



UNIVERSITY  
OF WOLLONGONG  
AUSTRALIA

University of Wollongong  
Research Online

---

Faculty of Science, Medicine and Health - Papers:  
Part B

Faculty of Science, Medicine and Health

---

2018

# Effect of individualised dietary advice for weight loss supplemented with walnuts on blood pressure: the HealthTrack study

Rhoda Ndanuko

*University of Wollongong*, [rnn954@uowmail.edu.au](mailto:rnn954@uowmail.edu.au)

Linda C. Tapsell

*University of Wollongong*, [ltapsell@uow.edu.au](mailto:ltapsell@uow.edu.au)

Karen E. Charlton

*University of Wollongong*, [karenc@uow.edu.au](mailto:karenc@uow.edu.au)

Elizabeth Neale

*University of Wollongong*, [elizan@uow.edu.au](mailto:elizan@uow.edu.au)

Marijka Batterham

*University of Wollongong*, [marijka@uow.edu.au](mailto:marijka@uow.edu.au)

---

## Publication Details

Ndanuko, R. N., Tapsell, L. C., Charlton, K. E., Neale, E. P. & Batterham, M. J. (2018). Effect of individualised dietary advice for weight loss supplemented with walnuts on blood pressure: the HealthTrack study. *European Journal of Clinical Nutrition*, 1758 129-138.

Research Online is the open access institutional repository for the University of Wollongong. For further information contact the UOW Library: [research-pubs@uow.edu.au](mailto:research-pubs@uow.edu.au)

---

# Effect of individualised dietary advice for weight loss supplemented with walnuts on blood pressure: the HealthTrack study

## Abstract

**Background/objectives:** In addition to weight-loss, healthy dietary patterns and lower sodium intakes can help reduce blood pressure (BP), but individualised dietary advice may be necessary to achieve these effects. This study aimed to examine the impact of individualised dietary advice on BP in the intensive phase of a weight-loss trial. **Subjects/methods:** Secondary analysis of baseline and 3-month data from the HealthTrack randomised controlled trial (n = 211). Participants were randomly assigned to one of three dietary advice groups: general advice (control), individualised advice (intervention group, I), or intervention group supplemented with 30 g walnuts/day (IW). Resting BP and 24-h urine sodium and potassium were measured. Dietary intake was evaluated through diet history interviews. **Results:** Unadjusted SBP reduced significantly in all groups (IW and I groups  $P < 0.001$ ; control group  $P = 0.002$ ) and DBP in IW and I groups ( $P < 0.001$ ). Compared to controls, the reductions in BP were 3-4 mmHg greater in the I and IW groups, but this only reached significance for DBP in the I group ( $-3.3$  mmHg;  $P = 0.041$ ). After controlling for age, sex, medication, weight-loss, physical activity and smoking, only the IW group showed a significant association between SBP reduction and increased urinary potassium ( $\beta = -0.101$ ,  $P = 0.044$ ), decreased sodium:potassium ratio ( $\beta = 2.446$ ,  $P = 0.037$ ) and increased consumption of seed and nut products and dishes ( $\beta = -0.108$ ,  $P = 0.034$ ). **Conclusions:** Dietary patterns with distinctive foods and lower sodium:potassium ratios may enhance the effects of weight-loss on BP. The patterns were best achieved with individualised dietary advice and food supplements.

## Publication Details

Ndanuko, R. N., Tapsell, L. C., Charlton, K. E., Neale, E. P. & Batterham, M. J. (2018). Effect of individualised dietary advice for weight loss supplemented with walnuts on blood pressure: the HealthTrack study. *European Journal of Clinical Nutrition*, 1758 129-138.

1 **Effect of individualised dietary advice for weight loss supplemented with walnuts on**  
2 **blood pressure: The HealthTrack study<sup>1-4</sup>**

3 Rhoda N Ndanuko<sup>5</sup>, Linda C Tapsell<sup>5</sup>, Karen E Charlton<sup>5</sup>, Elizabeth P Neale<sup>5</sup>, Marijka J  
4 Batterham<sup>6</sup>

5 <sup>5</sup>School of Medicine, University of Wollongong, Northfields Avenue, Wollongong NSW 2522,  
6 Australia; <sup>6</sup>Statistical Consulting Service, School of Mathematics and Applied Statistics,  
7 University of Wollongong, Northfields Avenue, Wollongong NSW 2522, Australia

8 Last name of each author: Ndanuko, Tapsell, Charlton, Neale, Batterham

9 <sup>1</sup>Funding source(s): Illawarra Health and Medical Research Institute and California Walnut  
10 Commission.

11 <sup>2</sup>HealthTrack study was registered on the Australian New Zealand Clinical Trials Registry, trial  
12 ID ACTRN12614000581662 ([www.anzctr.org.au](http://www.anzctr.org.au)).

13 <sup>3</sup>To whom correspondence should be addressed: Rhoda Ndanuko, School of Medicine,  
14 University of Wollongong, Northfields Avenue, Wollongong NSW 2522, Australia.  
15 Email: [rnn954@uowmail.edu.au](mailto:rnn954@uowmail.edu.au)

16 Running title: Dietary advice for weight loss and blood pressure

17 <sup>4</sup>Abbreviations used: BP, blood pressure; BMI, body mass index; C, control (usual care);  
18 DASH, Dietary Approaches to Stop Hypertension; DBP, diastolic blood pressure; I,  
19 interdisciplinary intervention with individualised dietary advice; IW, interdisciplinary  
20 intervention with individualised dietary advice plus a supplement of 30 grams of walnuts per  
21 day; Na:K, sodium-to-potassium ratio; SBP, systolic blood pressure.

22

23 **Abstract**

24 **Background/Objective:** In addition to weight-loss, healthy dietary patterns and lower sodium  
25 intakes can help reduce blood pressure (BP), but individualised dietary advice may be  
26 necessary to achieve these effects. This study aimed to examine the impact of individualised  
27 dietary advice on BP in the intensive phase of a weight-loss trial.

28 **Subjects/Methods:** Secondary analysis of baseline and 3-months data from the HealthTrack  
29 randomized controlled trial (n=211). Participants were randomly assigned to one of 3 dietary  
30 advice groups; general advice (control), individualised advice (intervention group, I), or  
31 intervention group supplemented with 30 grams walnuts/day (IW). Resting BP and 24-h urine  
32 sodium and potassium were measured. Dietary intake was evaluated through diet history  
33 interviews.

34 **Results:** Unadjusted SBP reduced significantly in all groups (IW and I groups  $P<0.001$ ;  
35 control group  $P=0.002$ ) and DBP in IW and I groups ( $P<0.001$ ). Compared to controls, the  
36 reductions in BP were 3-4 mmHg greater in the I and IW groups, but this only reached  
37 significance for DBP in the I group (-3.3 mmHg;  $P=0.041$ ). After controlling for age, sex,  
38 medication, weight-loss, physical activity and smoking, only the IW group showed a  
39 significant association between SBP reduction and increased urinary potassium ( $\beta=-0.101$ ,  
40  $P=0.044$ ), decreased sodium:potassium ratio ( $\beta=2.446$ ,  $P=0.037$ ) and increased consumption of  
41 *seed and nut products and dishes* ( $\beta=-0.108$ ,  $P=0.034$ ).

42 **Conclusions:** Dietary patterns with distinctive foods and lower sodium:potassium ratios may  
43 enhance the effects of weight-loss on BP. The patterns were best achieved with individualised  
44 dietary advice and food supplements.

45 **Keywords:** blood pressure, dietary patterns, obese, potassium, sodium, walnuts, seafood

## 46 INTRODUCTION

47 Hypertension or high blood pressure (BP) is a major risk factor for cardiovascular disease and  
48 the leading risk factor for total burden of disease and mortality worldwide.<sup>1</sup> Lowering systolic  
49 BP (SBP) by 10 mmHg or diastolic BP (DBP) by 5 mmHg through the use of BP lowering  
50 medication has been shown to reduce the incidence of coronary heart disease events and stroke  
51 by 25% and 30% respectively.<sup>2</sup>

52 Different lifestyle approaches have been recommended to lower BP. These include weight loss,  
53 regular physical activity, reducing dietary sodium intake and consuming a healthy diet.<sup>3</sup>

54 Previously, dietary trials for BP-lowering have primarily focused on interventions that result in  
55 reductions in sodium intake, either with or without a concomitant increase in potassium intake.

