American Journal of
Preventive Medicine

RESEARCH ARTICLE

Frequent Nutritional Feedback, Personalized Advice, and Behavioral Changes: Findings from the European Food4Me Internet-Based RCT

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Introduction: This study tested the hypothesis that providing personalized nutritional advice and feedback more frequently would promote larger, more appropriate, and sustained changes in dietary behavior as well as greater reduction in adiposity.

Study design: A 6-month RCT (Food4Me) was conducted in seven European countries between 2012 and 2013.

Setting/participants: A total of 1,125 participants were randomized to Lower- (n=562) or Higher- (n=563) Frequency Feedback groups.

Intervention: Participants in the Lower-Frequency group received personalized nutritional advice at baseline and at Months 3 and 6 of the intervention, whereas the Higher-Frequency group received personalized nutritional advice at baseline and at Months 1, 2, 3 and 6.

Main outcome measures: The primary outcomes were change in dietary intake (at food and nutrient levels) and obesity-related traits (body weight, BMI, and waist circumference). Participants completed an online Food Frequency Questionnaire to estimate usual dietary intake at baseline and at Months 3 and 6 of the intervention. Overall diet quality was evaluated using the 2010 Healthy Eating Index. Obesity-related traits were self-measured and reported by participants via the Internet. Statistical analyses were performed during the first quarter of 2018.

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0749-3797/$36.00
https://doi.org/10.1016/j.amepre.2019.03.024

Results: At 3 months, participants in the Lower- and Higher-Frequency Feedback groups showed improvements in Healthy Eating Index score; this improvement was larger in the Higher-Frequency group than the Lower-Frequency group (Δ=1.84 points, 95% CI=0.79, 2.89, p=0.0001). Similarly, there were greater improvements for the Higher- versus Lower-Frequency group for body weight (Δ= −0.73 kg, 95% CI= −1.07, −0.38, p<0.0001), BMI (Δ= −0.24 kg/m^2, 95% CI= −0.36, −0.13, p<0.0001), and waist circumference (Δ= −1.20 cm, 95% CI= −2.36, −0.04, p=0.039). However, only body weight and BMI remained significant at 6 months.

Conclusions: At 3 months, higher-frequency feedback produced larger improvements in overall diet quality as well as in body weight and waist circumference than lower-frequency feedback. However, only body weight and BMI remained significant at 6 months.

Trial registration: This study is registered at www.clinicaltrials.gov NCT01530139.

Am J Prev Med 2019;57(2):209−219.

INTRODUCTION

Poor diet and lack of physical activity are major risk factors for noncommunicable diseases, including type 2 diabetes, cardiovascular diseases, and many cancers.[1,2] Up to 80% of these diseases could be prevented by eliminating shared risk factors, including unhealthy diet, physical inactivity, and excess alcohol consumption.[3] This emphasizes the importance of changing lifestyle to improve public health.

Most population strategies to reduce the burden of noncommunicable diseases have used "one-size-fits-all" public health recommendations such as "eat at least five portions of fruit and vegetables daily."[4] However, the prevalence of obesity and the global burden of noncommunicable diseases continue to rise, underlining the need for more effective intervention strategies.[5] Personalized dietary interventions, designed according to key characteristics of the individual participants,[5,6] have been shown to be effective in improving lifestyle-related behaviors.[7−10] Recent evidence from the Food4Me Study, a European RCT, suggests that the Internet is a feasible and acceptable platform for delivering effective and large-scale lifestyle-based interventions.[7] However, the intervention designs that are associated with larger and more sustainable behavioral changes are unknown. As providing feedback is a behavior change technique associated with increased efficacy of dietary interventions,[11] within the Food4Me Study, the authors investigated whether higher-frequency feedback led to larger and more appropriate changes in health-related behaviors (diet and adiposity) than lower-frequency feedback and whether any advantage was sustained in the medium term.

METHODS

Study Population

The Food4Me "Proof of Principle" study was a 6-month RCT, conducted across seven European countries to compare the effects of three levels of personalized nutrition (PN) advice with standard population dietary recommendations (control group) on health-related outcomes. Participants were randomized to one of four intervention arms (Level 0 [L0]: control group; L1, L2, and L3: PN groups). Full details of the study protocol have been summarized in the Appendix, available online, and elsewhere.[6] The current study aimed to determine whether the provision of more frequent feedback and advice was more efficacious in assisting and motivating study participants to make, and to sustain, appropriate health-promoting behavior changes, than less frequent feedback. To answer this question, those participants randomized to L1, L2, and L3 only were further randomized into Lower- and Higher-Frequency Feedback groups (more details on the personalized feedback provided for L1, L2, and L3 participants are provided in the Appendix, available online). For that reason, participants randomized to the L0 control group were not included in this analysis. The following feedback was provided to Lower- and Higher-Frequency Feedback groups:

1. Lower-Frequency Feedback: personalized dietary advice based on individual dietary intake (at food and nutrient levels), phenotypic data, genotypic data, or all of these. Personalized feedback and advice were delivered at baseline, 3 months, and 6 months.
2. Higher-Frequency Feedback: personalized dietary advice based on individual dietary intake (at food and nutrient levels), phenotypic data, genotypic data, or all of these. Personalized feedback and advice were delivered at baseline and at 1, 2, 3, and 6 months.

