight (Nieman 2009). A number of highly competitive athletes have been very successful following a PBD, showing that it does not hinder performance when properly planned (Furhman et al. 2010). Additionally, it has been stated that those following PBDs can obtain their necessary intakes of macronutrients if managed properly (Barr et al. 2004, Borrione et al. 2009, Rogerson 2017). In athletes and non-athletes alike, PBDs provide anywhere from 51-62% of daily carbohydrate energy intake, while OMNI diets provide 44-50% (Clarys et al. 2014, Lynch et al. 2016, Nieman 2009). Thus, PBDs align well with the high carbohydrate requirements recommended for athletes of 45-65% of daily energy intake (American Dietetic Association 2009, Borrione et al. 2009, Venderely et al. 2006); proper fat intake can be achieved by eating oils, avocados, nuts, and seeds; and adequate protein intake, although the least available macronutrient available in a PBD, is still attainable by careful planning (Borrione et al. 2009, Rogerson 2017). Furthermore, average protein intake for both PB and OMNI populations is generally well over the recommended daily allowance of 0.8g/kg/day (Hever 2016). Thus, protein intake will typically be satisfactory, even for an athlete with increased energy expenditure, as the protein recommendations for endurance athletes is 1.0-1.6 g/kg/day and for strength athletes is 1.6-2.0 g/kg/day, as indicated by the International Society of Sports Nutrition and the American College of Sports Medicine (Academy of Nutrition and Dietetics Dietitians of Canada 2016, Barr et al. 2004, Fuhrman et al. 2010). In regard to micronutrient intake for athletes, it has been found that with monitoring and proper supplementation when needed, adequate levels of B12, iron, zinc, calcium, iodine, and vitamin D can be achieved (American Dietetic Association 2000, Borrione et al. 2009, Fuhrman et al. 2010, Rogerson 2017). Ultimately a well-planned diet and periodic monitoring can ensure proper nutrient intake in PBDs.

To date, there is very limited research taking into consideration athletes, athletic performance, and PBDs. Thus far, the research has shown limited differences in relation to athletic performance (Craddock et al. 2016, Nieman 1999). Many of these studies found no differences between strength and power between diet groups (Hanne et al. 1986, Raben et al. 1992, Campbell et al. 1999, Haub et al. 2005, Lynch et al. 2016). Furthermore, some studies report higher oxygen consumption in a PBD group sub-maximally (Hietvala et al. 2012) and maximally (Lynch et al. 2016), while others have shown no significant difference between diet groups in oxygen uptake (Hanne et al. 1986, Raben et al 1992). Some studies have demonstrated that PBD groups have, on average, lower BMIs (Campbell et al. 1999, Spencer et al. 2003, Lynch et al. 2016), but higher body fat percentages (Hanne et al. 1986, Campbell et al. 1999) and lower levels of lean body mass (Campbell et al. 1999, Lynch et al. 2016). These mixed results could, in part, be due to the range of populations tested, as some were young endurance athletes and others were older sedentary individuals. Additionally, few of these studies have had the PBD group implement the diet for longer than the duration of the study.

Of the research that has been done in relation to athletes and PBDs, the vast majority of these studies have only implemented a PBD in a group of participants for the duration of the study (i.e. not allowing time for physiological changes to occur internally) (Raben et al. 1992, Campbell et al. 1999, Haub et al. 2005, Baguet et al. 2011, Hietavala et al. 2012). However, Lynch et al. 2016 and Hanne et al. 1986, did use individuals already practicing a PBD. Additionally, a majority of these studies have not used individuals who are regularly active or on a regular exercise program. Rather they have often been unfit and older populations (Hanne et al. 1986, Campbell et al. 1999, Haub et al. 2005). A younger population who is fit and exercising regularly, as well as already implementing a PBD, may respond differently than the majority of previous populations tested. Most prior studies also examined endurance athletes who are PB, as opposed to strength- and power-trained athletes. Therefore, there is limited research on strength- and power-trained individuals who follow PBDs. However, each year there is a growing population of strength- and power-trained individuals who also adopt PBDs (Furhman et al. 2010), but little has been done in regard to research and what, if any, influences this is having on their training and performance.