56 A systematic review of these trials shows that reducing dietary salt to 4.4 g/day (1716 mg  
57 sodium/day) leads to an estimated reduction of 5.0 mmHg and 3.0 mmHg in SBP and DBP,  
58 respectively, in hypertensive subjects and 2.0 mmHg and 1.0 mmHg, respectively, in  
59 normotensive subjects.<sup>4</sup> On the other hand, a meta-regression has shown an increase in  
60 potassium intake by 44 mmol/day (1716 mg/day) to be associated with a reduction of 2.4  
61 mmHg and 1.6 mmHg in SBP and DBP, respectively.<sup>5</sup> However, the urinary sodium-to-  
62 potassium (Na:K) ratio may be more strongly associated with BP than urinary sodium or  
63 potassium alone,<sup>6</sup> and may be more indicative of total diet.

64 Given that weight loss itself helps to reduce BP,<sup>7</sup> adding knowledge of healthful food patterns  
65 to that of energy restriction may be beneficial in managing obesity and its related disorders  
66 such as hypertension. The relationship between obesity and hypertension is well established.<sup>8</sup>

67 Patients with higher body mass index (BMI) have an increased risk of hospitalisations due to a  
68 wide range of cardiovascular diseases in which hypertension may also be implicated.<sup>9</sup> As a  
69 result, weight loss is recommended as a strategy to lower BP in overweight and obese

70 individuals.<sup>3</sup> An average of 5 kg weight loss resulted in BP reduction of 4.4 mmHg and 3.6  
71 mmHg in SBP and DBP respectively in a meta-analysis of 25 randomized controlled trials.<sup>7</sup>

72 While weight loss is dependent on total food intake, investigations into the effects of single  
73 foods on BP have been conducted through randomized clinical trials and observational studies.  
74 These studies have focused on fruit and vegetables, meat, nuts, dairy foods, tea, and coffee.<sup>10-15</sup>  
75 Research that focuses on individual nutrients or single foods may not consider the complexity  
76 of the interdependence between nutrients and foods and their relationship with disease  
77 outcomes.<sup>16</sup> In nutritional epidemiology, research on dietary patterns may present a broader  
78 view of the impact of nutrient and food intakes and enable a better understanding of the  
79 association between diet and chronic disease risk.<sup>17</sup> Dietary patterns associated with BP include  
80 the Dietary Approaches to Stop Hypertension (DASH) diet,<sup>18</sup> the Mediterranean diet<sup>19</sup> and the  
81 Nordic diet.<sup>20</sup> Given that improved dietary choices is a goal of dietary advice in practice, the  
82 aim of this study was to examine the impact of individualised dietary advice, on BP during a  
83 weight loss trial.

## 84 **SUBJECTS AND METHODS**

85 The current study is a secondary analysis using baseline and 3 month data from the 12-month  
86 HealthTrack randomized controlled trial, commencing in May 2014 and investigating whether  
87 a novel lifestyle intervention is more effective than usual care in achieving weight loss in  
88 overweight/obese adults. Participants were randomized to one of three groups: intervention [(I)  
89 (interdisciplinary intervention with individualised dietary advice), intervention + walnut [(IW)  
90 (interdisciplinary intervention with individualised dietary advice plus a supplement of 30  
91 grams of walnuts per day), or control [(C) (usual care)]. Randomisation was performed by an  
92 investigator unrelated to the study using computer generated randomisation sequence.  
93 Participants were blinded to their randomised group. Dietary advice in both intervention groups

94 was provided in an individualised manner according to the targeted requirements and usual  
95 food habits of the participants. A number of food choices were prescribed from the food groups  
96 defined in the Australian Guide to Healthy Eating.<sup>21</sup> This Guide was also used for the controls  
97 but advice was given in a general manner. In the IW group, walnut supplementation was  
98 integrated into diets so as not to provide extra energy but to increase the specificity of the  
99 intervention to consume healthy food. The control group received general advice on food  
100 choices that enabled them to adjust their usual food patterns to the dietary guidelines.<sup>21</sup> The  
101 HealthTrack study was registered with the Australian and New Zealand Clinical Trial Registry  
102 (ANZCTR N 12614000581662) and was approved by the University of Wollongong/Illawarra  
103 Shoalhaven Local Health District Human Research Ethics Committee (HE13/189) including  
104 the current analysis. All participants provided their informed written consent before  
105 participating in the study. For the analysis reported here, the outcomes of interest were SBP  
106 and DBP.

107 **Study context: The HealthTrack Trial**

108 The HealthTrack study was conducted in the Illawarra, a major coastal region 70 km south of  
109 Sydney, Australia, with a detailed study protocol and primary results reported elsewhere.<sup>22,23</sup> In  
110 brief, adults aged between 25 and 54 years were recruited via advertisements in local media  
111 (Figure 1). Participants were included if they had a BMI of 25-40 kg/m<sup>2</sup> and were permanent  
112 residents of the Illawarra region. Participants were excluded if they did not have a good  
113 command of English language, had a serious medical condition that could limit their  
114 participation, immunodeficiency, reported regular alcohol intake of more than 50 g of alcohol  
115 per day, illegal use of drugs, or other major impediments to taking part in some components of  
116 the study.

117 SBP and DBP were measured in the supine position using an automatic BP monitor (OMRON  
118 BP-203RPE III, OMRON Healthcare Co. Ltd, Kyoto, Japan) and using appropriately sized BP  
119 cuffs for obese participants. Participants rested for 5 minutes after which a test BP reading was  
120 conducted. After 10 seconds, a confirmatory reading was recorded. All BP measurements were  
121 performed by trained health practitioners using standard techniques.

122 For estimation of dietary sodium and potassium intake, urinary sodium and potassium  
123 excretion were used as biomarkers since they are considered the gold standard.<sup>24</sup> It has also  
124 been shown that individuals with higher BMI usually under-report dietary sodium and over-  
125 report dietary potassium intake.<sup>25</sup> Participants were instructed to collect 24-h urine in the  
126 provided standard plastic containers. One 24-h urine collection was made at baseline and at 3  
127 months. After voiding the initial urine sample of the day, participants were requested to record  
128 the time and then collect all further urine samples for the subsequent 24 hours, ending at about  
129 the same time the following day. The collected sample was then taken to Southern IML  
130 Pathology whereby total urine volume was determined, and subsequently stored at 2-8 degrees  
131 centigrade. Indirect ion-specific electrodes were used to determine sodium and potassium  
132 concentrations whilst the creatinine concentration was determined using the Jaffe reaction  
133 colorimetric method.<sup>26</sup> Samples were considered to be incomplete if their total volume was less  
134 than 500 mL (n = 1 at baseline, n = 1 at 3 months) and/or creatinine concentration levels were  
135 below 5.0 mmol/d (n = 1 at baseline) and therefore excluded from the present analysis.<sup>27</sup>

136 Dietary intake was assessed through self-reported diet history interviews conducted by  
137 Accredited Practising Dietitians. Participants described their usual diet including types and  
138 amounts of food and drinks consumed using a validated protocol.<sup>28</sup> Dietary data was entered  
139 into the FoodWorks nutrient analysis software program (Xyris software, FoodWorks. 2012:  
140 Brisbane, Australia). Dietary data was originally analysed using AUSNUT 2007 (ref. 29),  
141 which was the most recent survey-specific food composition database available when the study



