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ORIGINAL RESEARCH

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Healthy plant-based diets and their short-term effects on weight loss, nutrient intake and serum cholesterol levels

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Abstract

Healthy plant-based diets (hPBD) are being promoted to reduce the risks of cardiovascular and associated diseases. This study investigates short-term adherence to a hPBD to examine whether these dietary changes impact weight and cardiovascular risk factors. A simple, uncontrolled, before and after design was used. Twenty women (mean BMI 31 ± 4 kg/m^2) participated in a 6-week hPBD intervention. Participants completed a 3-week reset, eliminating all refined sugar, heavily processed foods, artificial sweeteners, alcohol, meat, fish, dairy and oil from their diets, which could then be reintroduced into their diet if the participant chose to do so. Participants had 1-h, weekly group support sessions. A weight loss of 4.4 kg, SD = 1.8 kg ($n = 17$, $t = 10.2$, $p < 0.001$) was observed after 6 weeks following the hPBD. BMI reduced from 31 to 29 kg/m^2 (mean reduction = 1.38, SD = 0.76, $n = 17$, $t = 7.49$, $p < 0.001$). Reductions for waist circumference (mean reduction = 4.4 cm, SD = 5.22 cm, $n = 8$, $t = 2.55$, $p = 0.034$), LDL cholesterol (mean reduction = 0.600 mmol/L, SD = 0.828, $n = 17$, $t = 2.81$, $p = 0.014$) and total cholesterol (mean = 0.525 mmol/L, SD = 0.969, $n = 17$, $t = 2.24$, $p = 0.040$) were also observed. Body fat % was not significantly reduced (mean reduction = 2.3, SD = 6.6, $n = 17$, $t = 1.49$, $p = 0.154$). Dietary data were obtained from 17 participants at week 3 and from six participants at week 6. Energy intake at week 3 decreased compared with baseline (mean reduction = 1068 kcal/day, SD = 585 kcal, $n = 17$, $t = 7.07$, $p < 0.001$) and at week 6 (mean reduction = 715 kcal, SD = 645 kcal, $n = 6$, $t = 2.72$, $p = 0.042$). Protein, saturated fat and cholesterol intakes were also lower at weeks 3 and 6 compared with baseline. Fibre intake increased significantly from baseline to week 6 (mean increase = 11.3 g/day, SD = 8.9, $n = 6$, $t = 3.11$, $p = 0.027$) whilst sugar intake decreased from baseline to week 3 (mean reduction = 26.0 g/day, SD = 22.3, $n = 17$, $t = 4.52$, $p < 0.001$), but the reduction at week 6 was not significant. These results suggest that motivated participants can learn to adopt new dietary patterns for a few weeks at least with some support. This study demonstrated positive effects of a hPBD on weight reduction, cholesterol and BMI over a short time period, although the short- and long-term adherence to this diet requires further research.

KEYWORDS
BMI, cardiovascular disease, LDL cholesterol, obesity, plant-based diets, saturated fat

INTRODUCTION

Obesity is a worldwide, public health problem. In 2019, 60% of adult women and 67% of adult men in England were classified as either overweight or obese (statistics on obesity, physical activity and diet, England, 2019). By 2030, projections for the numbers of adults with obesity are said to be 11 million more in the UK and associated medical costs will go on to increase by £1.9–2 billion per year by 2030 (Wang et al., 2011). As an ongoing drive to reduce obesity and its associated morbidity in individuals, numerous diets for weight reduction have been employed, primarily focussed on energy restriction to promote reductions in bodyweight (Fleming and Kris-Etherton, 2016). A healthy plant-based diet (hPBD) has become increasingly popular due to several reported benefits to overall health and coronary heart disease risk (Freeman et al., 2017; Huang et al., 2012; Kim et al., 2019; Orlich et al., 2013; Ornish et al., 2007; McEvoy et al., 2012). A hPBD, consisting predominantly of wholegrains, fruits, vegetables and nuts, is different to an unhealthy PBD which may be associated with an increase in the consumption of less-healthy plant foods (e.g. sugar-sweetened beverages and desserts; Orlich et al., 2014). In aiming for a hPBD, reductions in animal food intake, alongside increasing the consumption of plant foods, have been recommended and were used for the purpose of this study.

Recent guidelines for the prevention of cardiovascular disease (CVD; Arnett et al., 2019) recommend following a PBD since they are associated with a lower risk of CVD. Research by Song et al. (2016) strengthened the link between dietary factors and CVD risk by observing associations between animal protein intake and CVD risk, cancer and all-cause mortality. Similarly, Kwok et al. (2014) found comparable results with vegetarians experiencing 29% lower risk of CHD mortality relative to non-vegetarians. Additionally, research conducted by Lara et al. (2019) found that individuals adherent to PBDs had the lowest risks of heart failure (41% reduced risk) of all the diet patterns examined. Whilst previous research suggests that low-fat PBDs reduce bodyweight and improve CV risk factors, few studies have examined the effects of a predominantly hPBD on body composition and blood glucose (BG). Research also suggests that low-fat PBDs can meet adequate protein needs (Craig and Mangels, 2009), but there is a need for more research into the changes in body composition during transition to a hPBD. Additionally, many of the PBDs clinical weight loss trials have recruited individuals who are managing a condition such as type 2 diabetes, for example. This may reduce the generalisability of any findings for other population groups.

