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Association of diet quality and weight increase in adult heart transplant recipients

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Abstract

Background: Understanding the quality of the diet of heart transplant recipients (HTRs) is essential to developing effective dietary interventions for weight control, but relevant evidence is scarce. We investigated diet quality and its association with post-transplant increase in weight adjusted for height (body mass index [BMI]) in Australian HTRs.

Methods: We recruited adult HTRs from Queensland's thoracic transplant clinic, 2020–2021. Study participants completed a 3-day food diary using a smart-phone app. Socio-demographic information was collected by self-administered questionnaire, and height, serial weight and clinical information were obtained from medical records. We calculated the Dietary Approaches to Stop Hypertension (DASH) index based on nine food groups and nutrients (index of 90 indicates highest possible quality), and any changes in BMI (≤ 0 kg m^{-2} or >0 kg m^{-2}) post-transplantation. Median DASH index values were assessed in relation to sex and BMI change using Mann–Whitney *U* test.

Results: Among 49 consented HTRs, 25 (51%) completed the food diary (median age 48 years, 52% females). Median BMI at enrolment was 27.2 kg m^{-2}; median BMI change since transplant was +3.7 kg m^{-2}. Fruit, vegetable, and whole grain intakes were generally lower than recommended, giving a low overall median DASH index of 30 with no sex differences. HTRs for which the BMI increased post-transplant had significantly lower median DASH indices than those whose BMI did not increase (30 vs. 45, $p = 0.013$).

Conclusions: The diet quality of HTRs appears suboptimal overall, with fruit and vegetable intakes especially low. HTRs whose BMI increased post-transplant had substantially lower quality diets than HTRs whose BMI did not increase.

KEYWORDS
body mass index, diet quality, heart transplantation, weight gain

Highlights

- Overall, consumption of wholegrains, vegetables, fruit and saturated fat was suboptimal in study heart transplant recipients
- Diet quality was significantly lower in study heart transplant recipients whose body mass index (BMI) increased after transplantation compared to those whose BMI did not increase

INTRODUCTION

Survival of heart transplant recipients (HTRs) has improved substantially in the last few decades, from a median of 8.6 years in 1981–1991 to 12.5 years in 2002–2009.[1] However, the risk of metabolic disorders in HTRs has increased alongside their improved prognosis. According to the Registry of the International Society for Heart and Lung Transplantation, at 5 years post-transplantation, 98% and 88% of adult HTRs have developed hypertension and dyslipidaemia respectively.[2] Similarly, post-transplant weight gain is common, with an approximate 7 kg weight gain reported on average in the first year after transplantation.[3] Excessive weight gain and other metabolic disorders can lead to the development of cardiac allograft vasculopathy, the main complication that limits the survival of HTRs.[4]

Among the general population, a fundamental approach to reducing risk of cardiometabolic disease is following a healthy diet. As a corollary, unhealthy diets that are low in vegetables and fruit and high in sugar and salt, are associated with high body mass, hypertension, diabetes and dyslipidaemia.[5,6] The same is considered to be true of HTRs, although to date, very few dietary studies among HTRs have been conducted.[7] In a dietary intervention study among thoracic transplant recipients in England, baseline diet was found to be low in fruit and vegetables.[8] In the same study, the weight of HTRs decreased slightly after 12 months of dietary intervention, whereas the weights of control HTRs who did not participate in the study, increased.[9] Similarly, in a study of US HTRs at least 12 months post-transplantation, 50% (14/24) were consuming high-fat diets (≥ 37% energy from fats) and significantly increased their mean weight (73 kg pre-transplant to 83 kg 12 months post-transplant $p < 0.05$).[10] Dietary studies of other organ transplant recipient groups have also shown low adherence to recommended diets, with subsequent weight increase. In kidney transplant recipients in the USA for example, diet quality before transplantation, at 3 months and at 12 months post-transplantation was low at all time points, and body weight increased during the same period.[11] Other studies of kidney transplant recipients' diets and body weight have reported similar findings.[12,13]

Understanding the dietary habits of contemporary HTRs is essential for the conduct of effective dietary interventions to control weight and slow progression of other metabolic dysfunctions. We therefore aimed to assess dietary intake and diet quality, as well as to explore any association between diet quality and increase in post-transplant weight adjusted for height, termed body mass index (BMI), among adult HTRs in the Australian state of Queensland.