The primary outcomes were change in dietary intake of food items or target nutrients and obesity-related traits (body weight, BMI, and waist circumference [WC]) between Higher- and Lower-Frequency Feedback groups, at Months 3 and 6.

Participants were recruited in seven European countries (Ireland, The Netherlands, Spain, Greece, United Kingdom, Poland, and Germany). Participants were screened online between August 2012 and August 2013 as described elsewhere.[6] The authors aimed to recruit a total of 1,540 study participants aged ≥18 years.[6] Participants were randomized using an automated server designed for the study according to an urn randomization scheme stratified by country, sex, and age (<45 or ≥45 years).[12]

Participants aged ≥18 years were included in the study with no restrictions on BMI levels. The following minimal sets of exclusion criteria were applied: (1) pregnant or lactating; (2) no or limited access to the Internet; (3) following a prescribed diet for any reason, including weight loss, in the last 3 months; and (4) diabetes, celiac disease, Crohn disease, or any metabolic disease or condition altering nutritional requirements, food allergies, or intolerances.

The Research Ethics Committees at each University or Research Center delivering the intervention granted approval for the study. Before participation, potential volunteers completed an informed consent form online before submitting personal data.

Participants randomized to PN groups (L1, L2, and L3) received personalized feedback and advice that was derived manually using decision trees, developed specifically for the Food4Me Study (Appendix Tables 1 and 2, available online).[13] For individuals randomized to the Lower-Frequency Feedback group, dietary intake (at food and nutrient levels), physical activity, and anthropometric measures were assessed and feedback provided within 1 week at baseline, Month 3, and Month 6 only, whereas measurements in those randomized to the Higher-Frequency Feedback group were performed and feedback provided within 1 week additionally at Months 1 and 2 (Appendix 1, available online). For body weight, BMI, and WC, participants were provided PN advice to reduce these phenotypic markers for both groups if their BMI was ≥25.0 kg/m^2 or WC was >88 cm and >102 cm for women and men, respectively. Dietary intakes were assessed using a validated online Food Frequency Questionnaire[13−16] and intakes of food groups and nutrients categorized as too high or too low were identified and ranked (Appendix Figure 1, available online). Contributing foods were identified and specific messages were developed, according to standardized algorithms, to advise change in intake of those foods and targeted nutrients.[13−16] To maximize potential for translation into improved dietary behavior, this advice was operationalized as three individual food-based dietary goals. For participants randomized to L2 and L3, the feedback also included, and referred to, phenotypic measures (including blood glucose, cholesterol, carotenoids, fatty acids, and obesity-related markers [L2]) and phenotypic plus genotypic data (L3). Details of these feedback reports are described in the Appendix Table 2 and Appendix Figures 1 and 2, available online, and elsewhere.[6]

Measures

Participants consented to self-report their measures via the Internet and to send biological samples (buccal swabs for DNA extraction and dried blood spots) by post (details are provided in Appendix 1, available online). A summary of all measurements made at each time point is provided in Appendix Table 1, available online.

Participants provided sociodemographic (age, sex, and ethnicity), smoking behavior, medically diagnosed diseases, and anthropometric data online at screening, and detailed information on dietary intake and food preferences.[6] Occupations were grouped according to the European classifications (professional and managerial, intermediate, routine and manual, service and sales workers, elementary occupations, students, and retired).[17]

Body weight, height, and WC were self-measured and self-reported by participants via the Internet. Participants were instructed to measure body weight after an overnight fast, without shoes and wearing light clothing using a home or commercial scale, and to measure height, barefoot, using a standardized measuring tape provided by the researchers. WC was measured at the midpoint between the lower rib and the iliac crest using the provided tape. Central obesity was defined as WC >88 cm for women and >102 cm for men. BMI (kg/m^2) was calculated from body weight and height. Adiposity status was defined using WHO criteria for BMI (underweight, <18.5 kg/m^2; normal weight, ≥18.5 kg/m^2 to ≤24.9 kg/m^2; overweight, ≥25.0 kg/m^2 to ≤29.9 kg/m^2; obese, ≥30.0 kg/m^2). At least 5% and 10% body weight reduction at Months 3 and 6 was used as a clinically meaningful degree of weight loss, as reported previously.[9,18] Self-reported measurements were validated in a subsample of the participants (n=140) across seven European countries and showed a high degree of reliability (Appendix 1, available online).

Participants completed an online Food Frequency Questionnaire to estimate usual dietary intake at baseline and at Months 3 and 6 of the intervention. This Food Frequency Questionnaire, which was developed and validated for the Food4Me Study,[13−16] included 157 food items consumed frequently in each of the seven recruitment countries.[13−16] Overall diet quality was evaluated using the 2010 Healthy Eating Index (HEI-2010).[19] Further details on dietary intake measures are provided in Appendix Table 3, available online.

Physical activity levels (i.e., total energy expenditure/calculated basal metabolic rate) and time spent in sedentary behaviors (minutes/day) were measured objectively using triaxial accelerometers (TracmorD, Philips Consumer Lifestyle, Amsterdam, The Netherlands). Physically active individuals were defined as those achieving ≥150 minutes of moderate-equivalent physical activity per week.[20] Further details on physical activity measures are described in detail in Appendix 1, available online.