Therefore, as well as measuring changes in overall weight over a short time, body composition, BG and serum cholesterol levels will also be measured to offer further support for these limited data.

METHODS

Subjects

Twenty women of any weight and with a stable medical status (free of chronic illness) were recruited through a local gym via posters, adverts and word of mouth. Participants attended an initial briefing session to learn about the study and hPBD and to complete the relevant consent forms. Participants were requested not to alter their exercise habits during the 6-week intervention period and to maintain their current physical activity levels of a minimum of 30 min of moderate-intensity exercise every day.

Participants were informed of the purpose of the study along with their right to withdraw. The study was approved by the Teesside University Ethics Committee (4929), and informed consent was obtained from volunteers prior to enrolment.

Study design

A simple before and after study design was used. Participants were provided with a 3-day dietary diary and instructed on how to record their food intake. Participants then completed a baseline 3-day dietary diary. They were asked to record their diet on three consecutive days of the week, ideally on the same days at each stage of the study. However, there are factors that can affect an individuals' dietary intake, so participants were advised not to record on those days that were atypical of their habitual intake (see Table 1). Dietary records during two weekdays and one weekend day during the 6-week dietary intervention phase were also recorded by the participants at week 3 and week 6. A registered nutritionist, using Nutritics (V 2.0 for Windows 98, First DataBank Inc., Hearst Corporation), analysed these dietary inputs.

Healthy plant-based diet

The hPBD recommended to the participants was compiled of predominantly whole plant foods as per the healthful plant-based diet index (Satija et al., 2017) and provided approximately 40% of energy from fat, 15%–20% from protein and 40%–45% from carbohydrate (see

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TABLE 1 Factors that could affect dietary intake

	Comments
Month	The study took place in November, as there is some evidence that people may gain weight going into the winter (Ma et al., 2002). So, we wanted to encourage these healthy habits prior to this time
What to record	Clear instructions, examples and guidance were provided prior to the recording of any data. Daily support was also available on recording should they have had any issues
Time of day	We advised they recorded as they went to save forgetting anything. Guidance was provided on the most reliable way to best capture this data
Day of week	For ease and consistency, participants were advised to record on the same days of the week. However, they were also advised not to worry if something had occurred which affected their intake and subsequent recording of it for that specific day and to record another, more typical day
Festivities	As above
Fasting periods	As above
Misreporting	The participants were given clear guidance on the implications of underreporting/ misreporting dietary information and that this would only impact on them. There were no issues reported to us regarding the recording of these data

Table 2). This consisted predominantly of wholegrains, vegetables, legumes, and fruits, nuts and seeds and plenty of fluids. Individuals were not limited on energy intake and were provided with a list of fibre-rich foods they could consume to increase satiety. Education was provided on both portion control and serving suggestions as well as an ABC model of eating (Appendix), which included three meals a day (from starchy carbohydrate, protein, vegetable and herb sources), one snack and unlimited highly nutrient dense (HND) foods. Participants were encouraged to consume more of these fibre-rich foods, whilst the behaviour change element of educating on carbohydrate and foods higher in energy aimed to promote a reduction in overall energy intake (without participants feeling restricted). No meals were provided, and participants prepared their own meals. Participants who completely removed all animal products from their diet were advised to supplement with vitamin B12 (1000 µg/week).

For the first 3 weeks, participants completed a reset phase which eliminated all refined sugar, heavily processed foods, artificial sweeteners, alcohol, meat, fish, dairy and oil from their dietary pattern. Heavily processed foods were defined as ultra-processed foods (UPF) and were explained to the participants according to the NOVA classification, which is 'formulations of ingredients, mostly for industrial use only, derived from a series of industrial processes' (Monteiro et al., 2019). Examples of UPF are breakfast cereals, savoury snacks, reconstituted meat products, frankfurters, pre-packaged frozen dishes, soft and/or sweetened drinks, distilled alcoholic beverages and supplements. Oil was removed initially as a lot of discussions with the participants were around heart health, whole food consumption and reducing unnecessary calories from the diet. A lot of the participants were adding extra oil to cooking, thereby increasing their calorie consumption unnecessarily. This was an obvious and easy initial change for the participants to make to encourage cooking without oil, and using spices and herbs to enhance the flavour, without the added extra calories from the oil. From week four, all foods could be reintroduced into the diet if the participant chose to do so. Nutritional instruction did not emphasise single micronutrients or macronutrients but rather focussed on the importance of a whole diet approach as recommended by Real et al. (2019). A daily checklist was recommended to provide ideas of both the types and quantity of foods they should be aiming to consume daily to ensure optimal micronutrients intake (Appendix and Table 2). This checklist was adapted from Gregor (2015).

