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# Vegetarian and Omnivorous Nutrition—Comparing Physical Performance

**Joel C. Craddock, Yasmine C. Probst, and Gregory E. Peoples**

Humans consuming vegetarian-based diets are observed to have reduced relative risk for many chronic diseases. Similarly, regular physical activity has also been shown to assist in preventing, and reducing the severity of these conditions. Many people, including athletes, acknowledge these findings and are adopting a vegetarian-based diet to improve their health status. Furthermore, athletes are incorporating this approach with the specific aim of optimizing physical performance. To examine the evidence for the relationship between consuming a predominately vegetarian-based diet and improved physical performance, a systematic literature review was performed using the SCOPUS database. No date parameters were set. The keywords *vegetarian* OR *vegan* AND *sport* OR *athlete* OR *training* OR *performance* OR *endurance* were used to identify relevant literature. Included studies (i) directly compared a vegetarian-based diet to an omnivorous/mixed diet, (ii) directly assessed physical performance, not biomarkers of physical performance, and (iii) did not use supplementation emulating a vegetarian diet. Reference lists were hand searched for additional studies. Seven randomized controlled trials and one cross-sectional study met the inclusion criteria. No distinguished differences between vegetarian-based diets and omnivorous mixed diets were identified when physical performance was compared. Consuming a predominately vegetarian-based diet did not improve nor hinder performance in athletes. However, with only 8 studies identified, with substantial variability among the studies' experimental designs, aims and outcomes, further research is warranted.

***Keywords:*** vegan, veganism, vegetarianism

A range of vegetarian diets exist, all of which are typically plant-based and are often classified on the exclusion or inclusion of animal, or animal derived products. Vegan, pesco-vegetarian, ovo-vegetarian, lacto-vegetarian, and lacto-ovo-vegetarian (LOV) diets are examples of vegetarian-based diets in which fruits, vegetables, grains, nuts, seeds and legumes represent a high proportion of dietary intake compared with meat and dairy products (Venderley & Campbell, 2006). Table 1 provides an overview of common vegetarian diets. Reductions in coronary heart disease, hypertension, diabetes mellitus, obesity and even some cancers have been observed in participants following vegetarian-based diets (Barnard et al., 2015; Olrich & Fraser., 2014; Ornish et al.,1998; Schmidt et al.,1997). Diets of this nature are typically higher in oligo and polysaccharides, fiber, fruits, vegetables, antioxidants and phytochemicals while lower in saturated fat and cholesterol compared with omnivorous diets (Venderley & Campbell, 2006). Some athletes have adopted a vegetarian diet to acquire the health benefits associated, but also believe the diet may assist in achieving appropriate carbohydrate intake, weight management and other performance enhancing advantages (Fuhrman & Ferreri, 2010). Physical performance is a broad term, however, in the context of this review will include; strength, speed, endurance and power, while excluding other traditional components such as balance and flexibility.

Although mechanisms linking a diet high in plant-based foods to improved physical performance are limited, there are three plausible theories described in the literature. Firstly, it has been hypothesized that a vegetarian diet may enhance an athlete's performance due to the high carbohydrate intake leading to improved glycogen stores in the body (Barr & Rideout 2004; Ferreira et al., 2006). Secondly, the increased phytochemicals and antioxidants consumed in vegetarian-based diets may also help reduce oxidative stress associated with prolonged exercise and improve general immunity (Trapp et al., 2010). Thirdly, it is widely accepted that intramuscular acidity can limit high-intensity exercise (Carr et al., 2011). A relationship has been established linking oral supplements, namely sodium bicarbonate and sodium citrate, to altered blood alkalosis levels. When ingested these buffers have been shown to have an ergogenic effect on high-intensity acute exercise (Carr et al., 2011). Conversely, ingested acidic supplements can be ergolytic. Evidence suggests consuming a vegetarian diet may have an alkaline effect on acid-base levels compared with nonvegetarians due to the high

The authors are with the School of Medicine, University of Wollongong, Wollongong, Australia. Address author correspondence to Joel Craddock at jcc256@uowmail.edu.au.