Statistical Analysis

To answer the research question of whether a higher frequency of feedback is more effective in assisting and motivating study participants to make, and to sustain, appropriate health-promoting changes than a lower frequency of feedback, intervention effects on overall diet quality and targeted personalized nutrients were assessed. Participants randomized to L1−3 only were included in this analysis because only they were randomized by feedback frequency.

Twenty multiple imputations were performed following current guidelines for epidemiologic and clinical research[21] by fully conditional specification methods,[22] which are powerful and statistically valid methods for creating imputations in large data sets that include both categorical and continuous variables. It specifies the multivariate imputation model on a variable-by-variable basis and offers a principled yet flexible method of addressing missing data, which is particularly useful for large data sets with complex data structures (level of missing data is summarized in Appendix Table 4, available online).

Results from descriptive analyses are presented as means and SDs or 95% CIs for continuous variables or as percentages for categorical variables. To answer the primary research question, the authors used a linear mixed model with fixed effects and random intercept for participants with time point fitted into the model as a linear term (baseline, Month 3, and Month 6), and baseline age, sex, occupation, country, and intervention arm as covariates (models for body weight, BMI, and WC were additionally adjusted for total physical activity levels). Contrast analyses were used to determine changes in outcomes (diet quality, target nutrients, body weight, BMI, and WC) from baseline to Month 3 and from baseline to Month 6 by feedback frequency group (Lower and Higher). These results were reported as Δ (Month 3 − Month 0) and 95% CIs. Similar estimations were performed for change at Month 6. The differences between Δ for Lower- and Higher-Frequency Feedback groups at Month 3 and at Month 6 were tested using a linear mixed model and reported as Δ (Higher − Lower) and 95% CIs. The effect size for the Δ between feedback groups at Months 3 and 6 were estimated as the ratio of the observed Δ to the baseline SD of each measure. This gives a value similar to a Cohen's d; therefore, effects sizes <0.2 would be considered small. These analyses were performed under two main scenarios. Scenario 1 included all participants randomized to the Lower- or Higher-Frequency Feedback groups with the overall HEI-2010 score as the outcome measure. Scenario 2 was conducted using a restricted sample, which included only those participants who were advised to reduce, or increase, the intake of specific nutrients (salt, saturated fat, dietary fiber, folate, polyunsaturated fat, and total energy intake) or received advice to change obesity-related traits (body weight, BMI, and WC).

Binomial regression with a log link to directly estimate RRRs were performed to investigate whether participants allocated to the Higher-Frequency Feedback group were more likely to achieve ≥5% and ≥10% weight loss than those allocated to the Lower-Frequency group, and findings are reported as RRR and 95% CIs. Similarly, to investigate differences in drop out from the study at Months 3 and 6 between frequency groups, binomial regression analyses were performed and RRRs were estimated (Lower-Frequency Feedback group was used as the ref) (Appendix Table 5, available online).

All statistical analyses were performed using Stata, version 14 during the first quarter of 2019, and significance was set at $p<0.05$.

RESULTS

A total of 5,562 participants were screened online between August 2012 and August 2013; the characteristics of these individuals have been reported elsewhere.[23] The first 1,607 volunteers meeting the inclusion criteria were recruited to the RCT (Figure 1); however, for this study, only those randomized to Lower-Frequency (n=562) and Higher-Frequency (n=558) Feedback groups were included in this analysis. Of these, 498 and 460 participants completed the study for the Lower- and Higher-Frequency groups, respectively (i.e., 85.2% of all participants) (Figure 1). However, the analysis revealed that, compared with individuals in the Lower-Frequency group, those in the Higher-Frequency group were more likely to have dropped out of the study by Months 3 and 6 (RRR=1.78, 95% CI=1.21, 2.62, p=0.003 and RRR=1.58, 95% CI=1.16, 2.16, p=0.004, respectively) independent of age, intervention arm, sex, country, occupation, and BMI (Appendix Table 6, available online). Baseline characteristics of the participants by feedback frequency are shown in Appendix Table 5, available online. No major differences in dietary intakes at baseline were observed between frequency groups (Table 1 and Appendix Table 7, available online).

Participants in the Food4Me Study who were randomized to PN improved their overall diet quality over the 3-month intervention period (Table 1 and Figure 2). However, the improvement was significantly greater in the Higher-Frequency group than in the Lower-Frequency group (Δ=1.84 points, 95% CI=0.79, 2.89, $p<0.0001$). The analysis by HEI-2010 subcomponent showed that, at Month 3, both groups achieved improvements in all HEI-2010 subcomponents except for dairy, seafood, plant proteins, and empty calories for both Frequency groups (Appendix Table 7, available online). However, compared with the Lower-Frequency group, participants in the Higher-Frequency group achieved significantly larger health-promoting changes in fatty acid ratio (Δ=0.07, 95% CI=0.03, 0.11, p=0.001), refined grains (Δ= −6.96, 95% CI= −13.6, −0.29, p=0.041), and salt intake (Δ= −0.08, 95% CI= −0.14, −0.01, p=0.019) (Appendix Table 7, available online). There were no differences between frequency groups for fruit, vegetables, greens and beans, whole grains, dairy, total protein, refined grains, and empty calories (Appendix Table 7, available online).