Participants were given examples of plant-based protein sources, fruits, vegetables and wholegrains. In practice, this led to the group basing their meals around beans (e.g. pinto, black and kidney beans), soy foods (e.g. tofu and soy-based products), wholegrains (e.g. brown rice, whole wheat/spelt pasta, quinoa, barley and oats), vegetables and fruit.

The recommended hPBD translated into 3 to 4 servings of plant-based protein/day (e.g. 100 g beans/palm serving size of tofu). Starchy vegetables were recommended for mealtimes only with HND foods unlimited throughout the day and 2 servings of fruit (200 g) plus a handful of berries in a day (30 g) and 3–4 servings of wholegrains a day (120–150 g). A typical hPBD menu is presented in Table 2. This guidance remained the same throughout the whole 6-week period, and guidance on

TABLE 2 Sample plant-based menu

Sample plant-based menu				
Breakfast	**Lunch**	**Snack**	**Dinner**	**High nutrient dense foods**
Oatmeal with cinnamon and soymilk topped with berries 1 tsp of sugar and oil-free nut butter. 1 tbsp flaxseed	Hummus wholemeal wrap with spinach and cucumber	Carrot and pepper batons with tahini and lemon dip Dairy-free yogurt with berries and sunflower seeds. Piece of fruit with 1 tbsp nut butter	Three bean chilli, brown rice, mixed vegetables 1 tbsp guacamole	Onions, mushrooms, celery, any type of lettuce and leafy greens Courgette, nori/kelp/seaweed All herbs and spices Turmeric root/powder Ginger root or powder Tamari Tomato puree—no oil added Tabasco

meal planning and food alternatives were discussed within the weekly educational and support sessions.

Physical measures

All measurements were taken by the same researcher at the same time of day. All measurements took place in a fasted state upon arrival to the laboratory before 10 AM. Baseline total cholesterol (TC), low-density lipoprotein (LDL), high-density lipoprotein (HDL), HDL/LDL ratio and triglycerides (TG) were measured using the Mission Cholesterol monitoring system. BG was measured using NESCO Glucose monitor (Nesco Pro MultiCheck IVD Machine).

Body composition was measured using InBody S10, and bodyweight was determined via a digital scale (accurate to 0.1 kg; Seca 869 digital scales). Participants wore leggings and a light vest whilst getting weighed. Waist circumference (WC) was measured with a tape measure (Lufkin W606PM) placed 2.5 cm above the umbilicus. This was rounded to the nearest 5 mm. All these measurements were replicated under the same fasted state conditions following 6 weeks on the plant-based diet.

Behaviour change education and support

Participants were invited to a 1-h initial nutrition lecture to help familiarise them with the hPBD and study procedures. Thereafter, participants attended weekly, face-to-face 1.5-h group lectures providing group support, nutritional information and education about their hPBD along with recipe ideas and shopping lists.

The sessions were developed and delivered by two nutritionists registered with the Association for Nutrition and were informed by the Diabetes Prevention Program, which has been successful in maintaining weight loss and reducing the incidence of diabetes (DPP, 2002). Participants were also invited to join a closed Facebook group after session 1 to provide social support during the transition to the hPBD. Whilst the participants were in the same gym, they did not directly know each other before the study began.

The topic sessions for the group were as followed:

- Ways to stay motivated: Overview of PBD and setting goals and motivation
- Problem solving: Using a food diary and overcoming challenges
- Four keys to healthy eating out and eating in: batch cooking and portioning
- Tip the calorie balance: Food swaps—healthy snacks
- Talkback to negative thoughts: is it hunger or a craving? How to tell the difference and what you can do, examining emotional cravings.

Statistical analysis

Within this present study, 20 participants were tested for a number of health parameters at the outset. Following 6 weeks on a hPBD, the same parameters were measured again. This is known as a 'repeated measures' test involving the same individuals both before and after an intervention. An appropriate test to look for significant changes in the measurements before and after an intervention is the paired *t*-test. As this is a parametric test, the data were tested for approximate conformity with the normal distribution. Significance levels for all the tests were set at an alpha of 0.5.

RESULTS

Within the present study, 17 out of the initial 20 participants successfully completed the study. Two participants were unable to commit to the dietary changes and one was unable to attend the meetings due to lack of time. In practice, however, whilst 17 respondents provided full information in week 3, only six respondents provided dietary information at week 6. Where occasional missing data values occurred in the week 3 information, it was assumed that no change had taken place for the respondents with missing data. This is a

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conservative form of ITT (intention to treat) analysis. ITT analysis was not attempted for the week 3 WC and week 6 data as this is not recommended with high drop-out fractions.