METHODS

This cross-sectional study was conducted among HTRs treated at The Prince Charles Hospital, Queensland's cardiac transplant centre. Eligible participants were HTRs ≥3 months post-transplantation, aged ≥18 years at time of recruitment who had access to a smart phone or iPad and were able to communicate in English. Between November 2020 and May 2021, a transplant clinic nurse or a transplant physician invited patients to take part during attendance at routine follow-up clinics; a research assistant obtained signed consent from agreeable patients. Metro North Hospital and Health Services Human Research Ethics Committee reviewed and approved the study (LNR/2020/QPCH/65776).

Data collection

Participants were asked to complete a 3-day (two weekdays and one weekend day) food diary using a smart phone app called Research Food Diary (Xyris Pty Ltd). This app have shown feasible for collecting dietary intake data in Australian adults in clinical and research settings.[14] We provided patients with an information booklet that contained detailed instructions for installing the app and recording their intakes on diary days. Respondents were asked to list all foods and beverages consumed, including brand names, recipes (as applicable), total volume consumed and the defined meal occasions (e.g., breakfast, snack). In addition, HTRs could attach additional text and/or photo information.

Diet quality: DASH dietary index

To evaluate diet quality, we used the Dietary Approaches to Stop Hypertension (DASH) dietary pattern.[15] Originally developed to manage high blood pressure and prevent cardiovascular disease, DASH has consistently shown beneficial effects on body weight,[16] blood pressure,[17] blood cholesterol[18] and cardiovascular health.[19] The DASH diet is high in fruit, vegetables and whole grains, with limited intake of high-fat meats, sugar-sweetened beverages, sweets and sodium.

We used energy-adjusted (kcal) DASH dietary pattern index,[20] comprising seven food groups and two nutrients, positively weighting (i) high consumption of whole grains, vegetables, fruit, plant protein and dairy and (ii) limited consumption of animal protein, added sugars, saturated fat and sodium (Table 1). The DASH dietary intakes of food-group targets are based on total energy requirements that vary with age, sex and activity levels[15] but, because we did not have information on activity levels, we conservatively assumed all participants were sedentary. An energy-adjusted DASH dietary index was calculated for each patient: first calculating daily energy-adjusted intakes of each food component by summing each of the total food group intakes (servings) over 3 days and dividing by three. Second, the total daily intake was divided by energy requirements (kcal), and then multiplied by 1000, which

TABLE 1 Dietary approaches to stop hypertension (DASH) dietary components and scoring.

	Maximum score (10 points)	Intermediate score (5 points)	Minimum score (0 points)
Whole grains (servings[a] /1000 kcal)	≥2	<2 to ≥1	<1
Vegetables (servings[b] /1000 kcal)	≥2.4	<2.4 to ≥1.2	<1.2
Fruit (servings[c] /1000 kcal)	≥2.4	<2.4 to ≥1.2	<1.2
Animal protein (servings[d] /1000 kcal)	≤2.4	>2.4 to ≤3.4	>3.4
Plant protein (servings[e] /1000 kcal)	≥0.35	<0.35 to ≥0.2	<0.2
Dairy (servings[f] /1000 kcal)	≥1.6	<1.6 to ≥0.8	<0.8
Sugar (teaspoons/1000 kcal)	≤1.5	>1.5 to ≤3	>3
Sodium (mg/1000 kcal)	≤1095	>1095 to ≤2099	>2099
Percentage energy from saturated fat	≤6	>6 to ≤10	>10

[a]1 serving = 1 slice of bread, 0.5 cup cooked rice, pasta or cereal, 1 oz (28.35 g) of dry cereal.

[b]1 serving = ½ cup cooked vegetables, 1 cup leafy vegetables.

[c]1 serving = 1 medium size fruit, ½ cup fresh, frozen, or cooked fruit.

[d]1 serving = 1 oz of cooked meat.

[e]1 serving = 1/3 cup or 1 ½ oz of nuts; ½ cup of cooked legumes; 2 tablespoons of seeds.