**Table 1 Classification of Dietary Patterns**

| Type of diet | Definition | Red meat | Poultry | Fish | Dairy | Eggs |
|---|---|---|---|---|---|---|
| Non-Vegetarian | | | | | | |
| Omnivorous/Mixed | Eats red meat, poultry, fish, dairy and eggs. | ✓ | ✓ | ✓ | ✓ | ✓ |
| Vegetarian-Based | | | | | | |
| Pesco-lacto-ovo vegetarian | Eats fish, dairy and eggs, but not red meat or poultry. | ✗ | ✗ | ✓ | ✓ | ✓ |
| Lacto-ovo vegetarian | Eats dairy and eggs but not red meat, poultry or fish. | ✗ | ✗ | ✗ | ✓ | ✓ |
| Lacto-vegetarian | Eats dairy not red meat, poultry, fish, dairy or eggs. | ✗ | ✗ | ✗ | ✓ | ✗ |
| Ovo-vegetarian | Eats eggs but not read meat, poultry, fish, dairy or eggs. | ✗ | ✗ | ✗ | ✗ | ✓ |
| Pesco-Vegetarian | Eats fish but not red meat, poultry eggs or dairy. | ✗ | ✗ | ✓ | ✗ | ✗ |
| Vegan | Eats no red meat, poultry, fish, dairy or eggs. | ✗ | ✗ | ✗ | ✗ | ✗ |

*Note*. Adapted from "Beyond Meatless, the Health Effects of Vegan Diets: Findings from the Adventist Cohorts," by Lee & Sabate, 2014, *Nutrients,* 6, p. 2133. Copyright 2014 by the authors; licensee MDPI, Basel, Switzerland. Adapted with permission.



fruit and vegetable intake, while being lower in animal based proteins (Hietavala et al., 2015; Deriemaeker et al., 2010). Although a long-term vegetarian-based diet may not have the same effect as an acute sodium bicarbonate supplement, it is plausible, that a small 'resetting' change in the homeostatic baseline may be approached when a sustained vegetarian-based diet is followed, leading to a potential increase in physical performance. Despite these promising notions, there remains concern that a suboptimal vegetarian diet may increase risk for micronutrient deficiencies and reduce muscle creatine concentrations leading to submaximal performance (Barr & Rideout, 2004). Studies connecting vegetarian diets to improved health are well-established (Barnard et al., 2015; Olrich & Fraser, 2014; Ornish et al.,1998; Schmidt et al.,1997); however, the evidence for this phenomenon to be transferred to improved physical performance in athletes is less clear. The aim of this study was to examine the evidence for the relationship between consumption of a vegetarian-based diet and improved physical performance by conducting a systematic literature review. Due to a vegetarian-based diet theoretically increasing muscle glycogen, cell alkalinity, and immunity while reducing oxidative stress, it was hypothesized that this diet may improve physical performance in athletes.

# Methods

## Study Protocol

A systematic literature review (NHMRC, 2000) was conducted in January 2015 using the SCOPUS database with no date exclusions. The search used the following keywords; *vegetarian* OR *vegan* AND *sport* OR *athlete* OR *training* OR *performance* OR *endurance* in article, keywords or abstract. A search for unpublished literature was not performed though reference lists of the included publications were examined for additional relevant studies. National Health Medical Research Council's levels of evidence were applied to the included studies.

## Study Selection

Inclusion of studies met the following requirements. The studies (i) directly compared a plant-based diet (e.g., ovo-vegetarian, LOV or vegan) to a typical omnivorous/mixed diet, (ii) directly assessed physical performance, not solely biomarkers of physical performance (immune biomarkers were exempt from this inclusion criterion as physical detection of immunity is difficult to measure). The inclusion criterion was created to assess diet and its effect on performance rather than other external factors such as supplementation and lifestyle factors. It was important for physical performance to be measured, as biomarkers alone may not translate into effects on physical performance. Studies that met the following exclusion criteria were omitted: (i) studies with key words *pregnancy*, *nonhuman*, *high performance liquid chromatography* (excluded within database search limits); (ii) journal articles not published in English; (iii) studies examining the relationship between diet and lifestyle factors on physical performance; (iv) published conference papers, short surveys, letters, notes, editorials, articles in press, book series, erratum and conference proceedings; and (v) participants taking supplementation to emulate a vegetarian diet.

