Original Article

Nutritional adequacy of energy restricted diets for young obese women

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Aim: Energy restricted meal plans may compromise nutrient intake. This study used diet modelling to assess the nutritional adequacy of energy restricted meal plans designed for weight management in young obese women. Methods: Diet modelling of 6000 kJ/d animal protein based meal plans was performed using Australian nutrient databases with adequacy compared to the Australian Nutrient Reference Values (NRVs) for women (19-30 years). One diet plan was based on the higher carbohydrate (HC) version of the Australian Guide to Healthy Eating for women 19-60 years. An alternative higher protein (HP) plan was adapted from the CSIRO Total Wellbeing Diet. Vegan and lacto-ovo versions of these plans were also modelled and compared to the appropriate vegetarian NRVs. Results: Both animal protein diets met the estimated average requirement (EAR) or adequate intake (AI) for all nutrients analysed. The recommended dietary intake (RDI) was also satisfied, except for iron. HC met 75±30% and HP 81±31% of the iron RDI when red meat and iron fortified cereal were both included three days a week, and remained below the RDI even when red meat was increased to seven days. Iron for the modified vegan (57±5% HC; 66±4% HP) and lacto-ovo (48±6% HC; 59±7% HP) plans was below the RDI and zinc below the EAR for the vegan (76±8% HC; 84±9% HP) plans. Conclusion: The 6000 kJ/d animal protein meal plans met the RDI for all nutrients except iron. Iron and zinc failed to meet the vegetarian RDI and EAR respectively for the vegan plans.

Key Words: iron, zinc, nutritional requirements, obesity, overweight

INTRODUCTION

Obesity prevalence is rising and US data indicate that the incidence of major weight gain is twice as high in women than men, with younger women (25-44 years) especially those already overweight at greatest risk.[1] Weight gain is also an issue among young (18-23 years) Australian women, with 41% increasing body mass index by greater than 5% over a four year period.[1] A greater risk for weight gain in younger women has been attributed to a number of lifestyle factors. Inclination to be physically active when compared to men is lower, with activity declining rapidly between the ages of 18-29 years.[2] Frequent consumption of take-away foods also promotes weight gain in young women.[1] Lifestyle changes at this life stage including moving away from the family home, entering a marriage or de facto relationship and pregnancy are all associated with weight gain.[1,3,4]

Despite the increased risk for significant weight gain in young women, studies investigating obesity treatment in this population are under-represented in the literature. This group have been reported to adopt short term and unhealthy weight management practices.[1] Failed weight loss attempts and weight cycling make long term weight management more difficult and increase the risk for inadequate nutrient intake.[5] Obesity related inflammation may also influence micronutrient status, specifically decreasing iron absorption and altering iron metabolism.[6,7] This is important to the clinical management of obesity in this population as iron deficiency is already prevalent in young women within the general community.[8]

This study modelled animal protein, vegan and lacto-ovo vegetarian based energy restricted meal plans to assess nutritional adequacy and determine strategies for tailoring food choice to meet the nutritional needs of young women who seek dietetic support for weight management.

MATERIALS AND METHODS

Diet modelling of two different seven day energy restricted meal plans suitable for young women (19-25 years) was undertaken (Table 1). An energy restriction of 6000 kJ/d was chosen as consistent with a reduction of approximately 2-4 MJ from daily energy expenditure with a physical activity level (PAL) of approximately 1.6. The first plan, higher in carbohydrate and containing moderate

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animal protein (HC) was modeled on the Australian Guide to Healthy Eating (AGHE) using sample serves from a diet based on breads and cereals for women aged 19-60 years.[9] To satisfy energy restriction criteria, the lower end of serves and portion sizes were selected. To achieve a balanced macronutrient profile, one serve of fats/oils was included. A maximum of 3.5 serves was modelled for bread and cereals to conform to the energy restriction (Table 1).