[f]1 serving = 1 cup of milk, 1 ½ oz of cheese.

resulted in daily servings per 1000 kcal.[20] If recommended food group intake was a range (e.g., four or five servings of vegetables for 2000 calories) then the higher value was chosen for foods that were encouraged and the lower value for limited foods. The DASH diet recommends ≤6% energy from saturated fat and, to calculate percentage from saturated fat, we first summed energy from saturated fat over 3 diary days, divided by total energy consumption over the 3 days, and multiplied by 100. The maximum score for each component was 10; a score of 5 was given for midway intake levels, and otherwise a score of 0 (Table 1). Finally, the total DASH dietary index was calculated as the sum of nine component scores, giving a maximum possible total score of 90 with higher scores indicating closer adherence to DASH dietary patterns.

Other information collected

At study enrolment, HTRs completed a two-page self-administered questionnaire about socio-demographic factors (marital status, education level and employment status), smoking status and usual alcohol intake, whereas date of birth, sex, underlying heart disease, date of transplant, height (cm), and weight (kg) at transplantation and at study enrolment were ascertained from medical records.

Statistical analysis

Diary data were exported onto FoodWorks 10 Professional nutrient analysis software (Xyris Pty Ltd), nutrient and food intakes were processed, and data downloaded onto SAS (SAS Institute Inc.) for subsequent analysis. We calculated BMI (kg m^{-2}) at time of transplantation and date of enrolment. BMI was categorised as underweight/normal weight (<25 kg m^{-2}) or overweight/obese (≥25 kg m^{-2}). We also assessed change in BMI retrospectively from time of transplant to study enrolment date, and dichotomised changes as increased (>0 kg m^{-2}) or not increased (≤0 kg m^{-2}).

To compare categorical variables by sex or BMI categories, we used the chi-squared test (or Fisher's exact test when one or more cells had expected frequencies <5). The Mann–Whitney test was used for continuous variables. We used SAS, version 9.4 (SAS Institute Inc.) for all analyses. All statistical tests were two-sided. $p < 0.05$ was considered statistically significant.

RESULTS

Among 55 HTRs approached, 49 (89%) agreed to participate (Figure 1). Of the 49, 25 (51%) completed a 3-day food diary. Diary completers were more likely to be female (12 (48%) vs. 4 (17%), $p = 0.032$) and less likely to have underlying non-ischaemic cardiomyopathies than non-completers (17 (68%) versus 22 (92%), $p = 0.032$), but were otherwise similar.

The 25 HTRs who completed the diary (median age at study enrolment 48 years, range 21–70 years; 52% male) had a median BMI at study enrolment of 27.2 kg m^{-2} (range 18.1–42.6) (Table 2). Of the 25 food diaries completed, one (female) HTR was excluded because of missing serving sizes. Thus, we included the 3-day food diaries of 24 participants. Overall, the median total