142 began. Due to the subsequent release of AUSNUT 2011-2013 (ref. 30), dietary data was  
143 categorized as per the food groups in AUSNUT 2011-2013. In order to convert AUSNUT 2007  
144 foods to AUSNUT 2011-2013 equivalents, a matching file was created to using a systematic  
145 process which has been reported elsewhere.<sup>31</sup> Specifically, intakes of the AUSNUT 2011-13  
146 major food groups *seed and nut products and dishes*, *fruit products and dishes*, and *seafood*  
147 *products and dishes* were determined. These food groups were selected as they were  
148 significantly associated with BP in a previous baseline analysis in this sample.<sup>32</sup>

149 Physical activity was assessed through the International Physical Activity Questionnaire via the  
150 questionnaire's short questions.<sup>33</sup> Trained health practitioners conducted anthropometric  
151 measurements. Weight and percent body fat via bioelectrical impedance were measured on  
152 digital scales [Tanita scales, UM0703581(1), Tanita Corporation, Tokyo, Japan] with subjects  
153 wearing light indoor clothing and no shoes. Weight was recorded to the nearest 0.1 kg while  
154 percent body fat was recorded to the nearest 0.1%. Height was measured and recorded to the  
155 closest millimetre in accordance with established anthropometric protocols<sup>34</sup> using a wall-  
156 mounted stadiometer. The widest part of hip and narrowest waist circumference were measured  
157 to the nearest centimetre according to standard protocols.<sup>34</sup> BMI was computed as weight (kg)  
158 divided by the height (m) squared.

### 159 **Statistical analysis**

160 Power calculations to determine the sample size were conducted using SAS PROC POWER  
161 whereby 120 participants per group were considered adequate, in order to detect a minimum of  
162 2.7 kg weight loss difference between groups which was the primary outcome. In this  
163 secondary analysis, baseline characteristics were presented as means and standard deviation for  
164 normally distributed data and median and interquartile range for data that was not normally  
165 distributed. To assess differences between study groups at baseline, one-way analysis of  
166 variance was conducted for normally distributed data while Kruskal-Wallis H test was

167 conducted for data that was not normally distributed. A chi square test was performed to  
168 compare difference in the proportion of participants with hypertension (participants were  
169 categorised as hypertensive if BP was  $\geq 140/90$  mmHg and/or taking antihypertensives)  
170 between study groups. To determine between-intervention differences in the change in weight,  
171 BP and urinary excretion, the one-way analysis of variance was used. To determine the  
172 difference between baseline and 3 months in each study group in weight, BP and urinary  
173 excretion, paired-samples T-test was used while the Wilcoxon signed-rank test was used to  
174 assess differences in the intake of key food groups (*seed and nut products and dishes, fruit*  
175 *products and dishes, and seafood products and dishes*). The one-way analysis of variance or  
176 Kruskal-Wallis H test was used to determine the difference between groups at each time point,  
177 and significant results were explored via post-hoc Tukey, Games-Howell test or Mann Whitney  
178 U tests with Bonferroni adjustment. We also repeated these analyses after excluding  
179 participants who were taking diuretics at baseline and/ or 3 months, as diuretics have been  
180 shown to increase sodium and potassium excretion.<sup>35</sup> Multiple linear regression was performed  
181 to assess the association between change in BP from baseline and (1) change in urinary  
182 excretion and (2) consumption of key food groups, while controlling for age, sex, BP  
183 medication, weight loss, change in physical activity, and smoking. All analyses were  
184 performed in accordance with an as-treated analysis approach. Statistical analysis was  
185 performed using the Statistical Package for the Social Sciences (IBM Corp., SPSS for  
186 Windows Version 21, Armonk, New York, USA). Significance level was considered at *P* value  
187  $<0.05$ .

## 188 **RESULTS**

### 189 **Baseline characteristics**

190 Participants (n=377) were randomized to one of the 3 groups; intervention + walnut (IW),  
191 intervention (I) or control (C). For this secondary analysis, complete BP, urinary excretion data  
192 and dietary intake data at baseline and 3 months was available from 211 participants (60 men  
193 and 151 women). Table 1 shows the baseline characteristics of the 3 groups.

#### 194 **Change from baseline to 3 months**

195 Weight reduced significantly in all the three groups from baseline to 3 months ( $P < 0.001$  in all  
196 groups). Unadjusted for weight loss, SBP reduced significantly in all groups (IW, I:  $P < 0.001$ ;  
197 C:  $P = 0.002$ ) but DBP was only significantly reduced in the IW and I groups ( $P < 0.001$ )  
198 (Figure 2 and Table 2). Compared to controls, the reductions were greater in the IW group  
199 (SBP -3.7 mmHg,  $P = 0.06$ ; DBP -2.8 mmHg,  $P = 0.057$ ) and the I group (SBP -3.7 mmHg,  $P$   
200 = 0.095; DBP -3.3 mmHg,  $P = 0.041$ ). From a biomarker perspective, compared to the I group,  
201 the IW group showed greater reductions in urinary sodium ( $P = 0.007$ ) and urinary Na:K ratio  
202 ( $P = 0.012$ ), and the C group showed greater reductions in urinary sodium ( $P = 0.018$ ) (Table  
203 3). From a food perspective, the IW group consumed greater amounts of *seed and nut products*  
204 *and dishes* compared to the I group and C group at 3 months ( $P < 0.001$  and = 0.024  
205 respectively) and increased their intakes of these foods more ( $P < 0.001$  and  $< 0.001$   
206 respectively) across the intervention period. Both the IW and I groups also increased their  
207 intakes of *fruit products and dishes* during this time ( $P < 0.001$  and = 0.005 respectively).  
208 Results were similar when participants on diuretics were excluded from the analysis (data not  
209 shown).

210 Using multiple linear regression and controlling for age, sex, BP medication, weight loss,  
211 change in physical activity and smoking, only the IW group showed a significant association  
212 between the reduction in SBP and the increase in urinary potassium ( $\beta = -0.101$ , 95% CI:-  
213 0.199, -0.003;  $P = 0.044$ ) and decrease in urinary Na:K ratio ( $\beta = 2.446$ , 95% CI: 0.152, 4.740;

214  $P=0.037$ ) (Table 4). The control group did show an association between reduced urinary  
215 sodium and reduced DBP ( $P=0.028$ ). From a food perspective, the IW group also showed a  
216 significant association between reduction in SBP and an increase in the consumption of *seed*  
217 *and nut products and dishes*, and between a reduction in DBP and increased intake of *seafood*  
218 *products and dishes*. The results did not change after excluding participants who were taking  
219 diuretics at baseline and 3 months (data not shown).

## 220 **DISCUSSION**

221 This secondary analysis of data from a weight loss trial provided further insights into the  
222 impact of changes in dietary patterns, foods and nutrients on BP. The setting which tested  
223 individualised versus general dietary advice enabled this to occur. Dietary patterns,<sup>18</sup> key  
224 foods such as nuts<sup>36</sup> and dietary levels of nutrients such as sodium<sup>4</sup> and potassium<sup>5</sup> can all  
225 affect BP, but these effects are also inter-related.<sup>37</sup> The present analysis showed that  
226 individualised dietary advice, strengthened by a daily supplement of a healthy food, 30 g  
227 walnuts, resulted in greater decrease in urinary Na:K ratio, a parameter associated with lower  
228 BP.<sup>6</sup> After adjusting for weight loss, we found the decrease in Na:K ratio and concomitant  
229 increase in intakes of the “nuts and seeds” and “seafood” food categories were significantly  
230 associated with BP reduction, confirming the effect of diet composition.