Recent evidence has shown support for greater satiety and possibly compliance with higher protein diets.[10,11] Therefore, an alternative iso-energetic animal based higher protein, moderate carbohydrate (HP) plan was adapted from the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Total Wellbeing Diet (6000 kJ version).[12] Vegan and lacto-ovo versions of these plans were also modelled. Nutrient dense foods representative of the core groups and from clinical experience likely to be acceptable were selected to facilitate both plans meeting the Australian Nutrient Reference Values (NRVs) for women (19-30 years).[13] Multiple substitution runs of different food items representing the required core food groups was used to identify nutrient dense foods and refine meal plans.

Serves of bread and the meat/alternatives group differed in the HC and HP plans, but serves of dairy, fruit, vegetable and extra foods/oils were identical. Iron fortified cereal was included on three days to boost iron intake while allowing for some variation at breakfast. Modelling used multigrain bread and brown rice. Meat was lean and cooked using low fat methods (grill or barbecue). Water loss for meat was rounded to 25% (200 g raw meat equivalent to 150 g cooked).[14] Red meat was beef and lamb. As iron content differs across red meat cuts, those with the highest iron content were used including beef fillet (0.037 mg/g), rump steak (0.034 mg/g), lamb chump chop (0.034 mg/g) and shank (0.033 mg/g).[15] The HC diet provided one and the HP diet 3.5 AGHE defined serves of the meat/alternatives group each day (Table 1). The meat/ alternatives group serve on the HC diet (red meat, poultry or fish) was included at one (main) meal each day while for the HP diet, 2.5 serves (red meat, poultry or fish) were included at one (main) meal and the remaining one serve (poultry, fish, eggs or legumes) at another. Milk, cheese and yoghurt (artificially sweetened) were reduced fat and milk calcium fortified. Oil and margarines were olive or canola based.

The vegan HC and HP plans were identical, except meat/alternative servings (HC 1; HP 3.5 daily) were replaced with legumes or tofu (1 serve: 1/2 cup cooked) (Table 1). Dairy and added fat was replaced with reduced fat, calcium fortified soy beverage, soy cheese (not calcium fortified as this option was not available in database) and Nuttelex™. A lacto-ovo version of HC and HP replaced the meat/alternatives with egg and legumes.

Modelling analysis was performed using Food Works Version 6.0.2517 incorporating the AusFoods (Brands) revision 11, AusNut (All Foods) revision 18 and Nuttab

Table 1. Serves of food in the higher carbohydrate (HC) and higher protein (HP) diets compared to the Australian Guide to Healthy Eating (AGHE) and Commonwealth Scientific and Industrial Research Organisation (CSIRO) Total Wellbeing Diet

Food Group	Food	Lowest AGHE serving size	AGHE† (serves/day)		HC Diet (serves/day)	CSIRO‡ (serves/day)	HP Diet (serves/day)
			Plan A	Plan B			
Breads and Cereals	Bread	2 slices	4-6	4-9	3.5	1.5	1.5
	Pasta	1 cup cooked					
	Rice	1 cup cooked					
	Noodles	1 cup cooked					
	Cereal	1 1/3 cup flaky cereal					
Meat and Alternatives	Beef, lamb	65 g cooked	1-1.5	1	1	3.5	3.5
	Chicken	65 g cooked					
	Fish	80 g cooked					
	Egg	2 small					
	Legumes	1/2 cup cooked					
	Seeds; nuts	1/4; 1/3 cup					
Dairy	Milk	250 mL	2-3	2	2	2	2
	Yoghurt	200 g					
	Custard	250 mL					
	Cheese	40 g					
Fruit	Fresh	1 medium piece	2-3	2	2	2	2
	Canned	1 cup					
	Juice	1/2 cup					
Vegetables	Salad	1 cup	4-7	5	5	4.5	5
	Cooked	1/2 cup					
Fats and Oils§	Margarine	1 tablespoon	0-2.5	0-2.5	1	1	1
	Oil	1 tablespoon					

AGHE: Australian Guide to Health Eating; HC: Higher carbohydrate; CSIRO: Commonwealth Scientific and Industrial Research Organisation; HP: Higher protein