The purpose of this research study was to examine differences between healthy and highly active females who strength train, and whom had habitually (> 1 year) been following an OMNI or PBD. The main aim of the study was to determine if the PBDs negatively impacted anaerobic performance. The secondary aim was to determine if there were differences between diet groups in muscular strength, body composition, dietary intake, and physical activity. It was hypothesized that a PBD would not negatively impact anaerobic performance or muscular strength and no differences in body composition or physical activity would be observed. Furthermore, it was expected that PBD groups would have differences in some macronutrients (higher carbohydrate and lower fat) and micronutrients when compared to the OMNI group;however total energy intake would not be significantly different.

2. Materials and Methods

Institutional Approval:

This study was approved by the CSU San Marcos Institutional Review Board (#1191634-2). All subjects were fully briefed on study procedures and completed informed consent documents before initiating the study.

Participants:

Individuals who were PB (vegans & vegetarians) or OMNI were included, if they had practiced their respective diet for at least one year as well as had completed strength training activities at least 3 times a week for at least one hour for one year or more. Strength training included resistance training, circuit training, and high-intensity functional training (i.e. bootcamp, CrossFit, etc.). Participants were included so long as they were individuals between 18-30 years old; did not smoke; did not have a history of any chronic cardiovascular or metabolic diseases as indicated by a health history questionnaire; did not have HIV/AIDS, hepatitis, or any other communicable diseases; and met the dietary and strength training criteria. Individuals were excluded from the study if they did not meet any of the previously listed criteria, took any medications that influenced metabolism or had any physical handicaps preventing them from completing vigorous exercise.

Pre-lab standardization:

Subjects arrived in a fasted state, having abstained from food and drink (except water) in the preceding 8 hours.

Design overview: This was an observational cross-sectional study. Subjects completed informed consent and health history questionnaires before reporting to the Human Performance Lab for testing. After the lab, food logs and free-living activity and energy expenditure were collected for at least 2 consecutive days.

Laboratory testing:

Once consent had been obtained and initial paperwork completed, participants attended the Human Performance Laboratory for one visit. Height was recorded using a wall-mounted stadiometer. Participants' body composition was taken using air displacement plethysmography (BOD POD, Life Measurement, Inc., Concord, CA, USA), which provided data on fat and fat-free mass. Prior data from our lab revealed standard errors of 1.28 % 1.3 kg, and 1.14 kg for percent body fat, fat-free mass, and fat mass in our lab (Schubert et al. 2018). They were then fitted with an activity monitor (ActiHeart, CamNTech Ltd., Cambridge, UK) worn on the chest and connected with a chest strap (Polar H7; Polar Electro, Lake Success, NY, USA). The activity monitor was then individually calibrated during a sub-maximal exercise test. This test was a computer-prompted step test on a 21.5 cm bench step at a cadence beginning with 15 steps/min and increasing to 33 steps/min (Brage et al. 2007). The ActiHeart is a valid tool for measuring laboratory and free-living activity and energy expenditure and has been validated against indirect calorimetry and doubly-labelled water (Brage et al. 2015; Chowdhury et al. 2017).

Participants then completed a standard warm-up on a cycle ergometer (Monark CE, 5 minutes at 50-100 watts) prior to strength and anaerobic performance testing. Peak torque during leg flexion and extension of the participant's dominant leg was obtained during 5 repetitions at 60 degrees$\cdot$sec^{-1} using an isokinetic dynamometer (Biodex System 4, Shirley, NY, USA). Prior research has reported a coefficient of variation for peak torque at this velocity to be 1% (Drouin et al. 2004). Finally, a Wingate test (Velotron Dynafit Pro, Racemate Inc., Seattle, WA) was performed to assess anaerobic capacity of the participants. This test is a 30-second "all out" bout against a resistance set as a percent of the participants' body weight (8.5% for women). Data collected included peak power, mean power, and fatigue index. Prior research has shown that peak and mean power data have good test-retest reliability (Astorino & Cottrell 2012).