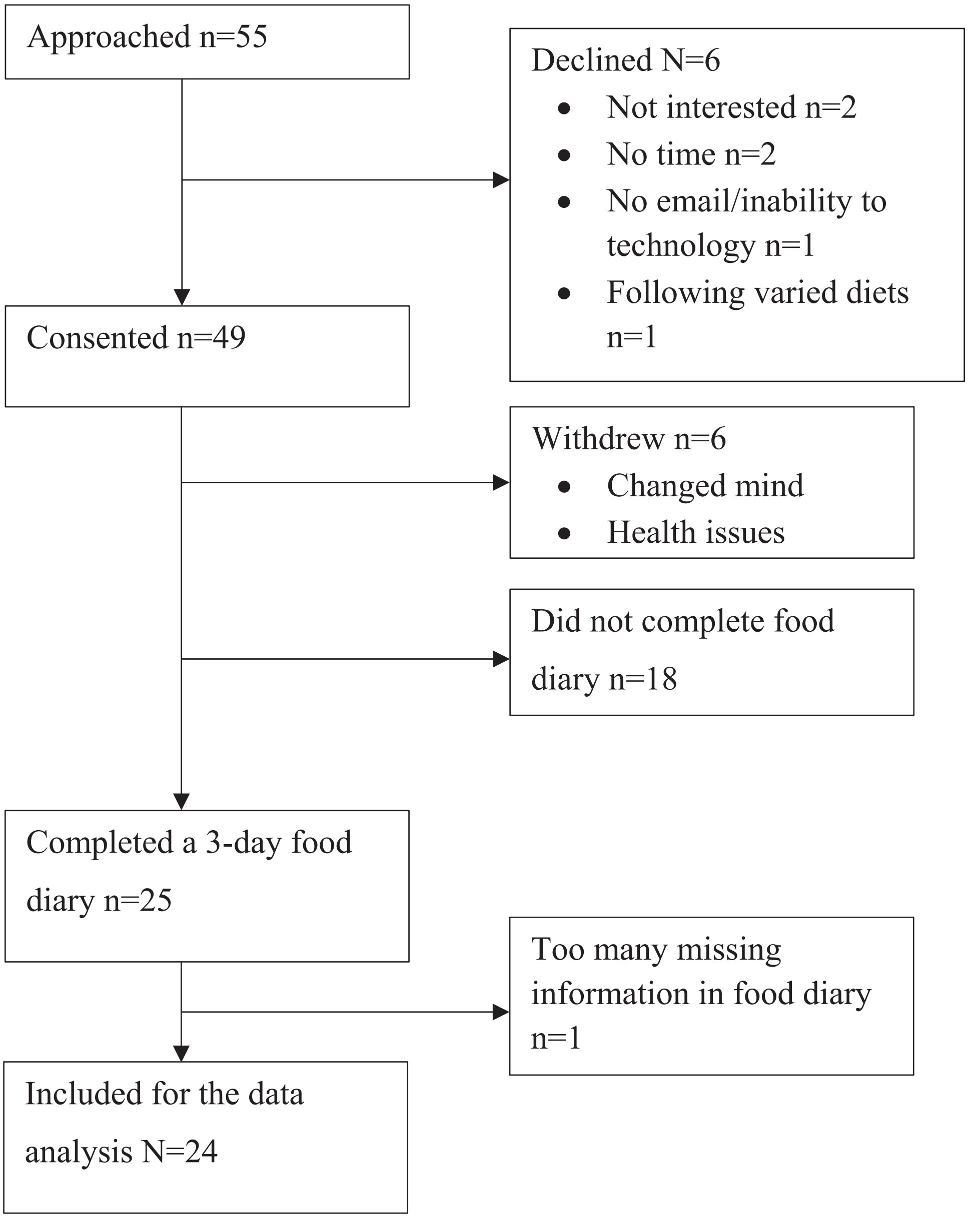

FIGURE 1 Flow diagram for the recruitment of study participants.

energy intake was 6905 kJ for males and 4849 kJ for females (Table 3) and, for both males and females, median daily intakes of fibre, vitamin A equivalent, vitamin E, calcium and long-chain omega-3 fatty acids tended to be lower than recommended daily intake. Among females, median total folate and iron also tended to be lower than recommended. The median percentage of energy from fat, protein and carbohydrate of study HTRs were within recommended intake ranges, but the median energy from fat in males tended to be higher than recommended (35%) (Table 3).

Overall, the median daily servings of whole grains, fruit, vegetables, seafood, and nuts and seeds were low (see Supporting information, Table S1) and higher median daily intakes were seen in males compared to females for refined grains (3.5 vs. 1.7 serves), fats (7.2 vs. 4.2 teaspoons), oils (6.9 vs. 4.4 teaspoons) and added sugars (3.4 vs. 2.1 teaspoons). Median daily vegetable intakes were similar for male and female HTRs, but serves per day among males were much higher than females for starchy vegetables (0.9 vs. 0.3) and potatoes (0.8 vs. 0.3).

DASH dietary scores by sex

Regarding energy-adjusted consumption of DASH dietary components, wholegrain, fruit, plant protein and dairy product intakes of HTRs were lower than recommended, whereas percentage energy from saturated fat was higher,

TABLE 2 Characteristics of heart transplant recipients according to completion of 3-day diary.