At Month 6, there were improvements in the overall HEI-2010 score and for HEI-2010 subcomponents, except for dairy, seafood, plant proteins, and empty calories, in both Lower- and Higher-Frequency groups compared with baseline. However, the magnitudes of these changes between frequency groups were no longer significant (Appendix Table 7, available online).

To determine effects on feedback frequency on specific nutrients targeted by the PN intervention, the authors assessed changes in the five most common targets for personalized advice (salt, saturated fat, dietary fiber, folate, and polyunsaturated fats). In addition, changes in total energy intake, body weight, BMI, and WC were assessed for those participants who were advised to reduce these variables.

At Month 3, there were improvements from baseline for all target outcomes in both the Lower- and Higher-Frequency groups, except folate, which was not improved at 3 months in the Lower-Frequency group (Table 1). The magnitude of these changes was significantly greater for participants in the Higher-Frequency group than for those in the Lower-Frequency group for salt and saturated fat intake as well as body weight, BMI, and WC (Table 1). At Month 6, all target outcomes showed improvements compared with baseline for both Lower- and Higher-Frequency groups except for dietary fiber in the Higher-Frequency group. Differences between frequency groups were no longer significant except for body weight and BMI (Table 1 and Figure 3).

Figure 2 shows the percentage of participants who achieved at least 5% or 10% weight loss at Months 3 and

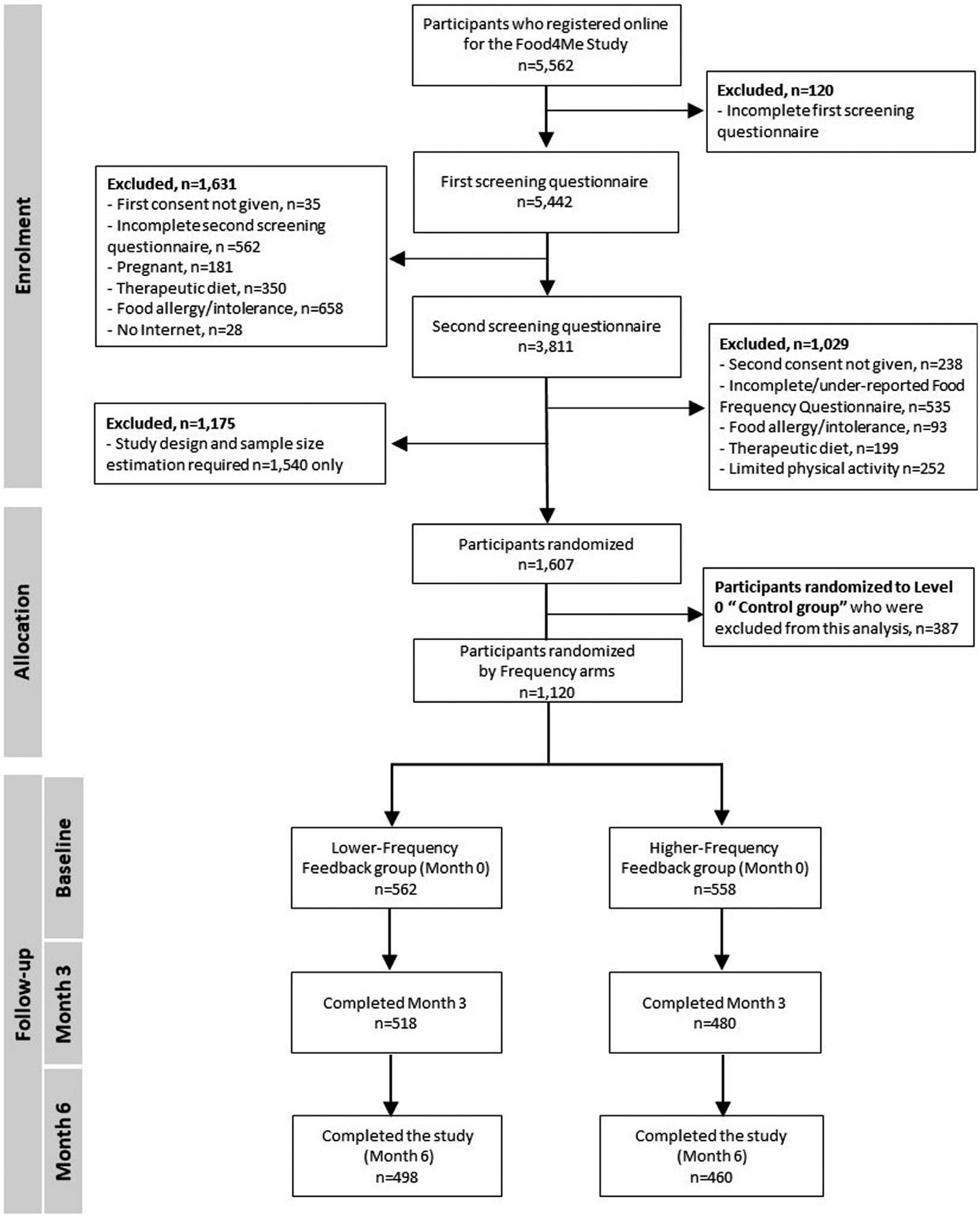

Figure 1. CONSORT Diagram.