Free-living assessment and analysis:

After leaving the lab, dietary data were collected electronically using the National Cancer Institute's Automated Self-Administered 24-hour dietary assessment tool (ASA-24). The ASA-24, version (2016), was developed by the National Cancer Institute, Bethesda, MD (https://epi.grants.cancer.gov/asa24). Participants were asked to complete an electronic, prompted 24-hour food recall via a secure website, after which the data was stored for later download and analysis. Participants were required to complete at least 2 recalls after their laboratory visit to be included in the final analysis (Median = 3, range 2-4). To allow for comparisons with PB endurance athletes, we exported the same variables previously reported by Lynch et al. (2016). The ASA-24 assessment method is used in a wide range of research, and while self-report is prone to underreporting, the online interface and integrated database significantly reduces participant and investigator burden. The diet logs 1) confirmed compliance to the dietary criteria and 2) permitted comparisons of nutrient intake between the dietary groups.

Total energy expenditure (TEE), physical activity energy expenditure (PAEE), and resting metabolic rate (RMR)were determined by combined heart-rate/accelerometry (ActiHeart, CamNTech Ltd., Cambridge, UK) for a minimum of 3 days (2 weekdays, 1 weekend day) after the laboratory visit. To be considered a full day, participants needed to have ≥ 80% of recorded data from each day (> 1152 minutes), and at least 3 days of data, to be considered "valid" for inclusion in analysis. Resting metabolic rate was calculated using the equations of Schofield (1985) by software (ActiHeart v. 4.0.129, CamNTech, Inc., Cambridge, UK). TEE was also calculated based on each individual heart rate-VO_2 relationship determined through the lab-based step test. Diet-induced thermogenesis (DIT) was calculated from diet logs assuming energy equivalents of 4, 7, 8.9, and 3.75 kcal/g for protein, alcohol, fat, and carbohydrate, respectively (Bender 2006). From there, DIT was calculated using a 21% thermic effect of protein, 15% for alcohol, 2% for fat, and 8% for carbohydrate as has been used previously (Walhin et al. 2013). DIT in the current study was equal to 8.34 ± 0.96 % of energy intake. Once DIT was calculated, RMR and DIT were subtracted from TEE to yield PAEE. ActiHearts also provided information on time spent in varying levels of physical activity throughout the day. This included time spent in sedentary (≤1.5 metabolic equivalents, METs), light (>1.5 > 3 METs), moderate (3-6 METs), and vigorous (> 6 METs) activity during the day.

Power Calculation and Statistical Analysis:

Sample size was estimated based on the prior work of Lynch et al., who reported that to observe a 10% difference in isokinetic strength at a power level of 80% and alpha level of 5%, 15 participants per group would be necessary. All data were analyzed in IBM SPSS statistics for Mac (version 24, IBM Corporation, Armonk, NY). Data were analyzed using independent *t*-tests. Data are reported as means ± standard deviations unless otherwise noted. For all variables, mean differences, 95% confidence intervals, and Cohen's d effect sizes are reported. Effect sizes are interpreted as trivial (<0.20), small (0.20–0.40), moderate (0.40–0.80), and large (>0.8), respectively. Statistical significance was accepted when $p < 0.05$.

3. Results

A total of 20 participants completed the study, 12 in the PB group and 8 in the OMNI group. In the PBD group, 10 of the women followed a vegan diet completely free of animal products, while two followed a vegetarian lifestyle. All had been following their diet for at least one year (average duration=5 years).

Age, height, weight, and body composition data were similar between groups (Table 1) ($p > 0.05$). Peak and mean leg extension torque were also not significantly different (Table 1) ($p > 0.05$). Peak and mean anaerobic power were similar between groups (Table 1) ($p > 0.05$), but fatigue index was lower in the OMNI diet group (Table 1) ($p < 0.05$), indicating a greater fatigue resistance.

There was a trend for women in the PBD group to have a higher calculated physical activity level (Table 2) ($p = 0.06$; $d = 0.92$). They also had ~2x greater moderate-intensity physical activity (Table 2) ($p = 0.02$; $d = 1.23$). Despite this, no significance differences in energy expenditure were detected between groups (Figure 1) ($p > 0.05$). Women following PBDs had a TDEE of 2831 ± 560 kcal/d compared to 2463 ± 268 kcal/d ($p > 0.05$; $d = 0.84$). This was largely mediated by a trend for higher physical activity thermogenesis (1226 ± 539 vs. 902 ± 170 kcal/d, $p = 0.07$; $d = 0.81$). Resting metabolic rate was not significant different (1440 ± 126 vs. 1411 ± 150 kcal/d, $p > 0.05$; $d = 0.21$). Finally, diet-induced thermogenesis was also not different (165 ± 54 vs. 150 ± 40 kcal/d, $p > 0.05$; $d = 0.32$).