	All *n* (%)	Completed *n* = 25 (51%)	Not completed *n* = 24 (49%)	*p*-value
Age at transplant (years)[a]	43 (9, 66)	40 (9, 64)	45 (14, 66)	0.83[b]
Age at enrolled (years)[a]	50 (18, 74)	48 (21, 70)	50 (18, 74)	0.92[b]
Sex				
Males	33 (67)	13 (52)	20 (83)	0.032[c]
Females	16 (33)	12 (48)	4 (17)	
Aetiology of transplantation				
Non-ischaemic cardiomyopathies	39 (80)	17 (68)	22 (92)	0.028[d]
Ischaemic cardiomyopathy	6 (12)	6 (24)	0 (0)	
Congenital heart disease	4 (8)	2 (8)	2 (8)	
Months from transplantation[a]	51.4 (3.1, 411.0)	51.4 (3.4, 411.0)	54.1 (3.1, 305.7)	0.44[b]
Marital status				
Single/never married	8 (16)	4 (16)	4 (17)	0.86[c]
Married/de facto/living with a partner	36 (73)	19 (76)	17 (71)	
Divorced/separated	5 (10)	2 (8)	3 (13)	
Employment				
Full-time/part-time worker	19 (39)	12 (48)	7 (29)	0.46[d]
Home duties/student/unemployed/retired	25 (51)	11 (44)	14 (58)	
Other	5 (10)	2 (8)	3 (13)	
Highest education completed				
Up to grade 12	19 (39)	8 (32)	11 (46)	0.67,[ce]
Trade/technical certificate/diploma	13 (27)	7 (28)	6 (25)	
University/college degree or higher	16 (33)	9 (36)	7 (29)	
Missing	1 (2)	1 (4)	0 (0)	
Smoking				
Non-smoker	37 (76)	18 (72)	19 (79)	0.73,[ce]
Ex-smoker	11 (22)	6 (24)	5 (21)	
Missing	1 (2)	1 (4)	0 (0)	
Alcohol consumption status				
Current	32 (65)	9 (38)	7 (29)	0.54,[ce]
Former/never	16 (33)	15 (63)	17 (71)	
Missing	1 (2)	1 (4)	0 (0)	
Medication use				
Antihyper medication	41 (84)	21 (84)	20 (83)	1.00[d]
Lipid lowering medication	47 (96)	24 (96)	23 (96)	1.00[d]

(Continues)

TABLE 2 (Continued)

	All n (%)	Completed $n = 25$ (51%)	Not completed $n = 24$ (49%)	p-value
Glucose lowering medication	13 (27)	9 (36)	4 (17)	0.20[d]
Immunosuppressive medication use				0.89[d]
Mycophenolate and tacrolimus	9 (18)	5 (20)	4 (17)	
Mycophenolate, tacrolimus and prednisolone	9 (18)	4 (16)	5 (21)	
Everolimus and tacrolimus	7 (14)	4 (16)	3 (13)	
Mycophenolate and cyclosporine	6 (12)	4 (16)	2 (8)	
Other	18 (37)	8 (32)	10 (42)	
Weight at consent (kg)[a]	83.5 (41.85, 116.9)	87.3 (41.9, 109.0)	79.2 (53.4, 116.9)	0.62[b]
	83.6 ± 17.8	84.8 ± 18.8	82.3 ± 17.1	
Body mass index at consent (kg m^{-2})[a]	27.2 (18.1, 42.6)	27.2 (18.1, 42.6)	27.6 (20.2, 35.7)	0.53[b]
	28.1 ± 5.1	28.7 ± 5.8	27.3 ± 4.2	

[a]Median (minimum, maximum)].
[b]Mann–Whitney test.
[c]Chi-squared test.
[d]Fisher's exact test.
[e]Excluded "missing."

with no sex differences (Supporting Information, Table S2). Sodium intakes for most HTRs were below recommended levels, and sodium intake was significantly lower in females compared to males (median males 1265.7 mg vs. females 792.2 mg per 1000 kcal per day, $p = 0.024$). Across all HTRs, each component of the DASH dietary score was generally low resulting in a low median total score of 30 (range, 10–60), with no sex differences (see Supporting information, Table S3).