Bodyweight and composition

After 6 weeks following the hPBD, bodyweight (kg) showed a significant reduction (mean reduction = 4.4 kg, SD = 1.8 kg, n = 17, t = 10.2, $p < 0.001$) and BMI was significantly reduced from 31 to 29 kg/m^2 (mean reduction = 1.38, SD = 0.76, n = 17, t = 7.485, $p < 0.001$; Table 3). Significant reductions in WC were also observed from baseline (95 cm) to week 6 (91 cm; mean reduction = 4.44 cm, SD = 5.22, n = 8, t = 2.553, p = 0.034), although technical issues led to a lack of data being collected for nine participants. Body fat % was not significantly reduced.

Total cholesterol, low-density lipoprotein, high-density lipoprotein, triglycerides and blood glucose

After 6 weeks following the hPBD, there was a significant reduction in LDL from 3.4 to 2.8 mmoL/L (mean reduction = 0.53 mmol/L, SD = 0.80, n = 17, t = 2.73, p = 0.015; see Table 3). TC showed a significant reduction from 5.81 to 5.29 mmol/L (mean reduction = 0.53, SD = 0.97, t = 2.236, n = 17, p = 0.040). Reductions in HDL, BG and TG were not significant.

Dietary intake

Regardless of the absence of any prescribed food intake limit, reported energy intake decreased in week three (mean reduction = 1068 kcal, SD = 585, n = 17, t = 7.07, $p < 0.001$ kcal) and in week six (mean reduction = 715 kcal, SD = 645, n = 6, t = 2.72, p = 0.042) relative to the baseline week.

Intakes of protein (mean reduction = 52.2 g, SD = 19.8 g, n = 17, t = 10.2, $p < 0.001$), saturated fat (mean reduction = 22.6 g, SD = 10.8, n = 17, t = 8.1, $p < 0.001$) and cholesterol (mean reduction = 247.8 mg, SD = 150.5 mg, n = 17, t = 6.4, $p < 0.001$) were significantly lower at week 3 compared with baseline. The data for week 6 also showed significant reductions in these nutrients, albeit with data from only six participants.

Fibre intake increased significantly (mean increase = 11.3 g, SD = 8.9, n = 6, t = 3.11, p = 0.027.) from baseline to week 6. Reported sugar intake decreased from baseline at week 3 (mean reduction = 26.0 g, SD = 22.3 g, n = 17, t = 4.52, $p < 0.001$), but the reduction at week 6 was not significant.

Vitamin B12 decreased by 4.5 μg at 6 weeks to 0.8 μg. The relevant data including differences between weeks 3 and 6 are presented in Table 4.

DISCUSSION

This study examined the short-term effects of hPBD diets on factors including body composition, cholesterol, BG and nutrient intake. Similarly to Moore et al. (2015), this is one of the few studies that has attempted to encourage, educate and empower individuals in adopting a hPBD. Results for the present study suggest that motivated participants can learn to adopt entirely new dietary patterns with both limited contact time (approximately 2 h a week of support from the researchers and fellow participants) and dietary self-monitoring, which can be burdensome and time-consuming, although the long-term sustainability of these dietary changes was not assessed. The study offers evidence for weight loss as well as for improved macronutrient, fibre and cholesterol intakes over a short space of time within individuals following hPBDs. The favourable changes in free sugars, saturated fat, fibre and cholesterol intakes and the positive effects on LDL cholesterol and bodyweight point to potential uses of hPBD eating styles in both the prevention and treatment of obesity and related chronic diseases. Differences observed within

TABLE 3 Changes in low-density lipoprotein (LDL), high-density lipoprotein (HDL), total cholesterol (TC), triglyceride (TG), blood glucose (BG) and weight from baseline to 6 weeks on the healthy plant-based diet

	Baseline	6 weeks	*p* value	Number of participants
LDL (mmol/L)	3.4	2.8	0.01	15
HDL (mmol/L)	1.87	1.69	0.01	17
TC (mmol/L)	5.8	5.2	0.04	17
TG (mmol/L)	1.4	1.4	0.74	17
BG (mmol/L)	5.2	5	0.12	14
Weight (kg)	87.1	82.7	0.00	17
BMI (kg/m^2)	31	29	0.00	17
Body fat (%)	37.1	34.7	0.15	17
Waist circumference (cm)	95	90.6	0.03	9

TABLE 4 Nutrient profile of participants following 3 and 6 weeks on the healthy plant-based diet (hPBD) compared with baseline