Total energy intake was not significantly different between the groups (Table 3; Figure 1) ($p > 0.05$). Protein intake (total, % energy, or adjusted for bodyweight) was not significantly different between groups (Table 3) ($p > 0.05$); fat intake was also similar (Table 3) ($p > 0.05$). Cholesterol and saturated fat (% energy) were significantly lower in the PBD group (Table 3) ($p < 0.05$). Dietary carbohydrate intake (total and as % energy) were significantly higher in the PBD group (Table 3) ($p < 0.05$); fiber was also higher (Table 3; Figure 1) ($p < 0.05$). Most micronutrient data were not significantly different (Table 3) ($p > 0.05$). However, Vitamin D was significantly higher in the OMNI diet group (Table 3) ($p < 0.05$).

Variable	Plant-based diets (n = 12)	Omnivorous diets (n = 8)	P-value	Mean difference and 95% CI	Effect size (Cohen's d)
Age (yrs)	26 ± 6	26 ± 4	0.84	-0.5 (-5, 4)	-0.09
Height (m)	1.68 ± 0.07	1.64 ± 0.07	0.21	0.04 (-0.02, 0.1)	0.59
Weight (kg)	65.5 ± 9.3	62.7 ± 10.1	0.52	2.8 (-6.4, 12.1)	0.29
Body mass index ($kg \cdot m^{-2}$)	23.0 ± 2.4	23.0 ± 2.4	0.99	0.0 (-2.3, 2.3)	0.00
Percent body fat (%)	25.5 ± 5.8	20.3 ± 6.6	0.08	5.2 (-0.7, 11.1)	0.82
Fat Mass (kg)	16.7 ± 5.4	13.0 ± 6.0	0.14	3.7 (-1.5, 9.3)	0.69
Fat-free mass (kg)	48.6 ± 6.0	49.7 ± 6.8	0.71	-1.1 (-7.1, 5.0)	-0.17
Peak Extension Torque ($ft \cdot lbs^{-2}$)	93.2 ± 23.4	92.9 ± 20.7	0.98	0.3 (-21, 22)	0.01
Mean Extension Torque ($ft \cdot lbs^{-2}$)	79.2 ± 23.0	82.6 ± 18	0.73	-3.4 (-23.8, 16.9)	-0.16
Peak Power (W)	750 ± 168	723 ± 171	0.73	27 (-135, 189)	0.16
Mean Power (W)	433 ± 76	472 ± 81	0.29	-39 (-114, 36)	-0.49
Fatigue Index (%)	60 ± 8	52 ± 8	**0.03**	8 (1, 15)	1.04

Table 1: Differences in body composition and laboratory-based measures of strength and power
CI: confidence interval