231 The significantly greater reduction in Na:K ratio in the IW group was indicative of the dietary  
232 pattern achieved. Diets with a lower Na:K ratio have been negatively associated with  
233 hypertension in epidemiological studies<sup>38</sup> and have been found to reduce BP in randomized  
234 controlled trials.<sup>39</sup> Sodium and potassium play an interdependent role in affecting BP, whereby  
235 consumption of excessive sodium and insufficient potassium cause the vascular smooth muscle  
236 cell to contract and as a result lead to an increase in the peripheral vascular resistance which  
237 increases BP.<sup>40</sup>

238 The results of the current study build on our earlier analysis that identified an inverse  
239 association between BP and a dietary pattern that was rich in “nuts, seeds, fruit and fish” and  
240 BP.<sup>32</sup> In addition, we found significant inverse associations between SBP and dietary patterns  
241 characterized by fruit and nuts, and between DBP and dietary patterns characterized by seafood  
242 in analyses of food-based dietary trials previously conducted.<sup>41</sup> Other randomized controlled  
243 trials show have reported beneficial effects of walnut consumption on BP. In a 2-year study  
244 investigating the effect of a Mediterranean-style diet on endothelial function and inflammation  
245 markers in 180 patients with metabolic syndrome, a Mediterranean-style diet that included  
246 consumption of 25-50 g of walnuts per day significantly reduced SBP by 3 mmHg and DBP by  
247 2 mmHg compared to a control prudent diet.<sup>42</sup> Likewise, in the PREDIMED study, the group  
248 following a Mediterranean diet which contained a daily supplement of 30 g mixed nuts  
249 including 15 g of walnuts showed greater reductions in ambulatory SBP and DBP (-2.4 mmHg  
250 and -1.0 mmHg respectively) after one year compared to the control diet.<sup>43</sup> In a recent meta-  
251 analysis of 21 randomized controlled trials, total nut consumption was shown to lower SBP by  
252 1.29 mmHg in participants without type 2 diabetes.<sup>36</sup> Nuts contain high amounts of mono- and  
253 polyunsaturated fats, magnesium, potassium and fibre and are low in sodium and saturated fats  
254 and thus may elicit a BP lowering response.<sup>44</sup> Consumption of nuts may also be associated with  
255 improved diet quality<sup>45</sup> which in turn may lead to adoption of healthier dietary patterns.

256 In this study, we also found the IW group showed an association between increased seafood  
257 consumption and decreased DBP. The effect of fish consumption on BP has been assessed in  
258 previous studies. For example, moderate consumption of fatty fish (150 g salmon, three times  
259 per week) led to greater reductions in DBP in an 8 week weight-loss study compared to lean  
260 fish, fish oil capsules or placebo capsules.<sup>46</sup> While various studies have shown a BP lowering  
261 effect through supplementation with omega-3 polyunsaturated fatty acids,<sup>47</sup> conclusive  
262 evidence on the effect of dietary fish intake on BP is lacking. This is possibly due to other

263 factors that may attenuate the protective effects such as the method of preparation,  
264 consumption of salted fish or presence of other contaminants such as mercury and pesticides.<sup>48</sup>

265 Compared to individual foods, however, dietary pattern analysis may better demonstrate diet-  
266 BP relationships since foods are not consumed in isolation but as part of a total diet. In  
267 addition, the concept of food synergy proposes that investigation of patterns of food  
268 consumption may be more informative than focussing on individual nutrients or single foods.<sup>49</sup>  
269 Our study has demonstrated that under weight-loss conditions, a dietary pattern with an  
270 increase in nuts, seeds and seafood was associated with reductions in BP. Further  
271 investigations are warranted on the effect of change in dietary patterns on change in BP  
272 especially in different cultural contexts and cuisines.

273 One of the limitations of this analysis is that as a secondary analysis of a randomized controlled  
274 study testing the effects of forms of intervention on weight loss, there is a likelihood the  
275 analysis would be underpowered, particularly in relation to the analysis of changes in dietary  
276 patterns which carry a high degree of variability. However, as under-reporting of dietary  
277 sodium and over-reporting of dietary potassium occurs especially in individuals with higher  
278 BMI,<sup>25</sup> a strength of the study was the assessment of sodium and potassium intake by the gold  
279 standard of 24-h urine excretion,<sup>24</sup> with completeness of urine samples being determined by the  
280 use of urinary creatinine concentrations. Despite this, it is acknowledged that repeated 24-h  
281 urinary collections would have provided greater accuracy due to the well-known large day-to-  
282 day intra-individual variability of sodium and potassium intake.<sup>50</sup>

283 Our analysis observed significant reductions in SBP that were associated with increased intake  
284 of seeds and nuts and reduced Na:K excretion, while reductions in DBP were associated with  
285 increased intake of seafood. Identification of a dietary pattern that includes these foods and  
286 leads to a low Na:K ratio could be helpful in the development of food based dietary

287 recommendations in clinical practice that not only address weight loss but also BP. In the  
288 context of this trial, the impact of individualised dietary advice (and the inclusion of a relevant  
289 food supplement) helped to achieve a healthy dietary pattern and expose effects.

## 290 **ACKNOWLEDGEMENTS**

291 The authors would like to thank all the investigators and participants of the HealthTrack study.  
292 HealthTrack study was primarily funded by the Illawarra Health and Medical Research  
293 Institute with additional support from the California Walnut Commission. The authors'  
294 responsibilities were as follows: LCT, KEC, EPN and MJB designed research; RNN conducted  
295 research; RNN and MJB performed statistical analysis; RNN, LCT, KEC and EPN wrote the  
296 manuscript; RNN had primary responsibility for the final content. All authors read and  
297 approved the final manuscript.

## 298 **CONFLICT OF INTEREST**

299 The authors declare no conflict of interest.

300

301

302

303

304

305

306

307

308 **REFERENCES**

- 309 1. Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani H, et al. A  
310 comparative risk assessment of burden of disease and injury attributable to 67 risk  
311 factors and risk factor clusters in 21 regions, 1990-2010: A systematic analysis for the  
312 Global Burden of Disease Study 2010. *Lancet* 2012; **380**: 2224-2260.
- 313 2. Law MR, Morris JK, and Wald NJ. Use of blood pressure lowering drugs in the  
314 prevention of cardiovascular disease: meta-analysis of 147 randomised trials in the  
315 context of expectations from prospective epidemiological studies. *BMJ* 2009. **338**:  
316 b1665-b1665.
- 317 3. Eckel RH, Jakicic JM, Ard JD, De Jesus JM, Houston Miller N, Hubbard VS, et al.  
318 2013 AHA/ACC guideline on lifestyle management to reduce cardiovascular risk: A  
319 report of the American College of cardiology/American Heart Association task force on  
320 practice guidelines. *Circulation* 2014. **129**: S76-S99.
- 321 4. He FJ, Li J, and Macgregor GA. Effect of longer-term modest salt reduction on blood  
322 pressure. *Cochrane Database Syst Rev* 2013. **4**. CD004937.
- 323 5. Geleijnse JM, Kok FJ, and Grobbee DE. Blood pressure response to changes in sodium  
324 and potassium intake: a metaregression analysis of randomised trials. *J Hum Hypertens*  
325 2003. **17**: 471-480.
- 326 6. Perez V and Chang ET. Sodium-to-potassium ratio and blood pressure, hypertension,  
327 and related factors. *Adv Nutr.* 2014. **5**: 712-741.
- 328 7. Neter JE, Stam BE, Kok FJ, Grobbee DE, and Geleijnse JM. Influence of weight  
329 reduction on blood pressure: a meta-analysis of randomized controlled trials.  
330 *Hypertension* 2003. **42**: 878-884.
- 331 8. Rocchini AP. Obesity hypertension. *American J Hypertens* 2002. **15**: 50S-52S.