DASH dietary scores by BMI change

Of the 24 participating HTRs, BMI at time of transplant was available for 17 (53% male) and their median change in BMI to study enrolment date was 3.7 k m^{-2} (range –9.2 to 21.9 kg m^{-2}). Five HTRs experienced a decrease in BMI after transplant and the remaining 12 experienced an increase. Compared with the study HTRs whose BMI increased (change >0 kg m^{-2}), those whose BMI did not increase (change ≤0 kg m^{-2}) had significantly higher DASH scores for wholegrains, animal proteins, percentage energy from fat, as well as total score (Table 4). HTRs whose BMI increased tended to be transplanted longer than those with stable/decreased BMI (49.7 vs. 27.5 months, $p = 0.27$). We therefore repeated DASH dietary score analyses in strata of shorter vs. longer time since transplantation (median cutoff <51.4 vs. ≥51.4 months). Participants with longer time post-transplant showed significantly lower median scores for dairy intake (0 vs. 5, $p = 0.049$). On the other hand, although the median score for the percentage energy from saturated fat was 0 in both groups, HTRs with longer time since transplant had significantly higher scores for % energy from fat (all <51.4 months post-transplantation group had "0" score vs. ≥51.4 months post-transplant group had score range 5, $p = 0.016$). There were no other significant differences.

DISCUSSION

In the present study, we have described in-depth, the dietary intake of HTRs for the first time using a 3-day food diary. Both male and female study HTRs reported suboptimal consumption of fibre, vitamin A, vitamin E, calcium and long-chain omega-3 fatty acids, amounting to low diet quality based on the DASH dietary index. Study HTRs with low diet quality (lower DASH indices) were significantly more likely to gain weight (increase BMI) post-transplant. Specifically, we found that the median intakes of DASH dietary components were lower than recommended for whole grains, vegetables, fruit, plant protein and dairy, and higher for sugar and saturated fat.

Organ transplant recipients generally display low adherence to recommended diets, but dietary interventions have led to modest weight reductions after transplantation in kidney transplant recipients.[7] HTRs have also shown generally low adherence to recommended diets, with high fat and low fruit and vegetable intakes and increased

TABLE 3 Distributions nutrient intakes per day.

	All ($n = 24$)	Males ($n = 13$)	Females ($n = 11$)
Energy (kJ)	6336.4 (3025.2, 11151.2)	6904.5 (4683.6, 11151.2)	4848.7 (3025.2, 7512.7)
Protein (g)	78.4 (47.2, 116.1)	96.3 (47.7, 116.1)	62.6 (47.2, 89.9)
Total fat (g)	59.1 (18.4, 101.7)	64.2 (40.9, 101.7)	39.3 (18.4, 84.1)
Saturated fat (g)	18.2 (8.3, 62.3)	20.7 (11.1, 62.3)	15.8 (8.3, 33.3)
Trans fat (g)	0.7 (0.3, 2.5)	0.8 (0.3, 2.5)	0.6 (0.4, 1.6)
PUFA (g)	9.6 (2.2, 26.5)	11.4 (6.5, 17.4)	6.8 (2.2, 26.5)
MONO (g)	23.9 (6.1, 37.6)	24.4 (9.7, 37.6)	15.5 (6.1, 35.5)
Cholesterol (mg)	228.7 (75.2, 709.1)	262.7 (75.2, 709.1)	181.2 (105.4, 434.7)
Carbohydrate (g)	142.4 (77.1, 363.1)	168.4 (101.5, 363.1)	111.2 (77.1, 187.5)
Added sugars (g)	13.0 (3.9, 87.3)	14.5 (6.5, 87.3)	10.2 (3.9, 38.3)
Alcohol (g)	0.1 (0, 24.1)	0.0 (0, 19.5)	0.1 (0, 24.1)
Fibre (g)	16.5 (6.6, 34.1)	16.8 (10.2, 34.1)	14.5 (6.6, 29.0)
Niacin eq (mg)	32.6 (17.0, 56.5)	39.8 (19.9, 56.5)	30.5 (17.0, 46.1)
Vitamin C (mg)	51.1 (0.6, 164.8)	42.9 (0.6, 164.8)	62.8 (18.6, 161.3)
Vitamin E (mg)	8.7 (1.7, 22.9)	8.8 (1.7, 17.5)	6.6 (2.9, 22.9)
α-Tocopherol (mg)	6.8 (1.4, 20.9)	8.3 (1.4, 15.2)	5.5 (2.7, 20.9)
Total dietary folate equivalent (mcg)	444.9 (159.0, 985.2)	509.0 (159.0, 985.2)	379.0 (223.1, 926.4)
Total vitamin A eq (mcg)	493.2 (110.8, 2473.8)	467.8 (159.2, 1623.1)	521.6 (110.8, 2473.8)
Retinol (mcg)	149.3 (45.0, 336.5)	166.1 (92.0, 336.5)	128.7 (45.0, 275.7)
β-carotene eq (mcg)	2096.3 (139.3, 14078.4)	1833.0 (139.3, 8191.7)	2439.7 (232.2, 14078.4)
Sodium (mg)	1720.8 (762.3, 3524.0)	2531.3 (1360.4, 3524.0)	1426.0 (762.3, 2503.1)
Potassium (mg)	2271.0 (1300.1, 4131.1)	2118.2 (1300.1, 4113.1)	2423.8 (1305.2, 3405.8)
Magnesium (mg)	272.2 (129.5, 599.8)	274.9 (156.4, 580.3)	219.0 (129.5, 599.8)
Calcium (mg)	682.4 (233.7, 1162.1)	632.5 (390.6, 1026.2)	732.3 (233.7, 1162.1)
Iron (mg)	7.9 (4.3, 14.9)	8.2 (4.3, 14.9)	7.6 (5.1, 12.4)
n-3 (g)	1.2 (0.4, 4.6)	1.3 (0.4, 3.1)	1.2 (0.4, 3.5)
VLC *n*-3 (g)	0.1 (0.0, 2.2)	0.1 (0.0, 2.2)	0.1 (0.1, 1.1)
Linoleic acid (g)	7.5 (1.9, 22.7)	9.0 (5.8, 14.4)	5.0 (1.9, 22.7)
Caffeine (mg)	84.0 (0.0, 763.6)	71.9 (0.0, 334.7)	104.0 (4.1, 763.6)
Percentage energy from fat	35.0 (23.0, 51.2)	35.0 (23.0, 40.2)	30.0 (23.0, 51.2)
Percentage energy from protein	20.3 (15.1, 35.7)	21.1 (15.1, 28.5)	20.0 (17.3, 35.7)
Percentage energy from carbohydrate	40.4 (25.5, 60.7)	40.3 (34.0, 60.7)	40.4 (25.5, 49.3)