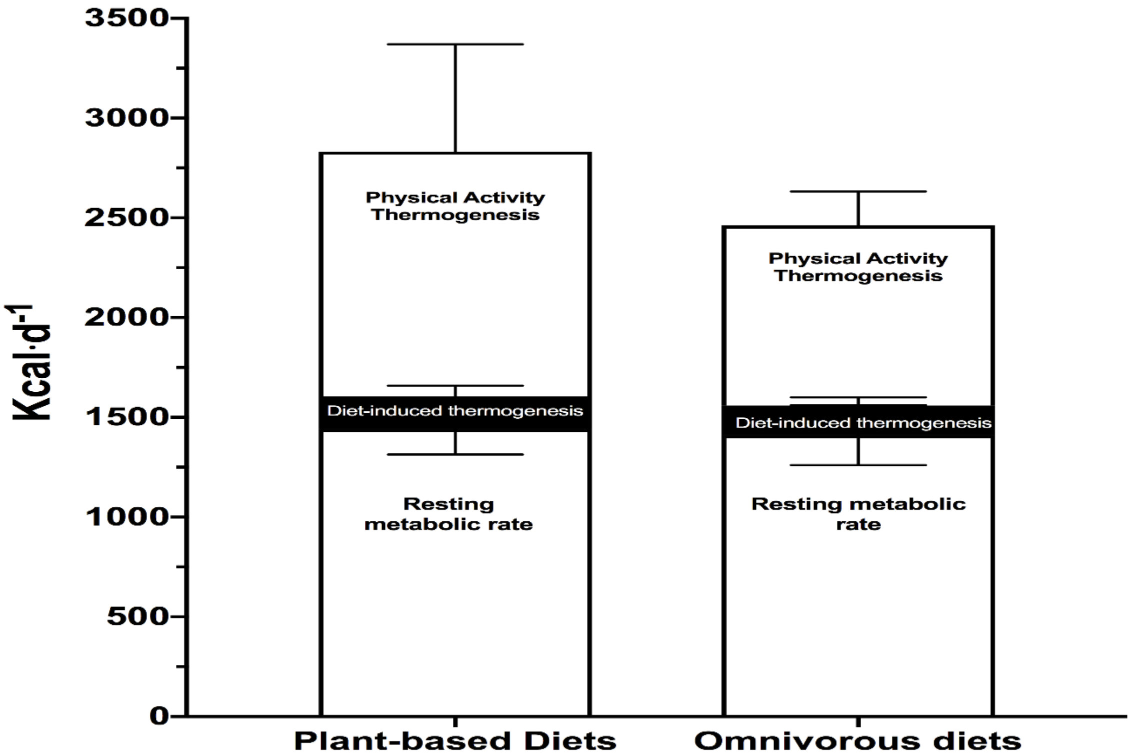
Variable	Plant-based diets (n = 12)	Omnivorous diets (n = 8)	P-value	Mean difference and 95% CI	Effect size (Cohen's d)
Physical activity level	1.97 ± 0.34	1.74 ± 0.12	0.06	0.23 (-0.01, 0.45)	0.92
Sedentary time (mins)	863 ± 170	960 ± 118	0.18	-97 (-242, 49)	-0.62
Light physical activity (mins)	404 ± 105	380 ± 118	0.64	24 (-82, 130)	0.22
Moderate physical activity (mins)	156 ± 86	81 ± 32	**0.02**	75 (17, 133)	1.23
Vigorous physical activity (mins)	17 ± 15	19 ± 13	0.76	-2 (-16, 12)	-0.14

Table 2: Differences in time spent in various levels of physical activity
CI: confidence interval

Variable	Plant-based diets	Omnivorous diets	P-value	Mean difference and 95% CI	Effect size (Cohen's d)	Dietary reference ranges
Energy intake (kcals)	1977 ± 456	1780 ± 496	0.37	197 (-256, 650)	0.41	--
Protein (g)	78 ± 53	90 ± 31	0.58	-12 (-56, 32)	-0.25	--
Protein (%)	15 ± 6	20 ± 6	0.07	-5 (-10.5, 0.4)	-0.87	10 – 35 %
Protein (g/kg BW)	1.2 ± 0.8	1.5 ± 0.5	0.47	-0.3 (-0.93, 0.44)	-0.33	0.8 g/kg
Fat (g)	68 ± 20	76 ± 35	0.55	-8 (-33, 18)	-0.28	--
Fat (%)	32 ± 7	37 ± 11	0.18	-5 (-16, 4)	-0.63	20 – 35 %
Carbohydrate (g)	272 ± 58	195 ± 59	**0.01**	77 (21, 133)	1.29	--
Carbohydrate (%)	56 ± 8	43 ± 10	**0.007**	13 (4, 21)	1.35	45 – 65 %
Alcohol (g)	5 ± 9	2 ± 4	0.31	3 (-4.2, 10.6)	0.41	--
Alcohol (%)	2 ± 3	1 ± 1	0.29	1 (-1.1, 3.5)	0.42	--
Fiber (g)	44 ± 21	17 ± 7	**0.002**	27 (11, 44)	1.60	25 g
Calcium (mg)	1214 ± 440	874 ± 416	0.10	340 (-73, 753)	0.77	1000 mg
Iron (mg)	19 ± 7	14 ± 7	0.12	5 (-1.5, 12)	0.74	18 mg
Phosphorus (mg)	1502 ± 700	1283 ± 385	0.43	219 (-354, 792)	0.36	700 mg
Sodium (mg)	2936 ± 1662	3537 ± 1005	0.37	-601 (-1984, 782)	-0.41	< 2300 mg
Zinc (mg)	12 ± 4	10 ± 3	0.36	2 (-2, 5.2)	0.42	8 mg
Selenium (mcg)	87 ± 69	120 ± 42	0.25	-33 (-91, 25)	-0.53	55 mcg
Vitamin C (mg)	228 ± 149	112 ± 80	0.06	116 (-6, 238)	0.90	75 mg
Vitamin B12 (mcg)	6 ± 6	5 ± 2	0.62	1 (-4, 6)	0.23	2.4 mcg
Vitamin D (IU)	91 ± 81	195 ± 135	**0.045**	-104 (-205, -2.06)	-0.96	600 IU
Cholesterol (mg)	66 ± 100	339 ± 171	**0.0001**	-273 (-400, -147)	-2.03	--
Saturated fat (g)	16 ± 10	26 ± 15	0.12	-10 (-21, 3)	-0.73	--
Saturated fat (%)	7.5 ± 4	12 ± 4	**0.034**	4.5 (-9, -0.4)	-1.02	< 10 %
Monounsaturated fatty acids (g)	27 ± 9	26 ± 12	0.89	1 (-9, 11)	0.06	