	Baseline	3 weeks hPBD (*n* = 17)	6 weeks hPBD (*n* = 6)
Energy (kcal)	2217	1107.2*	1402.5*
Fibre (g)	24	26.4	34.9*
Protein (g)	91.5	41	55.8*
Carbohydrate (g)	248.5	140	180
Free sugars (g)	35	7.3*	9.05
Total fat (g)	88	46	49
Saturated fat (g)	31.4	8.8*	13.5*
Cholesterol (mg)	271.5	19.4*	35.53*
Vitamin C (mg)	83	131.5*	124.5
Iron (mg)	12.2	12	13.15
Vitamin K (mcg)	50.4	96	216.5
Folate (mcg)	301.3	283.1	334.5
Magnesium (mg)	341.7	327	359
Vitamin B12 (mcg)	5.3	0.7	0.8*
Calcium (mg)	925.8	481	787.5
Omega 3 (g)	1.5	1	1.3

Note: Data are presented as means ± SD.
This comparison was baseline vs. week 3 and week 6, respectively.
*Statistical significance was set at the $p = \leq 0.05$ in paired *t*-test.

health and weight outcomes in the present study could be due to alterations in dietary intake of nutrients, since they reflect previous research which has consistently demonstrated higher dietary fibre and lower saturated fat intakes among vegans compared with omnivores (Barnard et al., 2005; Turner-McGrievy et al., 2004). The current hPBD findings of this study are similar to those of Dinu et al. (2017), who also observed significantly lower levels of BMI, TC and LDL cholesterol following the consumption of a hPBD. Suggestions for beneficial effects of hPBD on total and LDL cholesterol may lie in the lower intake of saturated fats as well as the higher consumption of foods known to decrease these parameters such as soybeans, legumes, nuts and vegetables upon which the study's hPBD recommendations were based.

Whilst the aim of this study was not weight loss, the average 6-week weight loss within this study (7.5%) was greater than that observed in previous behavioural weight loss interventions, which typically lead to averages of 5% weight loss using a diet-only approach (Siopis et al., 2015). Although adherence is vital, weight loss occurred despite participants having no restriction on the intake of fibre-rich foods. Participants also did not fully adhere to a hPBD for the full 6 weeks of the study and could reintroduce refined sugar, heavily processed foods, artificial sweeteners, alcohol, meat, fish, dairy and oil after 3 weeks if they wished. This aligns with previous suggestions that adherence to hPBD may not need to be complete to observe beneficial health effects (Moore et al., 2015) and suggests that the removal of these types of foods, in addition to adherence to exercise, may be effective in the short term to elicit some positive health effects.

Potential mechanisms underlying effects of hPBDs on BMI could be due to abundant intake of wholegrains, fruits and vegetables, which tend to be rich in components such as fibres, antioxidants, phytochemicals and minerals (ADA, 1997). These specific nutrients delay gastric emptying along with enhancing satiety (Bortolotti et al., 2008), which could support the participants voluntarily consuming fewer calories than before.

The increase in fibre intakes and the associated weight loss seen in this study support the findings of Song et al. (2016; Nurses' Health Study [NHS]), who found that those with higher fibre intakes gained less weight than those with lower intakes of fibre. Similarly, He et al. (2004) found that women within the NHS who significantly increased their fruit and vegetable intake had a 28% lower risk of major weight gain (≥25 kg) than those with lowest intake.

Nutrient profiles of the hPBD patterns can help support CV risk reduction since dietary fibres, folate, antioxidants and phytochemicals rich in fruits and vegetables (Haddad et al., 1999; Larsson and Johansson, 2005), wholegrains, soy and nuts (Sabate & Wien, 2010; Sabate, Oda and Ros, 2010; Ros, Tapsell and Sabate, 2010) are all associated with lower levels of serum cholesterol, as well as being low in saturated fat (Djousse et al., 2004). These nutrient profiles were reflected in the present study following the 6-week intervention.

Vegans, or individuals on a hPBD who have chosen to entirely remove all animal products from their diet, can have challenges in meeting nutritional requirements for vitamin B12 and calcium in comparison with those consuming animal products. In addition, optimising intakes of *n*-3 is highly recommended for individuals on a hPBD (Rosell et al., 2005). In the present study, *n*-3 fatty acid intake dropped slightly at 3 weeks but was similar to baseline levels at 6 weeks due to the participants getting familiar with their new diets, in terms of what are good sources of *n*-3, and also being able to reintroduce some foods into their diet that were initially restricted, if they wanted to. Calcium intakes were reduced due to the initial removal of dairy products. Vitamin B12 intakes were also reduced at 6 weeks to below the RNI and participants had to be reminded to take supplements if they were to continue on a hPBD since none of them were consuming supplements beforehand.

The present study found that daily protein intake was reduced from 91.5 to 55.8 g ($p = 0.001$), which is close to the RNI for UK adult females (45 g) and males (55 g). Analysis of data from the *National Health and Nutrition Examination Survey III* reported that higher protein intake was associated with increased risk for all-cause mortality among participants younger than 65 years although the association disappeared when animal protein intake was controlled for (Levine et al., 2014). These data suggest then that the recommended protein quantity was achieved and the quality was maintained through the range of hPBD sources, reducing the potential negative effects of animal sources of protein on health.