Values are the median (minimum, maximum).

Abbreviations: eq, equivalent; MONO, monounsaturated fatty acids; *n*-3, omega-3 polyunsaturated fatty acids; PUFA, polyunsaturated fatty acids; VLC *n*-3, very long-chain omega-3 fatty acids.

TABLE 4 Median score (minimum, maximum) of DASH dietary index component and total scores by change in body mass index (BMI) from time of transplantation to study baseline.

	BMI change ≤0 kg m^{-2} ($n = 5$)	>0 kg m^{-2} ($n = 12$)	p-value
Whole grains	5 (0, 5)	0 (0, 5)	0.005
Vegetables	5 (0, 10)	0 (0, 10)	0.18
Fruit	0 (0, 0)	0 (0, 10)	0.61
Animal protein	10 (10, 10)	5 (0, 10)	0.039
Plant protein	0 (0, 10)	0 (0, 10)	0.36
Dairy	5 (0, 5)	5 (0, 5)	0.45
Sugar	5 (0, 10)	5 (0, 10)	0.54
Sodium	10 (5, 10)	7.5 (5, 10)	0.76
Percentage energy from saturated fat	0 (0, 5)	0 (0, 0)	0.030
Total[a]	45 (30, 50)	30 (10, 45)	0.013

p-values are from Mann–Whitney U-test.

Age at transplantation <18 years old were excluded from the analyses.

[a]Total score ranges from 0 to 90.

body weight/BMI[8,10] similar to our findings. In Italian HTRs, only 50% (21/42) of study HTRs adhered to the recommended diet (American Heart Association's Step 1 Diet, similar to the DASH dietary patterns) and, importantly, those patients who adhered, lowered their weight, BMI, blood lipids and blood glucose over 12 months post-transplant, whereas the opposite was true among those who did not adhere.[21] Clearly, strategies to improve dietary adherence after heart transplantation are important for positive long-term outcomes.[7]

The DASH dietary pattern is now known as the “heart healthy diet” because the DASH dietary pattern reduces not only blood pressure,[22,23] but also other cardiovascular risk factors, including dyslipidaemia and diabetes.[19,24] In particular, plant-based components of the DASH diet, such as high intakes of fruit, vegetable and nuts, appeared to be critical in blood glucose and insulin sensitivity improvements.[25] We found the diet quality of study HTRs to be universally low, especially as a result of low fruit and vegetable intakes (median serves of vegetables day^{-1} and 0.5 serves of fruit day^{-1}). Because the prevalence of cardiovascular disease risk factors is high in HTRs[2] including in Queensland,[3] encouraging these patients to follow the DASH dietary pattern and focus on plant-based foods would likely improve their cardiometabolic status in the long-term.