Variable	Plant-based diets	Omnivorous diets	P-value	Mean difference and 95% CI	Effect size (Cohen's d)	Dietary reference ranges
Polyunsaturated fatty acids (g)	19 ± 6	17 ± 6	0.56	2 (-4, 7)	0.27	
EPA (g)	0.001 ± 0.001	0.04 ± 0.05	0.10	-0.03 (-0.07, 0.008)	-0.85	
DHA (g)	0.01 ± 0.02	0.08 ± 0.09	0.053	-0.07 (-0.15, 0.001)	-1.21	

Table 3: Differences in dietary macro- and micronutrient data
CI: confidence interval



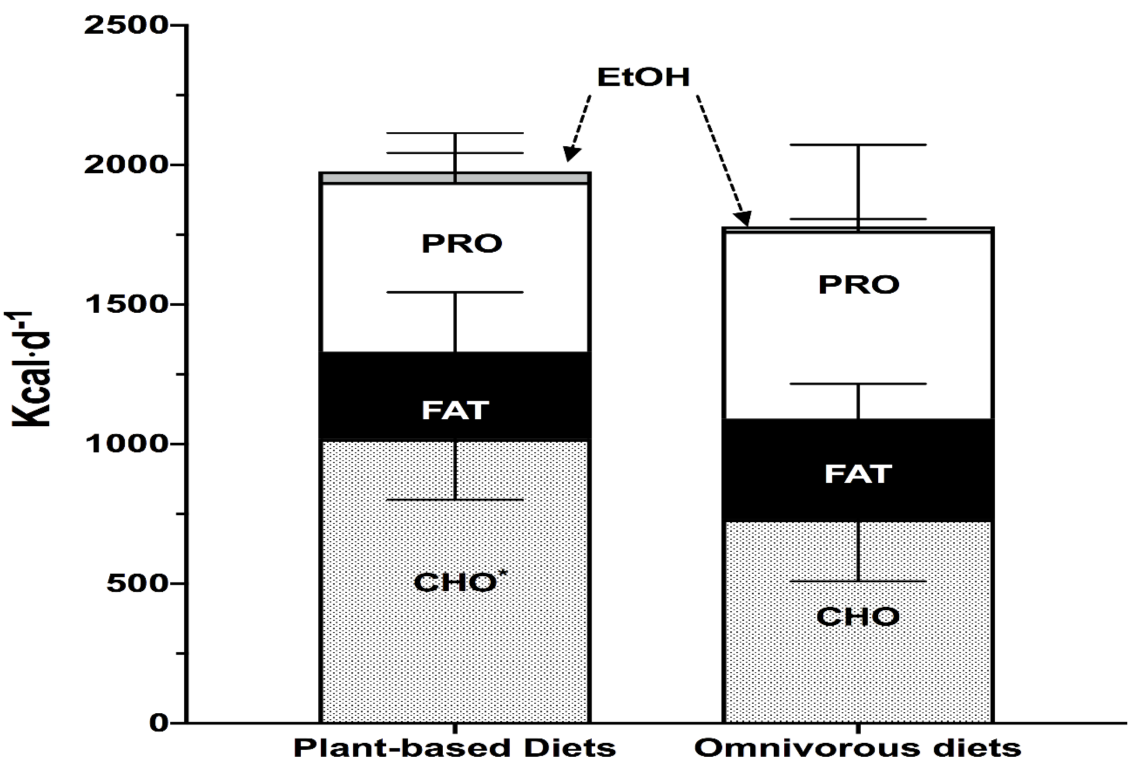


Figure 1: Differences in energy expenditure (top) and energy intake (bottom) between PB and OMNI diets. EtOH, alcohol. *significantly different from omnivores.

4. Discussion

The purpose of this study was to examine differences between PB and OMNI populations in terms of body composition, anaerobic performance, physical activity, and nutrient intake. It was hypothesized that having a PBD would not negatively impact body composition or anaerobic performance when compared to OMNIs, and there would also be no differences in physical activity. Finally, it was hypothesized that PBDs would show differing macronutrient and micronutrient intakes compared to their OMNI counterparts. Our findings partially support our hypotheses. Results show that females who practice PBDs do not have compromised strength and anaerobic exercise performance, compared to their OMNI counterparts. Furthermore, body composition between diet groups proved to be similar. There were differences between groups relating to some aspects of physical activity and dietary intake. Results from this study are important as they highlight similarities in strength-trained women, but also reveal how these diets influence different aspects of health and athletic performance.

Total energy intake did not differ significantly between dietary groups. Other studies in both endurance athletes (Lynch et al. 2016) and the general population (Schupbach et al. 2017) also showed similar total energy intake between diet groups. Additionally, although there was no difference found in protein or fat intake, there was an inclination for lower protein and fat intake in the PBD group, as has been found previously (Campbell et al. 1999, Lynch et al. 2016). Interestingly, both groups had protein intake above the RDA, although below recommendations for individuals undergoing strength training (1.6-2.0 g/kg BW) (ACSM position stand). The PBD group also had significantly higher intakes of carbohydrates, which aligns with previous research (Clarys et al. 2013, Lynch et al. 2016, Schupbach et al. 2017). Higher intakes of fiber, and lower intakes of saturated fats and cholesterol