- 332 9. Joshy G, Korda RJ, Attia J, Liu B, Bauman AE, and Banks E. Body mass index and  
333 incident hospitalisation for cardiovascular disease in 158 546 participants from the 45  
334 and Up Study. *Int J Obes* 2014. **38**: 848-856.
- 335 10. Miura K, Greenland P, Stamler J, Liu K, Daviglius ML, and Nakagawa H. Relation of  
336 vegetable, fruit, and meat intake to 7-year blood pressure change in middle-aged men:  
337 the Chicago Western Electric Study. *Am J Epidemiol* 2004. **159**: 572-580.
- 338 11. Engberink MF, Hendriksen MAH, Schouten EG, van Rooij FJA, Hofman A, Witteman  
339 JCM, et al. Inverse association between dairy intake and hypertension: the Rotterdam  
340 Study. *Am J Clin Nutr* 2009. **89**: 1877-1883.
- 341 12. Umesawa M, Kitamura A, Kiyama M, Okada T, Shimizu Y, Imano H, et al.  
342 Association between dietary behavior and risk of hypertension among Japanese male  
343 workers. *Hypertens Res* 2013. **36**: 374-380.
- 344 13. Zhou D, Yu H, He F, Reilly KH, Zhang J, Li S, et al. Nut consumption in relation to  
345 cardiovascular disease risk and type 2 diabetes: a systematic review and meta-analysis  
346 of prospective studies. *Am J Clin Nutr* 2014. **100**: 270-277.
- 347 14. Mozaffari-Khosravi H, Ahadi Z, and Barzegar K. The effect of green tea and sour tea  
348 on blood pressure of patients with type 2 diabetes: A randomized clinical trial. *J Diet  
349 Suppl* 2013. **10**: 105-115.
- 350 15. Steffen M, Kuhle C, Hensrud D, Erwin PJ, and Murad MH. The effect of coffee  
351 consumption on blood pressure and the development of hypertension: A systematic  
352 review and meta-analysis. *J Hypertens* 2012. **30**: 2245-2254.
- 353 16. Michels KB and Schulze MB. Can dietary patterns help us detect diet-disease  
354 associations? *Nutr Res Rev* 2005. **18**: 241-248.
- 355 17. Hu FB. Dietary pattern analysis: A new direction in nutritional epidemiology. *Curr  
356 Opin Lipidol* 2002. **13**: 3-9.

- 357 18. Appel LJ, Moore TJ, Obarzanek E, Vollmer WM, Svetkey LP, Sacks FM, et al. A  
358 clinical trial of the effects of dietary patterns on blood pressure. *N Eng J Med* 1997.  
359 **336**: 1117-1124.
- 360 19. Toledo E, Hu FB, Estruch R, Buil-Cosiales P, Corella D, Salas-Salvadó J, et al. Effect  
361 of the Mediterranean diet on blood pressure in the PREDIMED trial: Results from a  
362 randomized controlled trial. *BMC Med* 2013. **11**: 207
- 363 20. Brader L, Uusitupa M, Dragsted LO, and Hermansen K. Effects of an isocaloric healthy  
364 Nordic diet on ambulatory blood pressure in metabolic syndrome: A randomized  
365 SYSDIET sub-study. *Eur J Clin Nutr* 2014. **68**: 57-63.
- 366 21. National Health and Medical Research Council, *Australian Dietary Guidelines*. 2013,  
367 Canberra: National Health and Medical Research Council.
- 368 22. Tapsell LC, Lonergan M, Martin A, Batterham MJ, and Neale EP. Interdisciplinary  
369 lifestyle intervention for weight management in a community population (HealthTrack  
370 study): study design and baseline sample characteristics. *Contemp Clin Trials* 2015. 45:  
371 394-403.
- 372 23. Tapsell LC, Lonergan M, Batterham MJ, Neale EP, Martin A, Thorne R, et al. Effect of  
373 interdisciplinary care on weight loss: a randomised controlled trial. *BMJ Open* (in  
374 press).
- 375 24. McLean RM. Measuring population sodium intake: a review of methods. *Nutrients*  
376 2014. **6**: 4651-4662.
- 377 25. Murakami K, Livingstone MBE, Sasaki S, and Uenishi K. Ability of self-reported  
378 estimates of dietary sodium, potassium and protein to detect an association with general  
379 and abdominal obesity: Comparison with the estimates derived from 24' h urinary  
380 excretion. *B J Nutr* 2015. **113**: 1308-1318.

- 381 26. Campins Falcó P, Tortajada Genaro LA, Meseger Lloret S, Blasco Gomez F, Sevillano  
382 Cabeza A, and Molins Legua C. Creatinine determination in urine samples by  
383 batchwise kinetic procedure and flow injection analysis using the Jaffé reaction:  
384 Chemometric study. *Talanta* 2001. **55**: 1079-1089.
- 385 27. Reinivuo H, Valsta LM, Laatikainen T, Tuomilehto J, and Pietinen P. Sodium in the  
386 Finnish diet: II trends in dietary sodium intake and comparison between intake and 24-h  
387 excretion of sodium. *Eur J Clin Nutr* 2006. **60**: 1160-1167.
- 388 28. Martin GS, Tapsell LC, Denmeade S, and Batterham MJ. Relative validity of a diet  
389 history interview in an intervention trial manipulating dietary fat in the management of  
390 Type II diabetes mellitus. *Prev Med* 2003. **36**: 420-428.
- 391 29. Food Standards Australia and New Zealand (2008). *AUSNUT 2007 – Australian Food,*  
392 *Supplement and Nutrient Database for Estimation of Population Nutrient Intakes.*  
393 *Canberra: Food Standards Australia New Zealand.* Available from:  
394 <http://www.foodstandards.gov.au/consumerinformation/ausnut2007/> (accessed 25 May  
395 2015).
- 396 30. Food Standards Australia and New Zealand (2014). *AUSNUT 2011–13. Australian*  
397 *Food, Supplement and Nutrient Database for Estimation of Population Nutrient*  
398 *Intakes. Canberra: Food Standards Australia New Zealand.* . Available from:  
399 [http://www.foodstandards.gov.au/science/monitoringnutrients/ausnut/ausnutdatafiles/Pa](http://www.foodstandards.gov.au/science/monitoringnutrients/ausnut/ausnutdatafiles/Pages/default.aspx)  
400 [ges/default.aspx](http://www.foodstandards.gov.au/science/monitoringnutrients/ausnut/ausnutdatafiles/Pages/default.aspx) (accessed 25 May 2015).
- 401 31. Neale EP, Probst YC, and Tapsell LC. Development of a matching file of Australian  
402 food composition databases (AUSNUT 2007 to 2011-13). *J Food Composition Anal*  
403 2016. **50**: 30-35.

- 404 32. Ndanuko RN, Tapsell LC, Charlton KE, Neale EP, and Batterham MJ. Associations  
405 between dietary patterns and blood pressure in a clinical sample of overweight adults. *J*  
406 *Acad Nutr Diet* 2017: 228-239.
- 407 33. Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML, Ainsworth BE, et al.  
408 International physical activity questionnaire: 12-country reliability and validity. *Med*  
409 *Sci Sports Exerc* 2003. **35**: 1381-1395.
- 410 34. National Center for Health Statistics, *The Third National Health and Nutrition*  
411 *Examination Survey Plan and Operations manuals*. 1988, Centres for Disease Control  
412 and Prevention: Hyattsville.
- 413 35. Wile D. Diuretics: a review. *Ann Clin Biochem* 2012. **49**: 419-431.
- 414 36. Mohammadifard N, Salehi-Abargouei A, Salas-Salvadó J, Guasch-Ferré M, Humphries  
415 K, and Sarrafzadegan N. The effect of tree nut, peanut, and soy nut consumption on  
416 blood pressure: a systematic review and meta-analysis of randomized controlled clinical  
417 trials. *Am J Clin Nutr* 2015. **101**: 966-982.
- 418 37. Tapsell LC, Neale EP, Satija A, and Hu FB. Foods, nutrients, and dietary patterns:  
419 Interconnections and implications for dietary guidelines. *Adv Nutr* 2016. **7**: 445-454.
- 420 38. Zhang Z, Cogswell ME, Gillespie C, Fang J, Loustalot F, Dai S, et al. Association  
421 between Usual Sodium and Potassium Intake and Blood Pressure and Hypertension  
422 among U.S. Adults: NHANES 2005-2010. *PLoS ONE* 2013. **8**. e75289.
- 423 39. Saneei P, Salehi-Abargouei A, Esmailzadeh A, and Azadbakht L. Influence of Dietary  
424 Approaches to Stop Hypertension (DASH) diet on blood pressure: A systematic review  
425 and meta-analysis on randomized controlled trials. *Nutrition, Metabolism and*  
426 *Cardiovascular Diseases* 2014. **24**: 1253-1261.
- 427 40. Adrogué HJ and Madias NE. Sodium and potassium in the pathogenesis of  
428 hypertension. *N Engl J Med* 2007. **356**: 1966-1978.