Similarly, regarding sources of hPBDs, the results of the current study are in line with Satija et al., 2017 who found hPBDs to be associated with substantially lower CHD risk compared with consumption of animal products or unhealthy PBDs. Satija et al. (2017) highlighted the wide variation within nutritional quality of plant foods, making it crucial to consider the quality of plant foods consumed within plant-rich diets. The results of the current study as well as those of Satija et al. (2017) are in accordance with the recently released 2019 Dietary Guidelines for the prevention of CVD (Arnett et al., 2019), which recommends higher consumption of high-quality plant foods.

These findings, along with previously mentioned research describing an association between animal protein intake and CVD, cancer and all-cause mortality (Song et al., 2016), further strengthen the importance of both hPBD and protein sources. These findings also support recommendations to increase plant protein intake, which in turn calls for the education of GPs, patients and the general public about the largely unrecognised protein content of plants (Williams & Patel, 2017).

Whilst this study demonstrates that individuals in a real-life setting and preparing their own meals can make and adhere to dietary changes, there are some study limitations to be considered. The small sample size, the lack of dietary data from the majority of the participants at week 6 and the short duration of the study have an impact on the generalisability of the results. The recruitment of participants from a gym may also have meant that participants were more motivated than most. The lack of dietary data at week 6 from so many participants makes it difficult to know whether these participants were continuing with the diet or not. However, verbally participants fed back to the researchers that they were adhering to the dietary changes and the reduction in compliance with dietary intake recording and provision to the researchers as the weeks progressed anecdotally was due to the participants being more confident with what they were eating and how they were managing their intake, as initially they were using the diary as a log for themselves to remind them on what they had consumed and perhaps what they did/did not enjoy. Whilst it is positive to see such results within such a small sample size, future studies will need to monitor more people over a longer period to assess whether the dietary changes that were adopted can be maintained over time. This and future studies should also monitor the dietary changes more closely to identify which changes were maintained and why and also which aspects of the protocol supported these changes the most. This will be useful information in the development of weight management protocols in the future.

Another limitation is that a simple before and after study design was used. Whilst this is not as robust as a double-blind randomised, randomised controlled trial (Axelrod & Hayward, 2006), a randomised controlled trial (RCT) was not employed for the following reasons: it would be difficult to arrange a suitable reference diet for the control group; it would be apparent to the participants which arm of the trial they were on or it would be impractical and unethical to try to hide this from them; most participants might be expected to realise that the diet with the larger content of plant-based protein is the 'healthy option' so a control group would not protect against the Hawthorne effect where individuals modify an aspect of their behaviour in response to their awareness they are being observed. Since an RCT approach was thought to be difficult and of limited value, it was decided to proceed with a simple before and after study. The lack of a control group does not guard against the possibility that there was some overall change in the mean weight, for instance, of the group due to some confounding variable; hence, it is necessary to look carefully at the size of any change and consider what other factors may have caused it. However, the trial took place in November and there is some evidence that people may gain weight going into the winter (Ma et al., 2002) due to a number of factors including a reduction in physical activity levels. So, it may be argued that one obvious source of bias would be expected to produce an increase in mean weight rather than a decrease.

CONCLUSION

This small study enhances the growing body of evidence for the positive effects of hPBDs on weight reduction, cholesterol and BMI, suggesting that they could play a role in the prevention of several chronic diseases. Whilst both the dietary pattern changes and the sustainability of adhering to these dietary changes need further investigation, the results are positive in that motivated participants can adopt new dietary patterns for a few weeks at least with some support and education. These findings highlight the potential importance of hPBD sources and support recommendations to increase plant protein intake. However, longer-term studies with larger sample sizes, where the dietary pattern has been monitored, are required in order for this to become an evidence-based recommendation.

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CONFLICT OF INTEREST

None.

ETHICAL APPROVAL

This study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving research study participants were approved by the School of Science and Engineering ethics sub-committee at Teesside University. Written informed consent was obtained from all subjects.

DATA AVAILABILITY STATEMENT

Data available on request from the authors: #10; #10; The data that support the findings of this study are available from the corresponding author upon reasonable request.

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REFERENCES

ADA (American Dietetic Association). (1997) Position of the American dietetic association: vegetarian diets. *Journal of American Dietetic Association*, 97, 1317.

Arnett, D.K., Blumenthal, R.S., Albert, A.M., Buroker, A.B., Goldberger, Z.D., Hahn, E.J. et al. (2019) ACC/AHA guideline on the primary prevention of cardiovascular disease: a report of the American College of Cardiology/American Heart Association task force on clinical practice guidelines. *Circulation*, 140(11), e596–e646.

Axelrod, D.A. & Hayward, R. (2006) Nonrandomized interventional study designs (quasi-experimental designs). In: Penson, D.F. & Wei, J.T. (Eds.) *Clinical research methods for surgeons*. Totowa, NJ: Humana Press.

