Nutrition 32 (2016) 1033–1036

Contents lists available at ScienceDirect

Nutrition

journal homepage: www.nutritionjrnl.com

Brief report

Long-term effects of a very-low-carbohydrate weight-loss diet and an isocaloric low-fat diet on bone health in obese adults

Grant D. Brinkworth Ph.D. [a,*], Thomas P. Wycherley Ph.D. [b], Manny Noakes Ph.D. [a], Jonathan D. Buckley Ph.D. [c], Peter M. Clifton Ph.D. [c]

[a] *Commonwealth Scientific and Industrial Research Organisation, Food and Nutrition Flagship, Adelaide, South Australia, Australia*
[b] *University of South Australia, School of Health Sciences, Adelaide, South Australia, Australia*
[c] *Alliance for Research in Exercise, Nutrition and Activity (ARENA), Sansom Institute for Health Research, University of South Australia, Adelaide, South Australia, Australia*

A R T I C L E I N F O

Article history:
Received 11 September 2015
Accepted 2 March 2016

Keywords:
Diet
Weight loss
Macronutrient composition
Bone
Obesity

A B S T R A C T

Objective: Compromised bone health is a frequently cited concern of very-low-carbohydrate (LC) diets, although limited data are available from long-term, well-controlled, randomized studies. This study compared the effects of an energy-restricted LC diet and traditional, higher-carbohydrate, low-fat (LF) diet on bone health after 12 mo.
Methods: One hundred eighteen abdominally obese adults were randomized to consume either an energy-restricted (~6–7 MJ/d [~1450–1650 kcal/d]), planned isocaloric LC, or LF diet for 12 mo. Body weight, total body bone mineral content and bone mineral density (BMD), and serum bone crosslaps were assessed pre- and postintervention.
Results: Sixty-five participants completed the study (LC = 32, LF = 33; age: 51.3 ± 7.1 y; BMI: 33.4 ± 4.0 kg/m^2). Weight loss was similar in both groups (LC: −14.5 ± 9.8 kg, LF: −11.7 ± 7.3 kg; $P = 0.26$). By 1 y, total body bone mineral content had not changed in either group (LC: 2.84 ± 0.47 to 2.88 ± 0.49 kg, LF: 3.00 ± 0.52 to 3.00 ± 0.51 kg; $P = 0.07$ time × diet effect). In both groups, total body BMD decreased (LC: 1.26 ± 0.10 to 1.22 ± 0.09 g/cm^2, LF: 1.26 ± 0.09 to 1.23 ± 0.08 g/m^2; $P < 0.001$ time) and bone serum crosslaps increased (LC: 319.3 ± 142.6 to 396.5 ± 172.0 ng/L, LF: 276.3 ± 100.6 to 365.9 ± 154.2 ng/L; $P < 0.001$ time) independent of diet composition ($P \geq 0.25$ time × diet effect). Future studies would be strengthened by the assessment of regional BMD at clinically relevant sites (i.e., hip and spine) and multiple markers of bone turnover.
Conclusions: Weight loss following a hypocaloric LC diet compared with an LF diet does not differentially affect markers of bone health over 12 mo in overweight and obese adults.

This study was supported by project grants from the National Heart Foundation of Australia and the National Health and Medical Research Council of Australia (APP ID 401818). Simplot Australia, Mt Buffalo Hazelnuts Victoria, Webster Walnuts Victoria, Stahmann Farms Queensland, and Scalzo Food Industries Victoria donated foods for this study. None of the funding agencies played a role in the conception, design, or conduct of the study; collection, management, analysis, and interpretation of the data; or preparation, review, and approval of the manuscript.

Grant D. Brinkworth was responsible for conception, design, and coordination of the study; contributed to the statistical analyses; interpreted the data; and coordinated the writing of the manuscript. Grant D. Brinkworth had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Thomas P. Wycherley was responsible for statistical analysis and data interpretation for writing of the manuscript. Manny Noakes was responsible for the conception and design of the study and the experimental diets, interpretation of the data, and the writing of the manuscript. Jonathan D. Buckley contributed to the experimental design, statistical analysis, data interpretation, and writing of the manuscript. Peter M. Clifton was responsible for the conception and design of the study, and contributed to data interpretation and writing of the manuscript. All authors agree on the final version of the manuscript.