- 429 41. Anil S, Charlton KE, Tapsell LC, Probst Y, Ndanuko R, and Batterham MJ.  
430 Identification of dietary patterns associated with blood pressure in a sample of  
431 overweight Australian adults. *J Hum Hypertens* 2016. **30**: 672-678.
- 432 42. Esposito K, Marfella R, Ciotola M, Di Palo C, Giugliano F, Giugliano G, et al. Effect  
433 of a Mediterranean-style diet on endothelial dysfunction and markers of vascular  
434 inflammation in the metabolic syndrome: A randomized trial. *JAMA* 2004. **292**: 1440-  
435 1446.
- 436 43. Doménech M, Roman P, Lapetra J, García De La Corte FJ, Sala-Vila A, De La Torre R,  
437 et al. Mediterranean diet reduces 24-hour ambulatory blood pressure, blood glucose,  
438 and lipids: One-year randomized, clinical trial. *Hypertension* 2014. **64**: 69-76.
- 439 44. Kendall CWC, Josse AR, Esfahani A, and Jenkins DJA. Nuts, metabolic syndrome and  
440 diabetes. *B J Nutr* 2010. **104**: 465-473.
- 441 45. O'Neil CE, Nicklas TA, and Fulgoni VL, 3<sup>rd</sup>. Tree nut consumption is associated with  
442 better nutrient adequacy and diet quality in adults: National Health and Nutrition  
443 Examination Survey 2005-2010. *Nutrients* 2015. **7**: 595-607.
- 444 46. Ramel A, Martinez JA, Kiely M, Bandarra NM, and Thorsdottir I. Moderate  
445 consumption of fatty fish reduces diastolic blood pressure in overweight and obese  
446 European young adults during energy restriction. *Nutrition* 2010. **26**: 168-174.
- 447 47. Appel LJ, Miller ER, 3rd, Seidler AJ, and Whelton PK. Does supplementation of diet  
448 with 'fish oil' reduce blood pressure? A meta-analysis of controlled clinical trials. *Arch*  
449 *Intern Med* 1993. **153**: 1429-1438.
- 450 48. Yang B, Shi M-Q, Li Z-H, Yang J-J, and Li D. Fish, Long-Chain n-3 PUFA and  
451 Incidence of Elevated Blood Pressure: A Meta-Analysis of Prospective Cohort Studies.  
452 *Nutrients* 2016. **8**: 58-70.

- 453 49. Jacobs DR, Jr., Gross MD, and Tapsell LC. Food synergy: an operational concept for  
454 understanding nutrition. *Am J Clin Nutr* 2009. **89**: 1543S-1548S.
- 455 50. Liu K, Cooper R, McKeever J, Makeever P, Byington R, Soltero I, et al. Assessment of  
456 the association between habitual salt intake and high blood pressure: Methodological  
457 problems. *Am J Epidemiol* 1979. **110**: 219-226.

458

459

460

461

462

463

464

465

466

467

468

469

470

471

472

473 **FIGURE LEGENDS**

474 **Figure 1**

475 Participant flow in the HealthTrack study and available data for the current analysis. Adapted  
476 from Tapsell L.C., Lonergan M., Martin A., Batterham M.J., and Neale E.P., Interdisciplinary  
477 lifestyle intervention for weight management in a community population (HealthTrack study):  
478 study design and baseline sample characteristics. Contemporary Clinical Trials, 2015(45): p.  
479 394-403.

480 **Figure 2**

481 Change in systolic and diastolic blood pressure in each group from baseline to 3 months and  
482 between intervention groups and control group. C, control (usual care); DBP, diastolic blood  
483 pressure; I, interdisciplinary intervention with individualised dietary advice; IW,  
484 interdisciplinary intervention with individualised dietary advice plus a supplement of 30 grams  
485 of walnuts per day; SBP, systolic blood pressure; asterisks (\*) indicate significant change at  $P$   
486  $< 0.05$ ; Error bars indicate standard error of the mean.

487

488

489

490

491

**Table 1.** Baseline characteristics of the 211 participants with complete data on blood pressure, urinary sodium and potassium and dietary intake in the HealthTrack study (n=211)<sup>1</sup>

| Characteristic                         | IW (n=82)               | I (n=62)                | C (n=67)                 | P value for group difference <sup>2</sup> |
|--|-------------------------|-------------------------|--------------------------|---|
| Age, years                             | 43.2 (8.7)              | 45.2 (7.1)              | 45.1 (7.2)               | 0.242                                     |
| Height, m                              | 1.7 (0.1)               | 1.7 (0.1)               | 1.7 (0.1)                | 0.397                                     |
| Weight, kg                             | 90.0 (14.6)             | 93.0 (16.1)             | 89.6 (15.4)              | 0.4                                       |
| BMI, kg/m <sup>2</sup>                 | 32.0 (4.1)              | 32.6 (4.4)              | 32.2 (4.2)               | 0.784                                     |
| Waist circumference, cm                | 102.4 (11.4)            | 104.7 (11.8)            | 103.7 (13.3)             | 0.57                                      |
| Hypertensives, % (n) <sup>3</sup>      | 31.7 (26)               | 32.3 (20)               | 26.9 (18)                | 0.755                                     |
| <b>Dietary intake</b>                  |                         |                         |                          |   |
| Median energy, kj/day (IQR)            | 8671 (7309-10350)       | 8618 (7701-10981)       | 9486 (8066-11438)        | 0.165                                     |
| Median sodium, mg/day (IQR)            | 2453 (1974-3037)        | 2260 (1682-3099)        | 2521 (2003-3065)         | 0.452                                     |
| Median potassium, mg/day (IQR)         | 3694 (3027-4211)        | 3519 (3044-4452)        | 3849 (3191-4674)         | 0.123                                     |
| Median magnesium, mg/day (IQR)         | 423 (329-542)           | 427 (331-522)           | 449 (349-570)            | 0.214                                     |
| Median calcium, mg/day (IQR)           | 894 (663-1134)          | 985 (713-1234)          | 951 (731-1233)           | 0.334                                     |
| <b>Urinary excretion<sup>4</sup></b>   |                         |                         |                          |   |
| Volume, mL/day                         | 2114 (962)              | 2048 (874)              | 2018 (838)               | 0.799                                     |
| Creatinine, mmol/day                   | 13.6 (4.4)              | 14.2 (4.1)              | 13.8 (4.7)               | 0.758                                     |
| Sodium, mmol/day                       | 149.7 (54.6)            | 138.2 (62.5)            | 151.0 (61.7)             | 0.448                                     |
| Median sodium, mmol/day (IQR)          | 137 (108-191)           | 128 (97-170)            | 145 (99-181)             | 0.391                                     |
| Potassium, mmol/day                    | 75.5 (27.8)             | 77.9 (21.3)             | 84.5 (38.0)              | 0.276                                     |
| Median potassium, mmol/day (IQR)       | 72 (54-89)              | 77 (63-91)              | 75 (59-98)               | 0.319                                     |
| Sodium-to-potassium ratio              | 2.1 (0.99) <sup>a</sup> | 1.8 (0.57) <sup>b</sup> | 2.0 (0.85) <sup>ab</sup> | 0.024                                     |
| Median sodium-to-potassium ratio (IQR) | 1.9 (1.4-2.7)           | 1.8 (1.3-2.1)           | 1.9 (1.4-2.1)            | 0.206                                     |

<sup>1</sup>Values are expressed as means (standard deviation) unless otherwise stated; <sup>2</sup>Group comparisons were made using analysis of variance for normally distributed data; <sup>3</sup>Group comparisons were made using Chi square test; <sup>4</sup>Group comparisons were made using Kruskal-Wallis H test for data that was



not normally distributed; C, control (usual care); I, interdisciplinary intervention with individualised dietary advice; IQR, interquartile range; IW, interdisciplinary intervention with individualised dietary advice plus a supplement of 30 grams of walnuts per day.