Table 1. Changes in Dietary Intake Anthropometric Characteristics at Month 3 and Month 6 Between Frequency Feedback Groups

Measure/month	Lower-Frequency Feedback group (95% CI)	Higher-Frequency Feedback group (95% CI)	Δ (Higher − Lower)[a] value (95% CI)	Δ *p*-value	Effect size
HEI score					
M0 (mean)[b]	49.6 (48.8, 50.04)	48.6 (47.8, 49.4)	−1.11 (−2.26, 0.03)	0.058	
M3 (Δ [M3 − M0])[c]	**2.60 (1.94, 3.25)****	**4.44 (3.61, 5.27)****	1.84 (0.79, 2.89)	<**0.0001**	0.19
M6 (Δ [M6 − M0])[c]	**3.38 (2.70, 4.07)****	**4.03 (3.20, 4.87)****	0.65 (−0.43, 1.71)	0.240	0.07
Salt (g/day[1])					
M0 (mean)[b]	7.43 (7.13, 7.73)	7.36 (7.07, 7.66)	−0.07 (−0.48, 0.35)	0.752	
M3 (Δ [M3 − M0])[c]	**−1.12 (−1.40, −0.84)****	**−1.59 (−1.89, −1.29)****	−0.47 (−0.87, −0.05)	**0.026**	0.17
M6 (Δ [M6 − M0])[c]	**−1.29 (−1.56, −1.02)****	**−1.29 (−1.56, −1.01)****	0.003 (−0.38, 0.39)	0.984	0.01
Saturated fat (% TE)					
M0 (mean)[b]	14.1 (13.8, 14.4)	14.1 (13.9, 14.4)	−0.01 (−0.37, 0.35)	0.956	
M3 (Δ [M3 − M0])[c]	**−0.84 (−1.08, −0.61)****	**−1.25 (−1.51, −0.98)****	−0.40 (−0.75, −0.048)	**0.026**	0.14
M6 (Δ [M6 − M0])[c]	**−1.12 (−1.37, −0.87)****	**−1.18 (−1.45, −0.91)****	−0.06 (−0.42, 0.31)	0.760	0.02
Dietary fiber (g/day[1])					
M0 (mean)[b]	30.1 (28.9, 30.5)	29.1 (27.9, 30.4)	−0.96 (−2.62, 0.71)	0.261	
M3 (Δ [M3 − M0])[c]	**−1.34 (−2.39, −0.29)***	**−1.92 (−3.12, −0.72)****	−0.59 (−2.17, 0.98)	0.460	0.04
M6 (Δ [M6 − M0])[c]	**−1.19 (−2.24, −0.13)***	−0.90 (−2.07, 0.27)	0.29 (−1.30, 1.83)	0.739	0.02
Folate (μg/day[1])					
M0 (mean)[b]	429.6 (412.8, 446.4)	405.7 (388.9, 422.6)	−23.8 (−47.6, −0.08)	0.049	
M3 (Δ [M3 − M0])[c]	−25.9 (−52.2, 0.25)	**−38.5 (−64.7, −12.3)****	−12.9 (−50.1, 24.1)	0.493	0.05
M6 (Δ [M6 − M0])[c]	**−47.7 (−64.5, −31.0)****	**−44.3 (−60.9, −27.7)****	3.11 (−20.4, 26.7)	0.796	0.02
Polyunsaturated fat (% TE)					
M0 (mean)[b]	5.67 (5.55, 5.78)	5.78 (5.66, 5.90)	0.12 (−0.05, 0.28)	0.166	
M3 (Δ [M3 − M0])[c]	**0.17 (0.06, 0.28)****	**0.31 (0.18, 0.44)****	0.14 (−0.02, 0.31)	0.099	0.10
M6 (Δ [M6 − M0])[c]	**0.20 (0.07, 0.33)****	0.11 (−0.03, 0.21)	−0.11 (−0.29, 0.07)	0.243	0.08
Energy intake (kJ/day[1])					
M0 (mean)[b]	10,845 (10,481, 11,210)	10,693 (10,327, 11,059)	−152.7 (−669.3, 363.9)	0.563	
M3 (Δ [M3 − M0])[c]	**−1,366 (−1,699, −1,034)****	**−1,825 (−2,457, −1,193)****	−459.6 (−956.8, 37.5)	0.070	0.14
M6 (Δ [M6 − M0])[c]	**−1,549 (−1,894, −1,203)****	**−1,538 (−1,891, −1,193)****	11.2 (−479.7, 502.1)	0.964	0.003
Body weight (kg)					
M0 (mean)[b]	73.9 (72.7, 75.1)	75.5 (74.3, 76.7)	1.64 (−0.04, 3.28)	0.065	
M3 (Δ [M3 − M0])[c]	**−0.38 (−0.61, −0.14)****	**−1.11 (−1.37, −0.84)****	−0.73 (−1.07, −0.38)	**<0.0001**	0.05
M6 (Δ [M6 − M0])[c]	**−0.64 (−0.93, −0.35)****	**−1.36 (−1.70, −1.02)****	−0.71 (−1.15, −0.27)	**0.002**	0.05
BMI (kg/m^2)					
M0 (mean)[b]	25.1 (24.8, 25.5)	25.7 (25.3, 26.1)	0.58 (−0.03, 1.17)	0.054	
M3 (Δ [M3 − M0])[c]	−0.13 (−0.21, −0.05)	−0.37 (−0.46, −0.28)	−0.24 (−0.36, −0.13)	**<0.00001**	0.05