†AGHE plan A (balanced across food groups) and B (higher in breads and cereals) for women aged 19-60 years

‡Approximate serves/day for 6000 kJ weight loss program as serve sizes differ slightly to AGHE

§1 tablespoon = 4 teaspoon (20g) of margarine or oil. 1 teaspoon margarine/oil per 60% cereal foods is allowed in the AGHE in addition to the margarine and oil which can be eaten as part of the extra foods allowance (for 3.5 cereal serves this is about 2 teaspoons). More fat than this was required in the HC and HP diets to achieve a balanced macronutrient profile.

2006 revision 1 databases on foods in the meal plans 'as consumed' (i.e. cooked if appropriate).[15] Food selections were made using the description closest to the item. Due to limitations in the database, modelling was not performed for all nutrients (e.g. vitamin B-12, fatty acids). Nutritional adequacy was assessed by comparison to the NRVs (vegetarian for vegan and lacto-ovo), specifically recommended dietary intakes (RDI), or lowest adequate intakes (AI), and estimated average requirements (EAR) for Australian women aged 19-30 years.[13] The vegetarian NRVs are similar to omnivorous diets except that both the EAR and RDI are 50% higher for zinc and 80% higher for iron. When nutrients were limiting (below the EAR or RDI) standard deviations for intake (and percent EAR and/or RDI) were calculated as an indication of range across the seven days modelled.

RESULTS

The two animal protein based energy restricted HC and HP plans (Table 1) provided approximately 22% protein, 19% fat, 59% carbohydrate and 31% protein, 25% fat, 44% carbohydrate, respectively. Both plans were close to the current Australian NRV macronutrient distribution recommendations (protein 15-25%, fat 20-35%, carbohydrate 45-65%). Less than 10% of energy in both plans was provided by saturated fat. The vegan (lacto-ovo) HC and HP plans provided 16% (19%) protein, 21% (18%) fat, 62% (62%) carbohydrate and 19% (22%) protein, 24% (20%) fat, 55% (56%) carbohydrate, respectively.

Table 2 outlines the initial nutrient analysis of the animal protein based HC and HP plans. To provide sufficient iron intake, the AGHE recommends red meat consumption 3-4 times per week or use of alternative high iron foods. To control for wide variations in nutritional composition due to protein source, plans were initially modelled with red meat at the lower end of this range (three times a week), and fish and poultry each twice a week for the main meal. In this format, both diets met the EAR and RDI (or AI) for all nutrients except iron which met the EAR but was 75±30% of the RDI for the HC and 81±31% for the HP plan, with 9% and 24 % of the iron from meat (haem) sources respectively.

To address the inadequate iron intake, further models based on increasing red meat frequency were explored. Next to liver (0.093 mg/g) and kidney (0.084 mg/g) which are infrequently consumed by young women, red meat is the richest, most bio-available source of dietary iron.[15] Additional red meat replaced fish and poultry in the model. Consumption of red meat four times a week (with poultry once and fish twice) increased dietary iron to 77±28% of the RDI for the HC and 84±27% for the HP plan. Consumption of red meat seven times a week increased dietary iron to 81±31% and 95±32% of the RDI for the HC and HP plans respectively. All other nutrients in these models still met or exceeded the RDI or AI. In comparison, when poultry was modelled seven times a week, all nutrients except iron (71±30% for both HC and HP) met the RDI on both plans.