**Table 2.** Change in weight and blood pressure from baseline to 3 months in the HealthTrack study (n=211)<sup>1</sup>

|                |  | IW (n=82)                        | I (n=62)                         | C (n=67)                         | P value for group difference | IW vs. C (95% CI)   | P value | I vs. C (95% CI)    | P value |
|----------------|--|----------------------------------|----------------------------------|----------------------------------|------------------------------|---------------------|---------|---------------------|---------|
| Weight (Kg)    | Baseline                                       | 90.0 ± 14.6                      | 93.0 ± 16.1                      | 89.6 ± 15.4                      | 0.394                        |                     |         |                     |         |
|                | 3 months                                       | 87.2 ± 14.2                      | 90.0 ± 16.1                      | 88.2 ± 15.4                      | 0.54                         |                     |         |                     |         |
|                | Change (95% CI)                                | -2.8 (-3.6 to -2.0) <sup>a</sup> | -2.9 (-3.8 to -2.1) <sup>a</sup> | -1.4 (-1.9 to -0.9) <sup>b</sup> | 0.007                        | -1.4 (-2.5 to -0.2) | 0.021   | -1.5 (-2.8 to -0.3) | 0.013   |
|                | P value for difference between baseline and 3m | <0.001                           | <0.001                           | <0.001                           |                              |                     |         |                     |         |
| Blood pressure | Baseline                                       | 127.5 ± 16.6                     | 127.5 ± 18.6                     | 123.0 ± 13.0                     |                              |                     |         |                     |         |
|                | 3 months                                       | 120.5 ± 13.3                     | 120.5 ± 15.6                     | 119.7 ± 12.5                     |                              |                     |         |                     |         |
|                | Change (95% CI)                                | -7.0 (-9.5 to -4.6)              | -7.0 (-9.8 to -4.2)              | -3.3 (-5.4 to -1.2)              | 0.057                        | -3.7 (-7.5 to 0.1)  | 0.06    | -3.7 (-7.9 to 0.5)  | 0.095   |
|                | P value for difference between baseline and 3m | <0.001                           | <0.001                           | 0.002                            |                              |                     |         |                     |         |
| DBP (mmHg)     | Baseline                                       | 74.2 ± 10.3                      | 75.0 ± 12.5                      | 72.6 ± 9.4                       |                              |                     |         |                     |         |
|                | 3 months                                       | 69.8 ± 9.3                       | 70.1 ± 11.3                      | 71.0 ± 9.0                       |                              |                     |         |                     |         |

|  |  |                                       |                                      |                                 |       |                    |       |                        |       |
|--|--|---------------------------------------|--------------------------------------|---------------------------------|-------|--------------------|-------|------------------------|-------|
|  | Change<br>(95% CI)   | -4.4 (-6.0 to -<br>2.7) <sup>ab</sup> | -4.9 (-7.0 to -<br>2.8) <sup>b</sup> | -1.6 (-3.3 to 0.2) <sup>a</sup> | 0.027 | -2.8 (-5.7 to 0.1) | 0.057 | -3.3 (-6.6<br>to -0.1) | 0.041 |
|  | P value for<br>difference<br>between<br>baseline and<br>3m | <0.001                                | <0.001                               | 0.076                           |       |                    |       |                        |       |

Values are mean ± standard deviation unless otherwise stated; a,b,cGroups with different superscripts were significantly different after Bonferroni adjustment; change in blood pressure unadjusted for weight loss; C, control (usual care); DBP, diastolic blood pressure; I, interdisciplinary intervention with individualised dietary advice; IW, interdisciplinary intervention with individualised dietary advice plus a supplement of 30 grams of walnuts per day; SBP, systolic blood pressure.

**Table 3.** Change in 24-h urinary excretion and key food groups from baseline to 3 months in the HealthTrack study (n=211)<sup>1</sup>

|                                |  | IW (n=82)                  | I (n=62)                  | C (n=67)                   | P value for group difference |
|--------------------------------|--|----------------------------|---------------------------|----------------------------|------------------------------|
| Urinary excretion              |  |                            |                           |                            |                              |
| Urinary sodium (mmol/d)        | Baseline                                       | 149.7 (54.6)               | 138.2 (62.5)              | 151.0 (61.7)               | 0.448                        |
|                                | 3 months                                       | 118.9 (55.1)               | 138.3 (56.7)              | 125.0 (62.3)               | 0.135                        |
|                                | Change   | -30.8 (62.2) <sup>a</sup>  | 0.1 (69.6) <sup>b</sup>   | -26.0 (80.8) <sup>ab</sup> | 0.026                        |
|                                | P value for difference between baseline and 3m | <0.001                     | 0.991                     | 0.011                      |                              |
| Urinary potassium (mmol/d)     | Baseline                                       | 75.5 (27.8)                | 77.9 (21.3)               | 84.5 (38.0)                | 0.276                        |
|                                | 3 months                                       | 72.6 (29.3)                | 77.6 (24.9)               | 72.2 (22.8)                | 0.416                        |
|                                | Change   | -2.95 (26.5) <sup>ab</sup> | -0.26 (21.9) <sup>a</sup> | -12.3 (35.7) <sup>b</sup>  | 0.042                        |
|                                | P value for difference between baseline and 3m | 0.316                      | 0.926                     | 0.006                      |                              |
| Urinary Na:K ratio (mmol/mmol) | Baseline                                       | 2.13 (0.99) <sup>a</sup>   | 1.77 (0.57) <sup>b</sup>  | 1.96 (0.85) <sup>ab</sup>  | 0.024                        |
|                                | 3 months                                       | 1.79 (0.79)                | 1.91 (0.84)               | 1.80 (0.78)                | 0.654                        |
|                                | Change   | -0.34 (1.06) <sup>a</sup>  | 0.14 (0.80) <sup>b</sup>  | -0.16 (1.06) <sup>ab</sup> | 0.02                         |
|                                | P value for difference between baseline and 3m | 0.006                      | 0.187                     | 0.217                      |                              |
| Food groups                    |  |                            |                           |                            |                              |