Data extraction included information on the publication year, study design/quality, number of participants, total sample size, population type, dropouts, intervention, diet, study results/conclusions (Table 2). Study quality

**Table 2 Body of Evidence—Summary Table of Included Journal Articles with American Diabetes Association Quality Rating Template Results Included**

| Study | Study Design (Level of Evidence) | Population | Intervention | Dietary Group | Study Results/Conclusion |
|---|---|---|---|---|---|
| **Anaerobic and Aerobic Performance** | | | | | |
| Baguet et al. (2011) | Pseudo RCT (Level III-1*) | *n* = 20<br>Healthy, nonvegetarian participants.<br>11 males, 9 females. | 5 weeks, sprint training program<br>-Mixed diet<br>-Vegetarian Diet (*Both groups supplemented with creatine). | LOV<br>Energy 9321kJ (P= 13.13%, CHO = 55.08%, F = 28.00%, EtOH = 3.79%)<br>Mixed<br>Energy 9693kJ (P = 15.78%, CHO = 54.55%, F = 26.02%, EtOH = 3.67%) | No performance difference in repeated sprint ability test between LOV diet and mixed diet. |
| Hietavala et al. (2012) | RCT (Level II**) | *n* = 9<br>Healthy, recreationally active men.<br>No mention of prior eating habits. | Crossover design w/ 16-day washout period<br>4-day vegetarian diet<br>4-day normal diet. | Low protein vegetarian diet<br>Energy 1046 kJ, (P = 10.1%, CHO = 58.7%, Fat = 24.7%<br>(Limited grain and dairy)<br>Normal Diet<br>Energy 11687 kJ (P = 17.6%, CHO = 49.8%, Fat = 28.1%) | Oxygen consumption was significantly higher at 40, 60 and 80% of maximum oxygen capacity (cycle ergometer). Suggestive of poorer exercise economy in vegetarian diet. No further effect on maximal aerobic performance. |
| Raben et al. (1992)^^ | RCT (Level II**) | *n* = 8<br>Endurance trained male athletes. Nonvegetarians before study. | Crossover design with 4-week washout period, 6-week LOV diet<br>6-week nonvegetarian diet. | Both diets included:<br>57% E Carbohydrate, 14% E Protein, 29% E Lipids<br>LOV<br>Protein composition (16% animal derived protein, 84% vegetable protein)<br>Mixed Western<br>Protein composition (67% animal protein, 33% vegetable protein) | No difference in maximal oxygen uptake (graded ergometer cycle or treadmill test) or maximal voluntary contraction (measured with strain gauge) between groups. |
| Hanne et al. (1986) | Cross-sectional cohort (Level III-2***) | *n* = 98<br>49 vegan, lacto vegetarian or LOV<br>49 nonvegetarians. | NA | Vegetarian-based<br>> 2 years<br>(vegan, lacto vegetarian or LOV)<br>Mixed—Nonvegetarian-based diet | No difference in anaerobic (Wingate anaerobic test) or maximal oxygen uptake (cycle stress test) performance. |