were also found among the PBDs. Previous studies agree with PB groups having higher intakes of fiber (Lynch et al. 2016, Schupbach et al. 2017) and lower fat (Raben et al. 1992) and cholesterol (Raben et al. 1992, Lynch et al. 2016) intakes. Prior research examined dietary differences in a range of populations from endurance athletes (Raben et al. 1992, Lynch et al. 2016) to the general population (Schupbach et al. 2017), and even sedentary individuals (Campbell et al. 1999). The present study finds similar dietary differences and adds to this knowledge with the addition of a new population of young healthy females who are primarily trained in strength-based exercise. Therefore, we would not expect a negative impact on athletic performance based off of the results found in the dietary components of a PBD.

In addition to there not being any differences in total energy intake, total energy expenditure was not significantly different between dietary groups. Previous research is very limited regarding energy expenditure and different diets. However, studies done in the general population (Schupbach et al. 2017) and endurance athletes (Raben et al. 1992) have shown no differences in daily energy expenditure. Although, in the present study, there was a trend that the PBD group averaged about 400 more kcals a day. While overall the PBD group did not have a significantly higher total energy expenditure, the nearly 400 kcal difference between groups is enough to be considered clinically significant. For example, in metabolic ward studies with tight control over energy balance, 100-150 kcal/d is considered to be the smallest clinically important difference for daily energy expenditure (Hall et al. 2015). Furthermore, nearly all of the difference in energy expenditure between groups was in physical activity as opposed to resting metabolic rate or diet-induced thermogenesis. To date, there is very limited research regarding energy expenditure differences between dietary groups. Interestingly, Lynch previously reported that weekly physical activity was ~20% higher in PB endurance athletes compared to OMNI endurance athletes when assessed via self-report (Lynch et al .2016). Therefore, this study provides objective evidence using validated measures to suggest that individuals following a PBD may be more active than their OMNI counterparts. These higher rates of moderate-intensity physical activity could be attributed to higher inclinations of a healthy lifestyle, such as walking or biking instead of driving, more active jobs/careers, and so forth (Beezhold et al. 2015).