(*continued on next page*)

Table 1. Changes in Dietary Intake Anthropometric Characteristics at Month 3 and Month 6 Between Frequency Feedback Groups (*continued*)

Measure/month	Lower-Frequency Feedback group (95% CI)	Higher-Frequency Feedback group (95% CI)	Δ (Higher − Lower)[a] value (95% CI)	Δ *p*-value	Effect size
M6 (Δ [M6 − M0])[c]	−0.22 (−0.3, −0.12)	−0.46 (−0.57, −0.34)	−0.23 (−0.38, −0.79)	**0.003**	0.05
WC (cm)					
M0 (mean)[b]	1.02.7 (101.3, 104.2)	102.1 (100.7, 103.4)	−0.69 (−2.68, 1.29)	0.494	
M3 (Δ [M3 − M0])[c]	**−1.25 (−2.30, −0.19)***	**−2.65 (−3.40, −1.89)****	−1.20 (−2.36, −0.04)	**0.039**	0.12
M6 (Δ [M6 − M0])[c]	**−2.43 (−3.38, −1.48)****	**−3.82 (−4.7, −2.93)****	−1.21 (−2.59, 0.16)	0.083	0.12

Note: Boldface indicates statistical significance (*$p<0.05$; **$p<0.01$). Data are presented as adjusted mean or Δ with the corresponding 95% CI. Analysis is restricted to participants randomized to Levels 1−3 who received personalized advice targeting the specified dietary and anthropometric outcomes, except for HEI, which include all participants randomized to Levels 1−3. Analyses were adjusted for baseline age, sex, personalized nutrition intervention arm, occupation, and country. Body weight, BMI, and WC were additionally adjusted for total physical activity levels. The effect sizes for the Δs between Lower- and Higher-Frequency Feedback groups at Month 3 and Month 6 were estimated as the ratio of the observed Δ to the baseline SD of each measure. This gives a value like a Cohen's d; therefore, effects sizes <0.2 would be consider small. Significant differences between baseline and Month 3 or Month 6 were derived from the Linear Mixed Effect Models and post-hoc contrast analyses and denoted as. *$p<0.05$ and. **$p<0.01$.

[a]Δ estimated from differences between Higher- and Lower-Frequency Feedback groups.

[b]Adjusted mean at baseline.

[c]Δ between Month 3 and baseline or Month 6 and baseline.

g, grams; HEI, Healthy Eating Index score; kJ, kilojoules; M0, baseline; M3, Month 3; M6, Month 6; TE, total energy; WC, waist circumference.

6 by frequency group. Individuals randomized to the Higher-Frequency group were more likely to achieve ≥5% and ≥10% reduction in body weight than those in the Lower-Frequency group at Month 3 (RRs=1.72, 95% CI=1.24, 2.37, p=0.001 and RRs=1.81, 95% CI=1.29, 2.54, p=0.001, respectively). At Month 6, although participants in the Higher-Frequency group were more likely to achieve a ≥5% weight loss than those in the Lower-Frequency group (RRs=1.54, 95% CI=1.12, 2.10, p=0.008), no differences were found for participants achieving a 10% weight loss between intensity groups (RRs=1.14, 95% CI=0.54, 2.35, p=0.703).

DISCUSSION

The main finding of this study was that using either lower- or higher-frequency feedback in an Internet-based PN intervention was efficacious in improving health-related behaviors, including overall diet quality. In the short term (at 3-month follow-up), higher-frequency feedback produced significant benefits in overall diet quality, although the effect sizes were relatively small. These included reducing salt and saturated fat intake as well as reducing body weight, BMI, and WC in individuals who were overweight or obese at baseline. The public health implications of these findings are important because 10.8% of men and 14.9% of women are obese worldwide.[24] Thus, implementing higher-frequency feedback interventions (feedback provided once a month) could lead to significant improvement in diet and greater weight reductions than using lower-frequency feedback (feedback provided once every 3 months). However, in this study, most of these advantages in the Higher-Frequency Feedback group were not sustained at 6 months. The exception was in the percentage of participants achieving ≥5% weight loss, where the RR of achieving weight loss was significantly greater for the Higher-Frequency Feedback group at 6 months as well as at 3 months (Figure 1). Achieving ≥5% weight loss is often used as a cut off for clinically significant weight loss, although smaller weight losses are also associated with improvements in markers of cardiovascular disease risk.[9,18,25] Similarly, improving diet quality has important implications for health. For example, reduced salt intake is associated with a lower risk of developing hypertension, a major risk factor for cardiovascular diseases,[26] and improving overall quality of the diet is associated with reduced all-cause and cause-specific mortality.[27,28]