As the model of red meat seven times a week did not meet the RDI for iron, additional analysis was performed using the higher iron HP plan to explore what further dietary manipulation would be needed for individuals with iron needs close to the RDI. Addition of liver at the main meal (2.5 serves, where one serve equalled 65 g of cooked

Table 2. Nutrient analysis for higher carbohydrate (HC) and higher protein (HP) diets modelling red meat consumption three times a week for estimated average requirements (EAR), recommended dietary intakes (RDI) and adequate intakes (AI)

Nutrient	HC Plan			HP Plan		
	Daily Mean	EAR (%)	RDI/AI(%)	Daily Mean	EAR (%)	RDI/AI(%)
Energy (kJ)	6064			5971		
Protein (g)	77	209	168	109	295	237
Total fat (g)	32			41		
Saturated fat (g)	8.0			11.4		
Polyunsaturated fat (g)	6.0			6.1		
Monounsaturated fat (g)	13.4			18.8		
Cholesterol (mg)	86			255		
Carbohydrate (g)	211			154		
Sugars (g)	79			82		
Starch (g)	131			70		
Dietary fibre (g)	31		123	27		108
Thiamin (mg)	2.6	287	235	2.1	233	191
Riboflavin (mg)	3.4	379	310	3.6	394	323
Niacin equivalents (mg)	40.2	365	287	52.8	480	377
Vitamin C (mg)	154	514	343	137	458	305
Total folate (µg)	595	186	149	518	162	129
Vitamin A equivalents (µg)	1916	383	274	1899	380	271
Sodium (mg)	2159		469	1671		363
Potassium (mg)	3244		116	3604		129
Magnesium (mg)	418	164	135	405	159	131
Calcium (mg)	1262	150	126	1295	154	130
Phosphorus (mg)	1457	251	146	1673	289	167
Iron (mg)	13.5	169	75	14.5	182	81
Zinc (mg)	10.0	153	125	12.2	187	152

HC: Higher carbohydrate; HP: Higher protein; EAR: Estimated average requirements; RDI: Recommended dietary intakes; AI: Adequate intakes liver) once a week, with red meat for six days was selected as liver was the only food which provided more iron per gram than red meat. Liver once per week with red meat on other days increased the provision of iron above 100±28% of the RDI, with all other nutrients still at or above the RDI or AI. However, similar modelling for the HC diet failed to satisfy the RDI for iron. To reach the iron RDI on the HC plan, liver was needed seven days a week (data not shown). Alternatively, if the frequency of iron fortified cereal was increased to seven times a week in the initial model with red meat three times per week, the RDI was met for both the HP (108±6%) and HC (103±13%) plans.

In the vegan models, the vegetarian EAR and RDI/AI was met for all nutrients except iron and zinc (Figure 1). While the vegetarian EAR for iron was met on both plans, the RDI for iron and the EAR and RDI for zinc were not met on either the HC and HP plans. Modification by daily inclusion of iron fortified cereal failed to facilitate the vegan plans meeting the iron RDI (HC 57±5%; HP 66±4%). Inclusion of skim for soy milk and replacing serves of legumes with egg as lacto-ovo style plans met the EAR for zinc, but still failed to meet the RDI for iron. To meet the zinc EAR on the vegan plan, additional energy (500 kJ for HP and 1000 kJ for HC) by replacing iron fortified cereal with muesli (1 and 1/4 cups) six times a week and half a serving of meat/alternative with seeds (e.g. 1/8 cup or 20 g pumpkin, sesame, sunflower) daily was required. A similar approach using muesli three to four times a week on the lacto-ovo plans also met the zinc EAR. Dietary iron still remained above the EAR in these models. (Lacto-ovo versions of the HC plan met EAR (RDI) by 108±13% (48±6%) for iron and 106±20% (86±17%) for zinc while the lacto-ovo HP plan met EAR (RDI) by 132±14% (59±7%) for iron and 110±16% (89±13%) for zinc).

DISCUSSION

This study demonstrates that it is possible to develop acceptable 6000 kJ/d energy restricted eating plans that meet most of the Australian NRVs for young women. Iron was the limiting nutrient in the animal protein plans, and iron and zinc for the vegan and lacto-ovo plans. Careful selection of red meat, iron fortified cereal and other iron rich foods was needed to reach the RDI for iron in the animal protein plans. The vegan and lacto-ovo plans failed to meet the RDI for iron and zinc and the vegan plans failed to meet the EAR for zinc. Nutritional adequacy of iron and zinc in vegan and lacto-ovo diets may be at risk at this level of energy restriction, particularly for women with requirements close to the RDI.