The authors declare no conflicts of interest.
* Corresponding author. Tel.: +61 8 8303 8830; fax: +61 8 8303 8899.
E-mail address: Grant.brinkworth@csiro.au (G. D. Brinkworth).

http://dx.doi.org/10.1016/j.nut.2016.03.003

Introduction

The obesity epidemic has fueled increased interest in, and use of, very-low-carbohydrate (LC) diets due to their purported benefits for enhanced weight loss [1,2]. LC diets have a common theme of restricting carbohydrate intake (<20–50 g/d), while increasing fat and protein intake [3]; however, an often-cited concern related to the use of LC diets is their potential to elicit detrimental effects on bone health and osteoporosis risk [3,4].

It is well established that calcium intake and incorporation in bone plays an important role in building and maintaining bone mass and reducing bone loss [5]. It has been suggested that LC diets create a state of elevated metabolic acidosis due to increased blood ketones or a higher dietary protein intake associated with increased presence of sulphuric acid (from sulphur-containing amino acids) [6,7]. These may adversely affect bone quality by promoting calcium resorption from bone to buffer the increased acidity, leading to hypercalciuria [6,7]. Previous cross-sectional evidence has shown that high animal-protein intakes are linked to higher risks for osteoporosis [8], although controversy remains with other evidence suggesting that lower rather than higher protein intake may increase bone fracture risk [9]. To date, the availability of well-controlled, randomized studies evaluating the chronic effects of a LC diet on bone health is limited. In the only known long-term study, Foster et al. [2] found no differences in bone mineral density (BMD) between obese adults consuming either a LC diet or a higher-carbohydrate, low-fat (LF) diet after 2 y. However, further studies are warranted to confirm this and inform patients who choose to pursue weight reduction with a LC-diet approach of any potential risks. This study assessed the long-term effects of an energy-restricted LC diet and an LF diet on bone health in overweight and obese individuals.

Materials and methods

Study participants and design

Enrollment criteria, study design, and primary study outcomes have been previously described elsewhere [10]. Briefly, 118 participants (122 recruited, 4 withdrew before randomization) ages 24 to 64 y with abdominal obesity (waist circumference: ≥94 cm in men, ≥80 cm in women) and at least one additional metabolic syndrome risk factor [11] were recruited by public advertisement to participate in a 12-mo intervention. Exclusion criteria were a history of liver, respiratory, gastrointestinal, cardiovascular, or peripheral vascular disease; diabetes; pregnancy; or cancer. Participants were randomized to consume either an energy-restricted LC diet (n = 57) or an isocaloric conventional LF diet (n = 61) for 52 wk. The study was approved by the Human Research Ethics Committees of the Commonwealth Scientific and Industrial Research Organisation and the University of South Australia. All participants provided written informed consent.

Dietary intervention and compliance

Both diets were designed to be isocaloric with moderate energy restriction (~6 MJ/d [~1450 kcal/d] for females and ~7 MJ/d [~1650 kcal/d] for males). The initial planned macronutrient profiles of the dietary patterns were as follows: LC diet (4% of total energy as carbohydrate [<20 g], 35% protein, and 61% fat); LF diet (46% of total energy as carbohydrate, 24% protein, and 30% fat [<8% saturated fat]). After 8 wk, participants in LC were provided with the option of a 20 g carbohydrate exchange (i.e., a carbohydrate prescription of <40 g). To achieve the specified macronutrient profiles and energy levels, the dietary patterns were structured into prescriptive dietary plans of specific food quantities [10] that were provided to the participants in a quantitative food record that participants completed daily. Participants were asked to weigh and measure their food daily using scales that were provided. On a fortnightly basis for the first 8 wk, and monthly thereafter, participants also met individually with a qualified dietitian who provided detailed dietary advice, meal plans, and recipe information pertaining to each diet. Dietary compliance was assessed from the data attained from the daily quantitative food records based on analysis of 3 d from each 2-wk period of food records (2 weekdays and 1 weekend day) for the study duration using computerized dietary software (FoodWorks Professional, version 4, Xyris, Highgate Hill, Queensland, Australia). These food records were subsequently used to calculate the average nutrient intake over 52 wk. High levels of dietary compliance were achieved with both dietary patterns as reported previously [10].