The definition of feedback frequency for lifestyle interventions reported in the literature varies considerably,[10,29,30] incorporating frequency and total number of contacts, total contact time, and duration of the intervention. A recent meta-analysis of 12 randomized controlled weight loss interventions delivered via mobile phones reported that

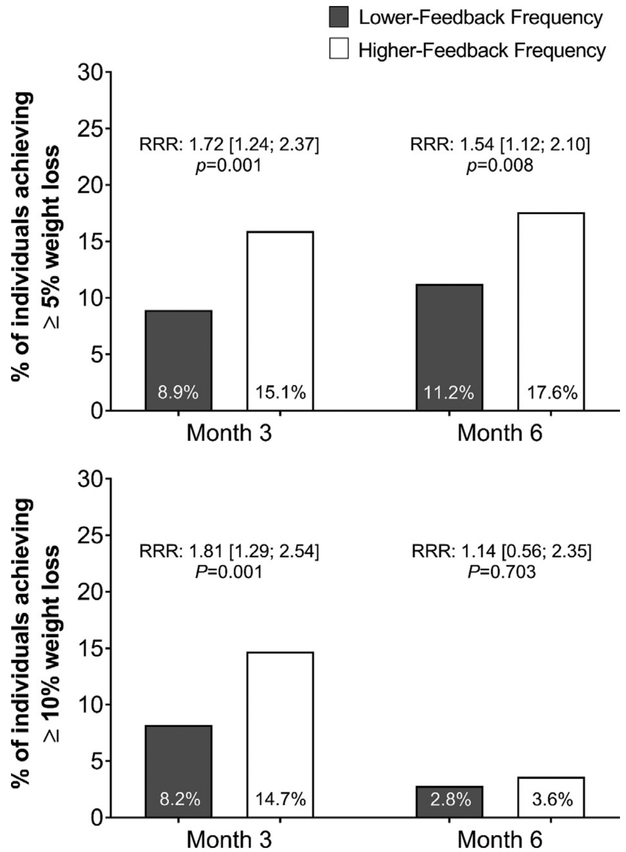

Figure 2. Percentage of Participants who Achieved ≥5% or ≥10% Weight Loss in the Lower- and Higher-Frequency Feedback Groups.

Note: Data are presented as percentage of individuals per frequency group at Month 3 and Month 6. Binomial regressions with log link function were performed to determine the RRR of achieving 5% or 10% weight loss by frequency group and time point (Month 3 and Month 6). Analyses were adjusted for age, sex, personalized nutrition intervention arm, country, occupation, total physical activity, and baseline body weight.

duration and interaction frequency improved efficacy of weight loss interventions.[10] Although this meta-analysis confirms that more feedback may lead to larger behavioral changes, the nature of the intervention (delivered via mobile phones) and the frequency of contact (once or more per day) differed from this study's protocol. O'Brien et al.[31] reported outcomes from a trial in which overweight/obese Australian adults were randomized to a standard online weight loss program or to an enhanced version of this program that provided additional personalized feedback and reminders. The intervention targeted self-efficacy, goal setting, and self-monitoring of weight, dietary intake, and physical activity levels. After 12 weeks, participants who were randomized to the enhanced group (personalized feedback and weekly contact) had larger weight reductions than those who were randomized to the basic intervention group (weekly contact). By contrast, change in diet quality, measured using an Australian diet quality score, was not significantly different between the enhanced and basic interventions.[31] In this case, the nature of the additional contacts differed between treatment groups so it is uncertain whether more feedback/contacts per se would be equally effective. Similarly, a meta-analysis of face-to-face trials reported that "higher-intensity" interventions (i.e., those with more frequent face-to-face contacts) were associated with larger changes in dietary intake and that this difference was significant for total dietary fat intake and for daily servings of fruits and vegetables.[32] The findings in this study corroborate the larger difference in total fat intake, but a significant difference between frequency groups for fruit and vegetable intake was not observed.

Importantly, the current results show that participants randomized to the Higher-Frequency Feedback group resulted in slightly, but significantly, fewer participants completing the 3-month study, 92.2% compared with 98.5% for those randomized to the Lower-Frequency group (Appendix Table 6, available online). However, between Month 3 and Month 6 when both Higher- and Lower-Frequency groups had the same number of feedbacks, the number of dropouts was the same (n=20) for both groups. Compared with the Lower Feedback group, the participants randomized to the Higher-Frequency group were more likely to have dropped out of the study by Months 3 and 6 (RRR=1.78 vs 1.58).

Although the two groups compared in this analysis differed in frequency of feedback (five times versus three times), all additional feedback occurred within the first 3 months of the study so that there was no difference in feedback frequency between the groups for the second half of the study (i.e., from 3 months to 6 months). Although there was good evidence that the Higher-Frequency Feedback group performed better at 3 months, almost all of those advantages had disappeared by 6 months. This suggests that the benefits of higher-frequency feedback do not endure when the extra feedback events are stopped; therefore, from a longer-term perspective, there may be no advantage in devoting resources to provide additional feedback beyond that offered to those in the Lower-Frequency Feedback group. In addition, randomization to the Higher-Frequency Feedback group resulted in slightly fewer participants completing the 6-month study. Although the impact of the intervention on the diet of those dropouts is not known, it would be reasonable to assume that they will not have benefited as much in terms of dietary change as those who remained in the study. Therefore, these findings question the overall benefit for public health in those randomized to the Higher-Frequency Feedback group.