Previous research has shown associations between components of the DASH dietary patterns and reduced body weight.[16,26-28] The potential beneficial mechanisms of action include early satiety and overall reduced energy (food) intake because of the consumption of dietary-fibre-rich fruit and vegetables with their low energy density.[29,30] High-fibre diets can also reduce energy intake by reducing fat absorption through faecal elimination.[29] High intakes of whole grains, legumes, nuts and seeds further increase fibre intake.[31,32] Additionally, the low sodium intake of DASH dietary patterns is associated with low BMI,[33] which is likely explained by avoidance of the fluid retention[34] and the increased appetite and energy intake through altered leptin levels[35] that may occur with high sodium intake. On the other hand, diets high in animal protein, especially red and processed meats, are associated with weight gain, possibly because of the high fat and energy contents in these foods.[36,37] However, not all studies that have assessed individual DASH components showed beneficial associations with body weight.[38,39] This may reflect the problem of examining specific foods or food groups because of the correlation with other foods; for example, high intakes of fruit and vegetables are associated with low intakes of red and processed meats,[40] leading to uncertainty about which is the beneficial component. Hence, examining dietary patterns better reflects associations with weight and BMI, and helps better understand the role of the overall diet.

We achieved 89% recruitment; however, only half of enrolled HTRs (25/49) completed the 3-day food diary. Many who did not complete the food diary informed us that they had difficulty in initiating or filling-in the diary. Similarly, several participants indicated to the study staff that their experience of recording the diary was more tedious compared to other diet-recording apps, although a previous study reported the app was easy and convenient to use.[14] Discrepancies between the previous app-study findings[14] and our participants' feedback may be a result of age differences, with our study HTRs being substantially older (50 vs. 31 years old). Future studies will need to carefully tailor their dietary assessment methods to their study populations.

Besides the poor completion rate of the 3-day food diary, the present study had some other limitations. The small number of study HTRs, with females over-represented, limits the generalisability of our findings, although we note that females generally have better diet quality than males,[41,42] indicating that our results are likely conservative. Additionally, our dietary recording method over 3 days may not have captured the usual diets of HTRs and we did not have information on participants' physical activity levels. Although we found a strong association between low diet quality and BMI increase post-transplant, our retrospective observational methods mean causation cannot be assumed. Despite these limitations, our study provides novel insights into the diet quality of HTRs, a topic that has been severely under-studied to date, using the DASH dietary index, a validated and widely used measure.

In conclusion, this is the first study to relate diet quality benchmarked to the “heart healthy diet” to post-transplant weight gain in adult HTRs. Notwithstanding the absence of physical activity data, we speculate that the suboptimal diet quality of HTRs, especially as a result of low fruit and vegetable intakes, contributed to the excess BMI observed overall. Effective interventions to improve the diets of HTRs are urgently needed to help prevent further weight gain and improve their cardiometabolic conditions.

AUTHOR CONTRIBUTIONS

Kyoko Miura and Adèle C. Green contributed to the research design. Regina Yu collected the data. Scott C. McKenzie helped with data acquisition. Kyoko Miura analysed the data. Kyoko Miura, Scott C. McKenzie, Timothy R. Entwistle and Adèle C. Green interpreted the data. Kyoko Miura wrote the manuscript. All authors participated in revising the manuscript and approved the final version of the manuscript submitted for publication.

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CONFLICTS OF INTEREST STATEMENT

The authors declare that there are no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available because of privacy or ethical restrictions.

ETHICAL STATEMENT

Metro North Hospital and Health Services Human Research Ethics Committee reviewed and approved the study (LNR/2020/QPCH/65776).

TRANSPARENCY DECLARATION

The lead author affirms that this manuscript is an honest, accurate, and transparent account of the studies being reported. The lead author affirms that no important aspects of the studies have been omitted and that any discrepancies from the studies as planned have been explained.

PEER REVIEW

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1111/jhn.13263.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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