Body-weight, body-composition, and bone-health measures

Body weight was measured using calibrated electronic digital scales (AMZ14, Mercury, Tokyo, Japan) at baseline and at each diet visit. At wk 0 and 52, total body bone mineral content (BMC), BMD, and percent body fat were measured using dual-energy x-ray absorptiometry (DEXA, Lunar Prodigy, General Electric, Fairfield, CT, USA). At wk 0 and 52, fasting blood samples were collected for the measurement of serum beta-crosslaps and a 24-h urine sample was collected for the measurement of urinary calcium excretion at a commercial laboratory (Institute of Veterinary Science, Adelaide, Australia). Beta-crosslaps is a collagen-degradation product that represents a biochemical marker of bone turnover, with clinical data providing supportive evidence that levels reflect bone resorption [12,13].

Statistical analyses

Baseline comparisons were made using independent *t* test for continuous variables and Pearson's χ^2 tests for categorical variables. Comparison of changes between diets over time for the outcomes was made using repeated measures analysis of variance (ANOVA) with time as within participant factor (i.e., wk 0 and 52) and diet (LC versus LF) and sex as between participant factors. No significant sex effects were observed for any outcomes; therefore, individual sex data are not reported except for total body BMC and BMD outcomes to allow for normative data comparison. Pearson's correlation was used to determine relationship of changes between variables. Statistical significance was set at $P < 0.05$. All analyses were performed using IBM SPSS Statistics, version 20.0 (IBM, Armonk, NY, USA). Values cited represent means ± standard deviation, unless otherwise stated.

Results

Of 118 participants randomized to dietary treatment, 65 had DEXA scans performed at baseline (wk 0) and wk 52 (LC = 32, LF = 33) and were included in the analysis. At baseline, groups did not differ for sex distribution (LC [10 male/22 female], LF [13 male/20 female]; $P = 0.49$), age (LC 51.6 ± 7.8 y, LF 51.0 ± 6.5 y; $P = 0.74$), body weight (LC 93.7 ± 15.7 kg, LF 95.1 ± 13.0 kg; $P = 0.70$) or body mass index (LC 33.7 ± 4.0 kg/m^2, LF 33.2 ± 4.0 kg/m^2; $P = 0.64$).

Food records indicated the dietary intakes of the groups were as follows: LC diet (6686 ± 734 kJ/d [1599 ± 176 kcal/d], 8 ± 3% [30.2 ± 12.3 g/d] carbohydrate, 34 ± 2% protein, 57 ± 4% fat [20 ± 2% saturated fat]); LF diet (6474 ± 793 kJ/d [1546 ± 189 kcal/d], 44 ± 11% [162.6 ± 44.3 g/d] carbohydrate, 24 ± 3% protein, 30 ± 9% fat [7 ± 4% saturated fat]). Reported calcium intake was higher in LC (904 ± 148 mg/d) compared with LF (802 ± 103 mg/d; $P < 0.01$).

At baseline, there were no differences between the groups for any of the outcome variables. Participants experienced an average 13.6 ± 8.1% weight loss, with no differences between groups ($P = 0.18$; Table 1). Total body BMC did not change in either diet group ($P = 0.07$ time × diet effect). Total body BMD, percent fat mass, and 24-h urinary calcium decreased, and serum bone crosslaps increased ($P < 0.001$ time), with no diet effect ($P \geq 0.25$). Changes in body weight correlated with changes in serum bone crosslaps ($r = -0.30$; $P = 0.02$) and changes in BMD ($r = 0.45$; $P < 0.001$).

Discussion

After 12-mo consumption of either a hypocaloric LC or an isocaloric traditional LF diet, both diets resulted in similar changes in bone-health parameters. This directly agrees with a previous 2-y study that reported no differences in changes in