*(continued)*

**Table 2 *(continued)***

| | | | | | |
|---|---|---|---|---|---|
| **Strength and Power** | | | | | |
| Haub et al. (2005)^ | RCT (Level II**) | $n$ = 21<br>Healthy men aged 59–78<br>BMI 24–33 kg/m$^2$. | 12-week RT program 3 days/week | LOV<br>0.6 g/protein/kg/day from TVP Energy 9.37MJ (P= 1.17 g/kg/day, CHO = 274 g/day, F = 85g/day)<br>LOV + Beef<br>0.6 g/protein/kg/day from beef Energy 9.09MJ (P= 1.10 g/kg/day, CHO = 282 g/day, F = 73g/day) | No difference in strength (repetitions until fatigue) or power gains (1 rep max) between a LOV diet + soy or LOV diet +Beef. No difference between groups for upper body or lower body power output. |
| Campbell et al. (1999) | Pseudo RCT (Level III-1*) | $n$ = 19<br>Sedentary men (51–69 years) overweight to moderately obese aged | 12-week resistance training program Group 1 (Mixed Diet) Group 2 (LOV) | LOV (self-selected)<br>Energy ~10.3 MJ (52% E Carbohydrate, 13% E Protein, 34% E Lipid<br>Mixed—(habitual unrestricted) (provided 50% of total dietary protein from meat)<br>Energy ~8.6 MJ (50% E Carbohydrate, 16% E Protein, 32% E Lipid | No difference in strength (1 Rep Max) with RT between groups for any of the exercises performed. |
| Wells et al. (2003)^ | RCT (Level II**) | $n$ = 21<br>Healthy men aged 59–78<br>BMI 24–33 kg/m$^2$ | 12-week RT program 3 days/week | LOV<br>0.6 g/protein/kg/day from TVP Energy 9.37MJ (P= 1.17 g/kg/day, CHO = 274 g/day, F = 85 g/day)<br>LOV + Beef<br>0.6 g/protein/kg/day from beef Energy 9.09MJ (P= 1.10 g/kg/day, CHO = 282 g/day, F = 73 g/day) | No differences in strength (1 rep max) between groups in all but one exercise. Vegetarian group had a larger increase in strength for knee extensions ($p < .01$). |
| **Immune Parameters** | | | | | |
| Richter et al. (1991) ^^ | RCT (Level II**) | 8 endurance-trained male athletes (4 cyclists, 1 runner, 1 rower, 2 mixed) Nonvegetarians before the study. | Crossover design with 4-week washout period, 6-week LOV diet<br>6-week nonvegetarian diet | Both Diets Included:<br>57% E Carbohydrate, 14% E Protein, 29% E Lipids<br>LOV<br>Protein composition (16% animal derived protein, 84% vegetable protein)<br>Mixed western<br>Protein composition (67% animal protein, 33% vegetable protein) | No difference in composition or concentration in in-vivo function of human blood mononuclear cells between a meat rich mixed diet, or a LOV diet. |

*Note.* CHO = carbohydrate, F = fat, P = protein, EtOH = alcohol, E = energy, LOV = lacto-ovo vegetarian, RCT = randomized controlled trial, RT = resistance training, TVP = textured vegetable protein.

*Pseudo RCT, Level III-I—A study of test accuracy with: an independent, blinded comparison with a valid reference standard, among nonconsecutive patients with a defined clinical presentation.

**RCT Level II—A study of test accuracy with: an independent, blinded comparison with a valid reference standard, among consecutive patients with a defined clinical presentation.

***Level III-2—A comparative study with concurrent controls: Nonrandomized, experimental trial, cohort study, case-control study, interrupted time series with a control group.

^Same experiment/data set—assessed different parameters of physical activity.

^^Same experiment /data set—assessed different parameters of physical activity.

was assessed using the quality criteria checklist of the Evidence Analysis Manual (http://www.andeal.org/) of the Academy of Nutrition and Dietetics (2012). All eight studies returned positive scores using the quality criteria checklist of the Evidence Analysis Manual (data not shown) of the Academy of Nutrition and Dietetics (2012).

# Results

The literature search identified 327 studies of which eight articles met the inclusion criteria.

The eight included studies were varied with respect to population, intervention period, diet composition, and primary objectives including attribute of physical performance (Table 2). For instance, several papers examined muscular power and strength (Campbell et al., 1999; Haub et al., 2005; Wells et al., 2003), four assessed anaerobic and aerobic performance (Baguet et al., 2011; Hanne et al., 1986; Hietavala et al., 2012; Raben et al., 1992) while one investigated immune parameters (Richter et al., 1991) in relation to a vegetarian-based diet. In addition, most papers used different physical testing and/or biomarkers. The following sections are structured according to the type of physical performance being analyzed, although there was some cross over between studies.