Barnard, N.D., Scialli, A.R., Turner-McGrievy, G., Lanou, A.J. & Glass, J. (2005) The effects of a low-fat, plant-based dietary intervention on bodyweight, metabolism, and insulin sensitivity. *American Journal of Medicine*, 118(9), 991–997.

Bortolotti, M., Levorato, M., Lugli, A. & Mazzero, G. (2008) Effect of a balanced mixture of dietary fibers on gastric emptying, intestinal transit and bodyweight. *Annuals of Nutrition and Metabolism*, 52, 221–226.

Craig, W.J. & Mangels, A.R. (2009) Position of the American dietetic association: vegetarian diets. *Journal of the American Dietetic Association*, 109, 1266–1282.

Dinu, M., Abbate, R., Gensini, G.F., Casini, A. & Sofi, F. (2017) Vegetarian, vegan diets and multiple health outcomes: A systematic review with meta-analysis of observational studies. *Critical reviews in food science and nutrition*, 57(17), 3640–3649.

Djousse, L., Arnett, D.K., Coon, H., Province, M.A., Moore, L.L. & Ellison, R.C. (2004) Fruit and vegetable consumption and LDL cholesterol: the National Heart, Lung, and Blood Institute family heart study. *American Journal of Clinical Nutrition*, 79, 213–217.

DPP. (2002) The diabetes prevention program (DPP). *Diabetes Care*, 25, 2165–2171.

Fleming, J.A. & Kris-Etherton, P.M. (2016) Macronutrient content of the diet: what do we know about energy balance and weight maintenance? *Current Obesity Reports*, 5, 208–213.

Freeman, A.M., Morris, P.B., Barnard, N., Esselstyn, C.B., Ros, E., Agatson, A. et al. (2017) Trending cardiovascular nutrition controversies. *Journal of the American College of Cardiology*, 69, 1172–1178.

Gregor, M (2015) How not to die first daily dozen checklist guidelines. ISBN: 978-1 509 852 505 pg 310

Haddad, E.H., Berk, L.S., Kettering, J.D., Hubbard, R.W. & Peters, W.R. (1999) Dietary intake and biochemical, hematologic, and immune status of vegans compared with nonvegetarians. *American Journal of Clinical Nutrition*, 70, 586s–593s.

He, K., Hu, F.B., Colditz, A.G., Manson, J.E., Willet, W.C. & Liu, S. (2004) Changes in intake of fruits and vegetables in relation to risk of obesity and weight gain among middle-aged women. *International Journal of Obesity and Related Metabolic Disorders*, 28(12), 1569–1574.

Huang, T., Yang, B., Zheng, J., Li, G., Wahlqvist, M.L. & Li, D. (2012) Cardiovascular disease mortality and cancer incidence in vegetarians: a meta-analysis and systematic review. *Annuals of Nutrition and Metabolism*, 60, 233–240.

Kim, H., Caulfield, L.E. & Rebholz, C.M. (2019) Healthy plant-based diets are associated with lower risk of all-cause mortality in US adults. *The Journal of Nutrition*, 148(4), 624–631.

Kwok, C.S., Umar, S., Myint, P.K., Mamas, M.A. & Loke, Y.K. (2014) Vegetarian diet, seventh day adventists and risk of cardiovascular mortality: a systematic review and meta-analysis. *International Journal of Cardiology*, 176, 680–686.

Lara, M.K., Levitan, E.B., Gutierrez, O., Shikany, M., Safford, M.M., Judd, S.E. et al. (2019) Patterns and incident heart failure in U.S. adults without known coronary disease. *Journal of the American College of Cardiology*, 73(16), 2046–2048.

Larsson, C.L. & Johansson, G.K. (2005) Young Swedish vegans have different sources of nutrients than young omnivores. *Journal of the American Dietetic Association*, 105, 1438–1441.

Levine, M.E., Suarez, J.A., Brandhorst, S., Balasubramanian, P., Cheng, C.W., Madia, F. et al. (2014) Low protein intake is associated with a major reduction in IGF-1, cancer, and overall mortality in the 65 and younger but not older population. *Cell Metabolism*, 19(3), 407–417.

Ma, Y., Olendzki, B., Li, W., Hafner, A.R., Chiriboga, D., Hebert, J.R. et al. (2002) Seasonal variation in food intake, physical activity, and bodyweight in a predominantly overweight population. *European Journal of Clinical Nutrition*, 60, 519–528.

McEvoy, C.T., Temple, N. & Woodside, J.V. (2012) Vegetarian diets, low-meat diets and health: a review. *Public Health Nutrition*, 15, 2287–2294.

Monteiro, C.A., Cannon, G., Levy, B.R., Moubarac, J.C., Louzada, M.L.C., Rauber, F. et al. (2019) Ultra-processed foods: what they are and how to identify them. *Journal of Public Health Nutrition*, 22, 936–941.