Given the lack of significant differences in energy intake and energy expenditure, it would be expected that there were no significant differences in body composition. Specifically, we observed no differences in regard to body fat percentage, fat mass, and fat free mass. In previous research, there have been mixed results where some studies have found higher body fat percentages (Hanne et al. 1986, Campbell et al. 1999) and lower absolute levels of lean body mass (Campbell et al. 1999, Lynch et al. 2016) in PBD groups, while others reported lower body fat percentages and higher lean body mass (Veleba et al. 2016). Additionally, there are some studies that showed no differences between diet groups in body fat percentage (Lynch et al. 2016) or BMIs (Raben et al. 1992, Lynch et al. 2016), as did this study. However, unlike in Lynch et al. 2016, there were no differences found in fat mass or lean body mass between groups in the present study. The percent body fat levels in the current study were similar to those reported for PBD endurance athletes by Lynch (Lynch et al. 2016), but those authors reported lower levels of body weight and lean mass in their population. Given that a lower bodyweight is not as important to strength and power performance as it is for endurance performance, our results indicate that a PBD would not negatively impact a strength and power athlete's performance as long as the diet is adequate in energy and nutrients.

As it has been speculated that PBDs may not provide sufficient protein to support lean mass development, this could impair strength and power gains with training. However, our measures of strength and power performance, such as peak and mean leg extension torque, and peak and mean power from a Wingate test refute this. However, fatigue index was lower in the OMNI diet group, indicating their ability to possibly maintain power output and resist fatigue more efficiently than the PBD group. Previous studies that measured peak and mean torque also found no differences between groups (Campbell et al. 1999, Haub et al. 2005, Lynch et al. 2016). Examining prior literature, Lynch et al. 2016, is the only one of these studies to use individuals who had already adopted a PBD prior to their studies. Our study confirms that our participants were strength trained, as their peak torque values were ~30% higher in the PBD group in the present study and 21% higher in the OMNI group compared to the female endurance athletes in their respective dietary groups in Lynch's study (Lynch et al. 2016). Looking at the Wingate data reported by Hanne et al. (1986), our PBD individuals achieved 33% higher peak power output values while the OMNI diet group had peak power outputs 32% higher than their respective comparison groups in that study. However, participants in the current study were likely more fit and strength/power trained. Examining norms for Wingate testing from collegiate athletes (n = 107 females, age 18-30, from tennis, softball, soccer, and volleyball teams), women in the PBDs had mean peak power values that would place them in the 75th-80th percentile (748-766 W; current study peak = 750 W) while the women on the OMNI diet would be in the 65th-70th percentile (707-724 W; current study peak = 723 W) (Baker et al. 2011). Our data confirm that there are no negative impacts of following a PBD on strength and anaerobic performance.

Limitations

There are some limitations to consider when interpreting this study and considering future research. Primarily, the sample size was small, and we did not achieve our a priori sample size to achieve the desired power to detect differences in isokinetic peak torque. Future research should push to acquire larger sample sizes. Furthermore, there was no strict regulation of the diets, aside from ensuring the participants were included and analyzed in their appropriate group, and dietary intake was obtained via self-report. Additionally, while all participants fell under the required training requirements to participate in this study, there was still a varying degree of training status and physical activity level that could be more tightly controlled for in future studies.

Conclusions

This cross-sectional study set out to determine differences in anaerobic performance, body composition, energy expenditure, and dietary intakes between PB and traditional (OMNI) diets, in young and healthy females who were primarily strength-trained. Results indicate despite some differences in macro- and micronutrients, total energy intake was similar and appeared adequate to support strength training without compromising strength, anaerobic performance, or body composition. Interestingly, individuals on PBDs also appeared to have a more active lifestyle. Results from this study, along with previous research, indicate that a PBD can be safely and effectively implemented without any negative effects in strength-trained young women.

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