## Resistance (Strength/Power) Training

Three studies examined the difference between a LOV diet and a typical beef-containing western diet and its effect on Resistance Training (RT) in elderly men (Campbell et al., 1999; Haub et al., 2005; Wells et al., 2003). The studies were unified regarding muscular strength. All three studies found no significant difference in muscular strength or power between the LOV groups and the omnivorous groups except in Wells et al. (2003) where the LOV group displayed a significant increase in strength for knee extensions ($p < .01$), yet both groups revealed significant improvements in muscular strength and power. Campbell et al. (1999) did, however, report resistance training induced changes in whole body composition ($p = .014$) and an increase in mean type II muscle fiber area size between groups ($p = .005$). Similarly, Wells et al. 2003, described hemoglobin and hematocrit were significantly increased in the meat group ($p < .01$) though this did not affect strength testing.

## Anaerobic and Aerobic Performance

Four studies were identified relating a vegetarian-based diet to either anaerobic and/or aerobic performance. Hietavala et al. (2012) revealed that a low protein vegetarian diet had no significant effect on exercise time to exhaustion, but oxygen consumption was significantly higher at 40%, 60% and 80% of maximum oxygen consumption compared with a mixed diet (2.03 ± 0.25 vs. 1.82 ± 0.21 L/min, $p = .035$; 2.86 ± 0.36 vs. 2.52 ± 0.33 l/min, $p < .001$ and 4.03 ± 0.50 vs. 3.54 ± 0.58 L/min, $p < .001$; respectively). Venous blood pH, strong ion difference, partial pressure of $CO_2$, $HCO_3^-$, was also measured with no significant difference between diets. Comparably, Baguet et al. (2011) found that anaerobic performance improvement (repeated sprint ability test) was not different between the diet groups. Hanne et al. (1986) assessed both anaerobic and aerobic capacity between vegetarian and nonvegetarian athletes. No significant difference in aerobic performance, as measured by predicted maximum oxygen consumption and rating of perceived exertion (RPE) was observed. Likewise, no significant differences between groups were measured using the Wingate test to assess anaerobic performance (Table 2).

Raben et al. (1992) reported no significant differences between a LOV diet and maximum oxygen consumption, maximal voluntary contraction, endurance performance or muscle glycogen concentrations compared with a mixed diet (both diets controlled for carbohydrate 57%, protein 14% and fat 29%). A significant decrease in fasting serum testosterone was observed over the 6-week intervention period in the vegetarian groups diet (median 21.1nmol$^{-1}$ to 13.7nmol$^{-1}$, $p < .05$), where no change was observed in the mixed diet. This did not have an effect on any physical performance parameters.

## Immune Function

Richter et al. (1991) reported that the immune parameters; blood mononuclear cells, and natural killer cells did not differ between a vegetarian and mixed diet after aerobic exercise. Similarly, phytohemagglutinin (PHA) and purified protein derivative (PPD; tuberculin) showed no significant differences between dietary groups.

# Discussion

This review is the first to explore an exclusive vegetarian-based diet and its effects on physical performance using a rigorous systematic approach. Earlier investigations have focused on components of a vegetarian diet and performance or supplementation emulating a vegetarian diet and performance but none have examined the diet holistically, the way individuals or athletes would typically eat. Due to the limited evidence pool, and the disparate outcomes of performance tested, evaluating the association between a vegetarian-based diet and improved physical performance in athletes was immeasurable. This did not align with the primary hypothesis that a vegetarian diet would improve physical performance in athletes.

Nieman (1998) similarly reviewed vegetarian diets and possible links to improved physical performance. Seventeen scientific papers were assessed by Nieman before 1998, with neither a beneficial nor a detrimental effect reported. Of the eight papers, which were reviewed in this investigation, all were unified with Neiman's findings. The vegetarian-based diet did not improve nor hinder physical performance. It is noteworthy to declare that all references used in Nieman's 1998 paper were hand searched for inclusion in this systematic review. No additional articles were included. Nieman's study was not extracted in the methodology, and therefore not