Moore, W.J., McGrievy, M.E. & Turner-McGrievy, G.M. (2015) Dietary adherence and acceptability of five different diets, including vegan and vegetarian diets, for weight loss: the new DIETs study. *Eating Behaviors*, 19, 33–38.

Orlich, M.J., Singh, P., Sabaté, J., Jaceldo-Siegl, K., Fan, J., Knutsen, S. et al. (2013) Vegetarian dietary patterns and mortality in Adventist health study 2. *The Journal of the American Medical Association Internal Medicine*, 173, 1230–1238.

Orlich, M.J., Jaceldo-Siegl, K., Sabaté, J., Fan, J., Singh, P.N. & Fraser, G.E. (2014) Patterns of food consumption among vegetarians and non-vegetarians. *British Journal of Nutrition*, 112, 1644–1653.

Ornish, D., Scherwitz, L.W., Billings, J.H., Brown, S.E., Gould, K.L., Merritt, T.A. et al. (2007) Intensive lifestyle changes for reversal of coronary heart disease. *The Journal of the American Medical Association*, 280, 2001–2007.

Real, H., Queirox, J. & Graça. (2019) Mediterranean food pattern vs. Mediterranean diet: a necessary approach? *International Journal of Food Sciences and Nutrition*, 71, 1–12.

Ros, E., Tapsell, L.C. & Sabate, J. (2010) Nuts and berries for heart health. *Current Atherosclerosis Reports*, 12, 397–406.

Rosell, M.S., Lloyd-Wright, Z., Appleby, P.N., Sanders, T.A., Allen, N.E. & Key, T.J. (2005) Long-chain *n*-3 polyunsaturated fatty acids in plasma in British meat-eating, vegetarian, and vegan men. *American Journal of Clinical Nutrition*, 82, 327–334.

Sabate, J., Oda, K. & Ros, E. (2010) Nut consumption and blood lipid levels: a pooled analysis of 25 intervention trials. *Archives of Internal Medicine*, 170, 821–827.

Sabate, J. & Wien, M. (2010) Nuts, blood lipids and cardiovascular disease. *Asia Pacific Journal of Clinical Nutrition*, 19, 131–136.

Satija, A., Bhupathiraju, S.N., Spiegelman, D., Chiuve, S.E., Manson, J.E., Willett, W. et al. (2017) Healthful and unhealthful plant-based diets and the risk of coronary heart disease in U.S. adults. *Journal of the American College of Cardiology*, 70, 411–422.

Siopis, G., Chey, T. & Allman-Farinelli, M. (2015) A systematic review and meta-analysis of interventions for weight management using text messaging. *Journal of Human Nutrition and Dietetics*, 28, 1–15.

Song, M., Fung, T.T., Hu, F.B., Willett, W.C., Longo, V.D., Chan, A.T. et al. (2016) Association of animal and plant protein intake with all-cause and cause-specific mortality. *The Journal of the American Medical Association Internal Medicine*, 176, 1453.

Turner-McGrievy, G.M., Barnard, N.D., Scialli, A.R. & Lanou, A.J. (2004) Effects of a low-fat vegan diet and a step II diet on macro-and micronutrient intakes in overweight postmenopausal women. *Nutrition*, 20, 738–746.

Wang, Y.C., McPherson, K., Marsh, T., Gortmaker, S.L. & Brown, M. (2011) Health and economic burden of the projected obesity trends in the USA and the UK. *Lancet*, 378, 815–825.

Williams, K.A. & Patel, H. (2017) Healthy plant-based diet what does it really mean? *Journal of the American College of Cardiology*, 70(4), 423–425.

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APPENDIX

ABC MODEL OF MEAL PLANNING

A

Choose your starchy (high fibre) carbohydrate.

Portion: Fist size, 1 slice, 1 wholemeal wrap, 1 wholemeal pitta, 30–40 g uncooked oats, brown rice, spelt/wholemeal pasta, noodles.

Example:

Baked sweet potato
Brown rice
Quinoa
Baby potatoes
Baked white potato
Sweet potato wedges—oil-free
Wholemeal or seeded wrap
Sourdough bread
Wholemeal bread/pitta
2 wholemeal thins
Barley
Couscous

B

Choose your protein.

Portion: Palm size or 100 g cooked/drained beans, lentils, tofu (nuts and seeds to be within the allowance—see daily checklist)

Examples:

Beans (e.g. butter, kidney, edamame, black, chickpeas)
Lentils (e.g. puy, red, green)
Tofu, Seitan, Veggie mince

C

Choose vegetables and herbs, the more vegetables you can add the better, try to have at least two vegetables, and load your plate with as many of the free foods as you can, and this will fill you up, feed your microbiome boosting your immunity and impacting on your overall wellbeing and glowing skin.