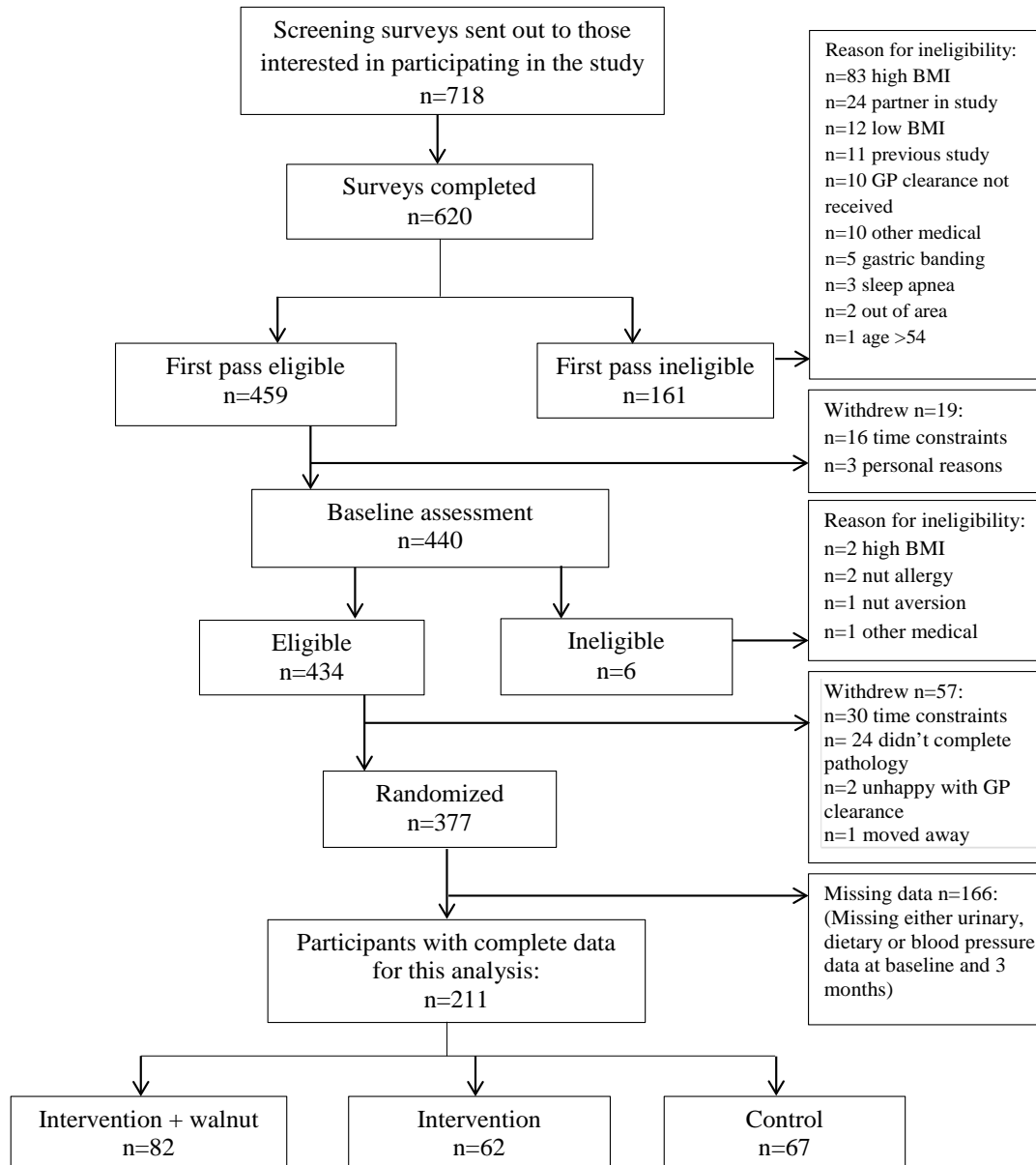
|  |  |                                   |                                  |                                    |        |
|--|--|-----------------------------------|----------------------------------|------------------------------------|--------|
| Seed and nut products and dishes (g/d), median (IQR) | Baseline                                       | 13.4 (5.4-34.4)                   | 16.2 (6.4-30.6)                  | 18.2 (7.1-37.5)                    | 0.56   |
|  | 3 months                                       | 30.0 (27.4-37.3) <sup>a</sup>     | 10.4 (4.2-19.1) <sup>b</sup>     | 20.4 (6.9-41.2) <sup>c</sup>       | <0.001 |
|  | Change   | 20.4 (4.9 to 30) <sup>a</sup>     | -1.5 (-13.5 to 5.1) <sup>b</sup> | -1.8 (-18.5 to 11.6) <sup>bc</sup> | <0.001 |
|  | P value for difference between baseline and 3m | <0.001                            | 0.008                            | 0.766                              |        |
| Fruit products and dishes (g/d), median (IQR)        | Baseline                                       | 113.1 (57.7-224.7)                | 151.4 (81.0-258.8)               | 140.8 (69.9-231.6)                 | 0.276  |
|  | 3 months                                       | 212.3 (146.7-270.9) <sup>ab</sup> | 241.9 (149.6-301.4) <sup>a</sup> | 160.9 (109.9-262.7) <sup>b</sup>   | 0.022  |
|  | Change   | 62.5 (-10.8 to 169.1)             | 79.2 (-37.6 to 168.9)            | 37.0 (-51.6 to 107.2)              | 0.073  |
|  | P value for difference between baseline and 3m | <0.001                            | 0.005                            | 0.096                              |        |
| Seafood products and dishes (g/d), median (IQR)      | Baseline                                       | 35.0 (19.8-58.3)                  | 35.4 (14.9-60.6)                 | 32.9 (20.0-67.1)                   | 0.957  |
|  | 3 months                                       | 35.1 (20.3-64.3)                  | 45.4 (21.1-67.5)                 | 40.1 (20.4-57.1)                   | 0.404  |
|  | Change   | 7.8 (-11.0 to 20.1)               | 2.9 (-15.8 to 29.6)              | 0.0 (-15.9 to 16.8)                | 0.641  |
|  | P value for difference between baseline and 3m | 0.224                             | 0.31                             | 0.716                              |        |

<sup>1</sup>Values are mean (standard deviation) unless otherwise stated; <sup>a,b,c</sup>Groups with different superscripts were significantly different after Bonferroni adjustment; C, control (usual care); I, interdisciplinary intervention with individualised dietary advice; IW, interdisciplinary intervention with individualised dietary advice plus a supplement of 30 grams of walnuts per day; Na:K, sodium-to-potassium ratio.

**Table 4.** Linear regression for association between change in blood pressure and change in urinary markers and key food groups in the HealthTrack study (n=211)<sup>1</sup>

|   | IW (n=82)      |         | I (n=62)       |         | C (n=67)        |         |
|---|----------------|---------|----------------|---------|-----------------|---------|
|   | B ± SE         | P value | B ± SE         | P value | B ± SE          | P value |
| Change in SBP   |                |         |                |         |                 |         |
| Change in urinary Na (mmol/d)                                   | 0.009 ± 0.021  | 0.687   | 0.010 ± 0.022  | 0.649   | 0.019 ± 0.013   | 0.154   |
| Change in urinary K (mmol/d)                                    | -0.101 ± 0.050 | 0.044   | 0.057 ± 0.074  | 0.445   | 0.022 ± 0.031   | 0.471   |
| Change in Na:K ratio  | 2.446 ± 1.171  | 0.037   | -1.107 ± 1.976 | 0.575   | 0.442 ± 1.041   | 0.671   |
| Change in consumption of seed and nut products and dishes (g/d) | -0.108 ± 0.051 | 0.034   | -0.002 ± 0.061 | 0.975   | -0.011 ± 0.021  | 0.608   |
| Change in consumption of fruit products and dishes (g/d)        | -0.002 ± 0.010 | 0.867   | -0.007 ± 0.010 | 0.451   | 0.002 ± 0.006   | 0.785   |
| Change in consumption of seafood products and dishes (g/d)      | -0.072 ± 0.041 | 0.083   | -0.056 ± 0.032 | 0.077   | -0.011 ± 0.030  | 0.72    |
| Change in DBP   |                |         |                |         |                 |         |
| Change in urinary Na (mmol/d)                                   | 0.007 ± 0.015  | 0.644   | 0.005 ± 0.017  | 0.751   | 0.024 ± 0.011   | 0.028   |
| Change in urinary K (mmol/d)                                    | -0.056 ± 0.034 | 0.103   | 0.070 ± 0.056  | 0.213   | 0.010 ± 0.025   | 0.697   |
| Change in Na:K ratio  | 1.500 ± 0.808  | 0.063   | -1.141 ± 1.497 | 0.446   | 0.856 ± 0.851   | 0.315   |
| Change in seed and nut products and dishes (g/d)                | -0.046 ± 0.035 | 0.195   | 0.003 ± 0.047  | 0.946   | -0.014 ± 0.017  | 0.925   |
| Change in fruit products and dishes (g/d)                       | -0.004 ± 0.007 | 0.59    | -0.003 ± 0.008 | 0.653   | 0.001 ± 0.005   | 0.672   |
| Change in seafood products and dishes (g/d)                     | -0.063 ± 0.028 | 0.024   | 0.030 ± 0.025  | 0.231   | -0.0002 ± 0.024 | 0.994   |

<sup>1</sup>Controlling for age, sex, BP medication, weight loss, change in physical activity, smoking; C, control (usual care); DBP, diastolic blood pressure; I, interdisciplinary intervention with individualised dietary advice; IW, interdisciplinary intervention with individualised dietary advice plus a supplement of 30 grams of walnuts per day; K, potassium; Na, sodium; Na:K, sodium-to-potassium ratio; SBP, systolic blood pressure.



**Figure 1**