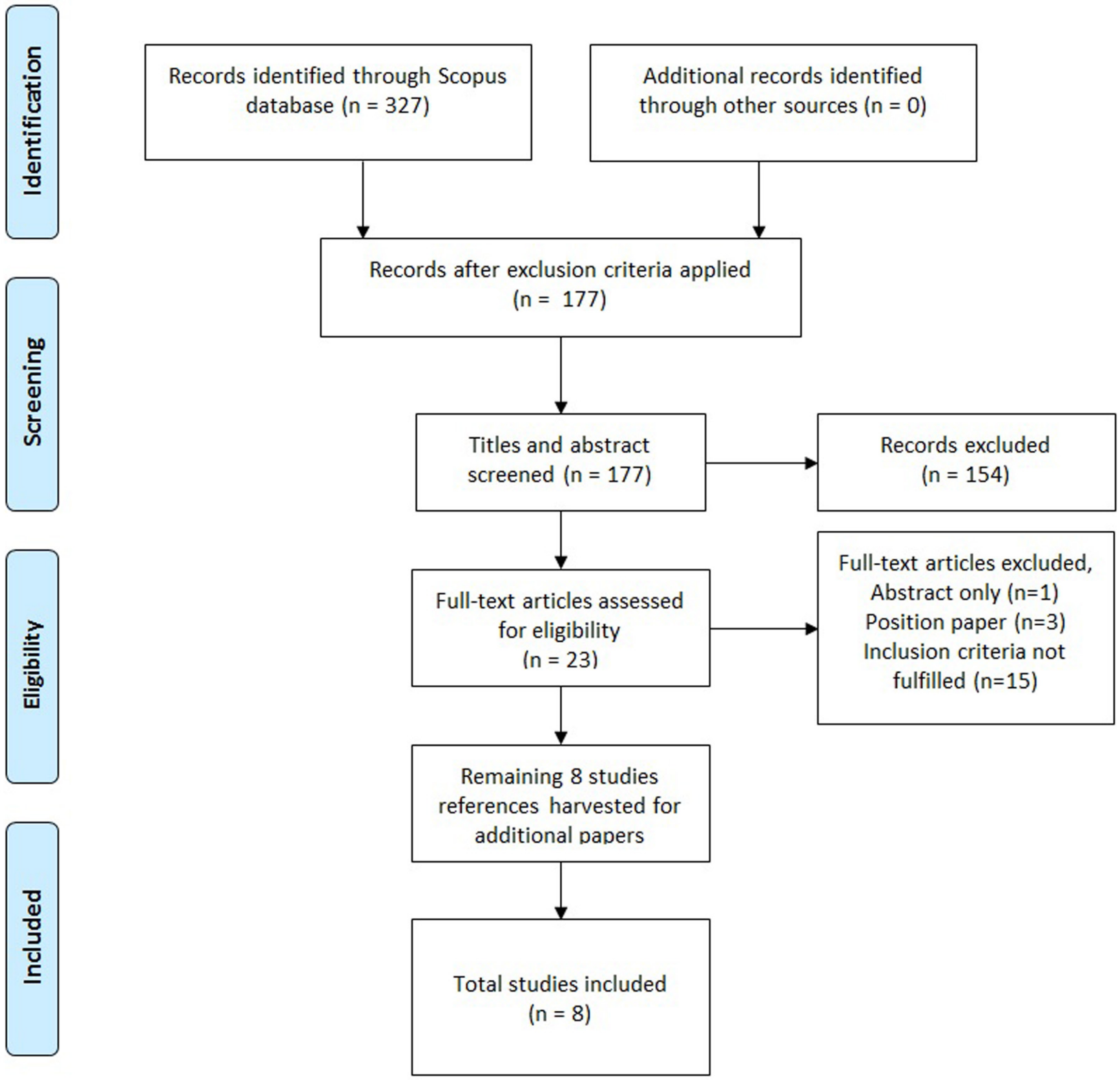


**Figure 1** — The PRISMA flowchart showing the initial and final number of studies obtained.

included in the results of the review. This occurred due to the keywords used by Nieman (exercise, endurance, athlete, carbohydrate, meat, iron, protein, creatine, vegetarian diet, humans) being broad with more focus on food groups and macronutrients.

Due to limited studies and dissimilar performance measurements, there may still be some merit to the hypothesis forecasting a vegetarian-based diet increasing performance due to increased muscle glycogen, cell alkalinity and immunity, while reducing oxidative stress. This is particularly true for reducing oxidative stress as no trials were found on the subject.