On the HP animal protein plan the consumption of red meat, a rich and highly bio-available source of iron seven times a week still did not meet the iron RDI. A HP plan which provided red meat on six and liver one day per week (approximately 1 kg of cooked red meat per week) was required to meet the RDI for iron. The HC plan only met the RDI for iron if liver was consumed daily. These plans may not be popular with young women and eating more than 500 g (cooked) red meat per week exceeds recommended levels of consumption.[14] Alternatively, the RDI for iron could be met on the HC and HP plans with the inclusion of red meat three days per week and iron fortified cereal daily.

Nutritional adequacy in this study was assessed using the EAR and RDI (or AI). The iron EAR (8 mg/d) for women during their reproductive years is based on maintenance of a normal, functional iron concentration but only a small store (15 μg/L). The large difference between the EAR and RDI (18 mg/d) is based on the wide variability of iron losses through menstruation. The HC and HP plans modelling red meat three times a week provided 75±30% and 81±31% of the RDI for iron, and when red meat was consumed four times a week this increased to 77±28% and 84±27% respectively. Based on the estimated distribution of iron requirements and an average iron bioavailability of 18% (omnivorous diet),[16] the iron provided by a red meat intake of three times a week on both HC (13.5±5.3 mg/d) and HP (14.5±5.6 mg/d) plans would be sufficient for approximately 90% of young women. This is increased to 95±32% of the RDI on the HP plan when red meat is consumed seven times a week. In comparison, daily poultry consumption provided 71±30% of the iron RDI for both HC and HP. This intake (12.8± 5.2 mg/d) would be sufficient for approximately 87% of healthy young women. Daily intakes of iron above 13.1 or 14.9 mg (90th and 95th percentile respectively) are only required by a small proportion of healthy (non pregnant) women with high menstrual loss.

In this study, the vegan plans met the EAR and RDI (or AI) for all nutrients analysed except iron and zinc. This was despite inclusion of 3.5 serves (1 and 3/4 cups) of cooked tofu or legumes and two serves of soy based dairy substitutes daily. Iron absorption is 10% from a vegetarian (based on non-haem iron) compared with 18% from an animal protein diet (rich in haem iron) and this substantially increases the NRV targets.[16] Even substitution of skim for soy milk and egg for legumes failed to satisfy the RDI for iron and zinc.

Within the animal protein diets, the content of haem iron was substantially higher in the HP (24%) compared to the HC (9%) plan (red meat, three times a week).

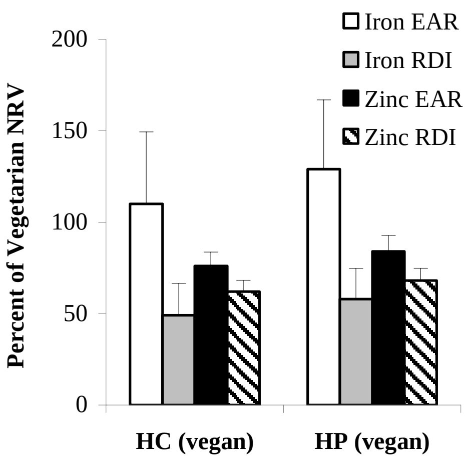

Figure 1. Comparison of dietary iron and zinc Nutrient Reference Values (NRVs) provision from the vegan versions of the higher carbohydrate (HC) and higher protein (HP) plans. Footnote: Lacto-ovo versions of the higher carbohydrate (HC) plan met EAR (RDI) by 108±13% (48±6%) for iron and 106±20% (86±17%) for zinc while the lacto-ovo higher protein (HP) plan met EAR (RDI) by 132±14% (59±7%) for iron and 110±16% (89±13%) for zinc.