## Strength and Power

The three papers examining a LOV diet were unified, identifying that both the control and LOV groups significantly improved muscular strength and power equally during the study period. All three studies used elderly men as subjects concluding there was no difference between LOV diets and omnivorous diets in resistance training in elderly men. However, this may not be representative of the larger population. Wider studies are required to confidently consolidate their findings with the inclusion of both genders, and a range of ages. In two out of the three studies texturised vegetable protein was used frequently in the LOV diets with breakfast patties, grillers, chick[pea] patties and veggie dogs highly prominent (Haub et al., 2005; Wells et al., 2003). Products such as these often contain food color, pH modifier, surface-active substrates, emulsifiers and surfactants (Asgar et al., 2010). Ideally, the aim of this study was to investigate a more whole food vegetarian-based diet. Research limiting the use of texturised vegetable protein products is warranted to more adequately align a plant-based dietary intake, and its response to resistive training.

## Anaerobic and Aerobic Performance

Four papers were identified analyzing a vegetarian diet and its effect on endurance and/or aerobic performance. These studies exhibited some heterogeneity with three of the papers reporting on maximal aerobic capacity, two papers reporting on anaerobic performance and one also including isometric strength performance. No significant differences were observed between dietary intake and physical performance.

As only four studies with small participant pools were identified, it is imprudent to make a judgment on the effect of a vegetarian diet regarding this type of physical performance. The studies were consistent, however, revealing no significant differences between dietary groups in short, middle or endurance performance. This should only serve as a preliminary statement with further research required. This is particularly true with Baguet et al. (2011) issuing both the vegetarian and nonvegetarian groups 1 g/day of creatine monohydrate to reduce a creatine deficiency in the vegetarian diet group.[1] Some studies, such as that of Bemben & Lamont (2005), have linked creatine to improved anaerobic performance. Although Baguet et al. (2011) were analyzing carnosine concentration, the creatine supplementation may have skewed the results, at least for the applicability of this review. In the study by Baguet et al. (2011), baseline measurements between vegetarians and nonvegetarians revealed lower total creatine concentration ($p < .05$). If creatine is implicated in improved performance, and vegetarians have reduced concentrations to nonvegetarians, creatine supplementation may be particularly influential in performance results. Supplementing with creatine eliminates it as a variable, enabling the specific focus of carnosine; which has been hypothesized to increase performance, however, greatly limits the findings to address the relationship between a vegetarian diet and performance in short to middle distance athletes. From this study, it can be supposed, that there is no difference in carnosine concentrations between the two dietary groups (Baguet et al., 2011), however, any links to physical performance must be questioned due to the creatine supplementation. Hietavala et al. (2012) interestingly found that although there was no overall difference between the dietary groups' acid-base status or overall effect on maximum oxygen capacity, cycling efficiency decreased in the LOV group. This would not be a desirable effect for any athlete, which deserves to be explored further. Three of the studies assessing anaerobic and aerobic performance used short treatment periods of vegetarian consumption (Baguet et al.; 5 weeks: Raben et al.; 6 weeks: Hietavala et al.: 4 days). The only study which was included where a vegetarian diet was adopted for an extended period of time, was that of Hanne et al. (1986). The participants in this study, were vegetarian for a minimum of two years. This timeframe would be more suitable to assess metabolic alterations. However, the sample size was small (39 vegetarians) and the investigation did not implement a randomized controlled study design, but a cross sectional assessment. A larger number of participants, longer treatment times, studies without additional supplementation and a greater number studies are needed to confidently make a conclusion about a vegetarian-based diet and its effect on anaerobic an aerobic performance.

## Immune Parameters and Performance

It has been suggested that due to the wealth of phytochemicals, antioxidants and plethora of micronutrients in vegetarian-based diets, immune function may be improved in the vegetarian population (Nieman, 1988). This was not observed in the single study identified comparing immune status between the two dietary groups (Richter et al., 1991). The treatment groups in this particular study were subjected to a macro energy controlled—57% Carbohydrate, 14% Protein, 29% Lipids LOV (16% animal derived protein, 84% vegetable protein)—or mixed western diet (67% animal derived protein, 33% vegetable protein) for a total of 6 weeks. This duration is perhaps lacking the duration for full effects of a vegetarian/vegan diet to become apparent. A larger body of research with an extended duration of vegetarian consumption is needed before this can be concluded.

## Mechanisms

Mechanisms other than those hypothesized to discriminate between a vegetarian-based diet and a mixed diet were proposed in some of the studies. Raben et al. (1992) for example hypothesized a decrease in sex serum testosterone due to a vegetarian-based diet. Raben et al. suggested nonheme iron may not be absorbed as readily as heme iron and increased fiber intake may reduce the bioavailability of some nutrients, causing implications to a heavily training athlete. This was found not to be the case as the study revealed low level sex serum hormones in the vegetarian group but no changes in physical performance.

Baguet et al. (2011) and Hietavala et al. (2012) investigated the relationship between vegetarian-based diets and their effect on acid-base balance. Hietavala et al. (2012) found no significant difference in venous blood pH, strong ion difference or total concentration of weak acids (Atot), suggesting a low protein, vegetarian-based diet (Protein 10.1% ± 0.26, Carbohydrate 58.7% ± 2.4, Fat 24.7% ± 2.3) may not optimize acid-base balance and thus improve physical performance. Baguet et al. (2011) predominately focused on carnosine and its buffering capacity. Lacto-ovo vegetarians revealed lower total creatine concentration ($p < .05$) compared with nonvegetarian participants, however, no difference in performance was observed, again suggestive of a vegetarian-based diet being ineffective at providing some sort of buffering effect.

## Limitations

A limitation with the body of evidence is that all of the randomized controlled trials used extremely short periods of dietary intervention ranging from 4 days to 12 weeks. Changes in stored nutrient concentration could take much longer than this period. For instance, a recent study revealed that the most notable decline in vitamin B-12 in vegan participants occurred between 24 months and 60 months (Madry et al., 2012). The results from the present literature review only offer understanding into the short-term effects of a vegetarian-based diet, which may be useful for acute purposes, such as leading into a competition or race, however; does not address long-term effects. This is significant, as athletes following a vegetarian-based diet would typically do so for extended periods.

In addition, many of the included papers lacked information on the standardization of dietary intake between groups and/or lacked detail about dietary compliance. Jeacocke and Burke (2010), note the possible impact poor dietary control can have on the outcome of a study. This is of particular interest in this review as the sample sizes were small, thereby likely to exaggerate the results of inadequate dietary standardization between groups.

While this systematic literature review has provided new insights into the effects of vegetarian-based nutrition and physical performance in athletes via a highly rigorous and structured review, some improvements could be made. The present SLR's search criterion encompasses dietary factors and effects on *total* physical performance. Refined search parameters focusing on *specific* domains of physical performance may uncover additional studies within that domain. Furthermore, as limited research was identified exploring vegetarian-based nutrition and physical performance, including cross-sectional studies comparing performance biomarkers may have increased the strength of this review.

# Conclusion

Currently, the evidence for consuming a predominately vegetarian-based diet and improved athletic performance is lacking. In the eight studies which were identified in this review, however, the vegetarian-based diet did not improve performance, nor did it hinder it. There appeared to be no differences at least acutely between a vegetarian-based diet and an omnivorous diet in muscular power, muscular strength, anaerobic or aerobic performance. Many limitations were identified within the body of evidence including the total body of evidence being very small (seven trials one cross-sectional analysis), the body of evidence experimental outcomes varied significantly, typically short dietary treatment times were administered (all but one study used treatments of 4 days to 12 weeks), resistance training focused only on elderly men and supplementation was used in one of the trials. More trials are needed to address the limitations and provide stronger evidence toward vegetarian-based diets and their effects on physical performance in athletes. It would be recommended that future research meets high level randomized controlled trial design with strict vegetarian-based dietary intervention lasting 6 months or greater to determine the association between a vegetarian-based diet and physical performance.

# Notes

1. Creatine monohydrate was used across both dietary groups to eliminate it as a variable. As both groups supplemented with creatine, it was included.

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