Based on estimates of the haem (25%) and non-haem (17%) iron absorption in typical US omnivorous diets,[16] and the proportion of haem and non-haem iron in the HC and HP plans (red meat three times a week), the bioavailability of iron was calculated to be 17.5 and 18.7% respectively, similar to the average of 18% used to estimate Australian NRVs. As the bioavailability of non-haem iron is influenced by ascorbic acid intake and inhibitors (e.g. polyphenols, phytic acid),[16] consideration should be given to bioavailability when planning energy restriction diets.

Adequacy of iron intake is important in the clinical application of weight management programmes as a higher prevalence of iron deficiency is consistently reported in the obese.[6,17] The aetiology is unclear but may be due to inadequate intake (micronutrient poor diets or frequent dieting) or a higher blood volume increasing requirements.[5,7] Chronic inflammation in obesity is also associated with increased adipokine production including higher levels of hepcidin secretion.[7,18] Hepcidin promotes sequestration of iron in the reticuloendothelial system and impairs intestinal iron absorption.[19-21] Laboratory assessment of iron status should be considered in weight management, particularly in those with a past history of iron deficiency, frequent menses or menorrhagia. Use of the oral contraceptive pill may improve iron equilibrium in such cases where dietary iron intake is limited.[22] Serum ferritin is elevated by inflammation and is not a reliable marker in obesity.[7,20] Measurement of α1-acid glycoprotein, soluble transferrin receptor, zinc protoporphyrin and C-reactive protein may help clarify iron status.[7,23-25] Laboratory monitoring is recommended if iron supplements are prescribed.

A limitation of this study is that the assessment of some nutrients including vitamin B-12 and specific fatty acids was not performed as nutrient content on the foods modelled was unavailable in the Australian food database. It is unknown if these nutrients were adequate. Clinical application of the diet models used in this study may also be limited in cases where individuals have additional food restrictions e.g. food allergies and intolerances. A final limitation is that the paper only addresses the adequacy of these diets for women aged 19 to 30 years. Additional modelling is required to determine adequacy of energy restricted diets for other age and gender groups.

This study demonstrates that it is possible to develop acceptable 6000 kJ/d energy restricted animal protein and vegan/lacto-ovo plans that meet most of the Australian NRVs for young women. Careful attention to food selection is required, particularly foods high in iron for animal protein and both iron and zinc for vegan/lacto-ovo plans as these nutrients are most limiting.

AUTHOR DISCLOSURES

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熱量限制膳食在年輕肥胖女性的營養適足度

目標：熱量限制膳食可能使營養素攝取不足，因而本篇研究利用膳食模式，評估針對年輕肥胖女性減重計畫設計的熱量限制膳食之營養適足程度。方法：設計出每日 6000 kJ 的葷食膳食模式，利用澳洲食品成份資料庫找出營養素含量，再與澳洲 19-30 歲女性的營養素建議量(NRVs)比較。其中一種膳食模式屬較高醣類飲食(HC)，是根據澳洲健康飲食指南對 19-60 歲女性的建議設計。另一種為較高蛋白質飲食(HP)，是由 CSIRO Total Wellbeing Diet 衍變而來。另外也設計這兩種膳食模式的全素和蛋奶素版本，並與素食者的營養素建議量比較。結果：兩種葷食的膳食模式所提供的營養素都達到平均需要量(EAR)或足夠攝取量(AI)。除了鐵，其他營養素均滿足膳食建議攝取量(RDI)。當一周中有三天攝取紅肉和鐵強化的穀類時，HC 飲食和 HP 飲食的鐵攝取量分別達到 RDI 的 75±30%和 81±31%；但即使紅肉的攝取天數增加到七天，鐵的供給量仍未及 RDI。全素和蛋奶素飲食提供的鐵量都低於 RDI，且全素飲食的含鋅量低於平均需要量。結論：每日提供 6000 kJ 的葷食膳食模式，除了鐵，其餘營養素皆達到 RDI。全素飲食中的鐵和鋅分別未達素食者的 RDI 和 EAR。

關鍵字：鐵、鋅、營養需要量、肥胖、過重