The Food4Me Study is the largest Internet-based PN intervention study to date and provides robust evidence for the beneficial impact of personalized Lower- and

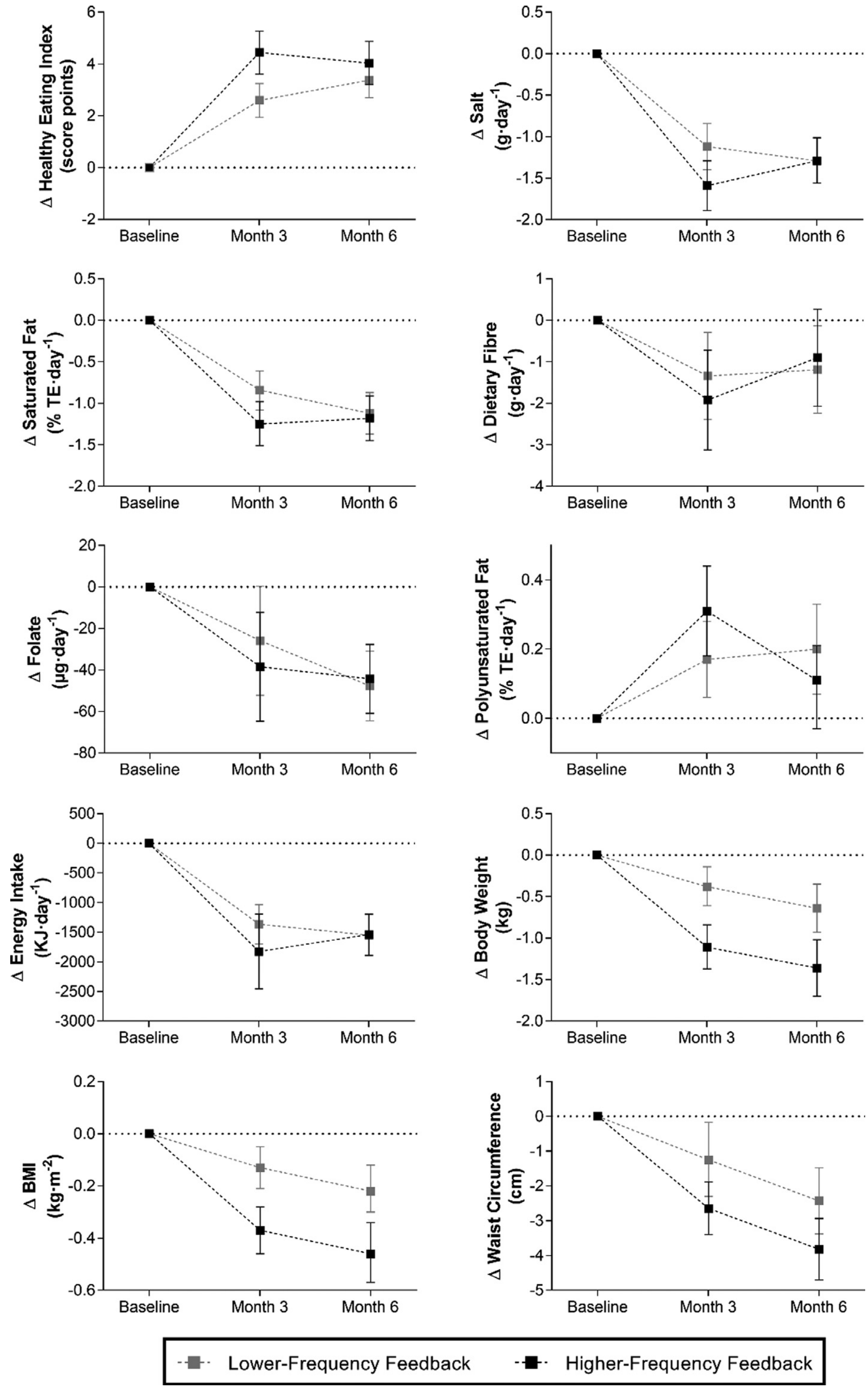

Figure 3. Changes in Overall Diet Quality, Nutrients, and Anthropometric Characteristics at Month 3 and Month 6 Between Lower- and Higher-Frequency Feedback Groups.

Note: Data are presented as Δs with the corresponding 95% CIs. Deltas between Month 3 and baseline or Month 6 and baseline are presented for the Lower- and Higher-Frequency Feedback groups. Analysis is restricted to participants randomized to Levels 1–3 who received personalized advice targeting the specified dietary and anthropometric outcomes, except for HEI, which include all participants randomized to Levels 1–3. Analyses were adjusted for baseline age, sex, personalized nutrition intervention arm, occupation, and country. Body weight, BMI, and WC were additionally adjusted for total physical activity levels. Significant differences between baseline and Month 3 or Month 6 by feedback group are presented in Table 2.

HEI, Healthy Eating Index; TE, total energy.

Higher-Frequency feedback on dietary intake and obesity-related outcomes. An Internet-based platform to deliver the intervention was effective in retaining participants: 85.2% completed the follow-up after 6 months of intervention, which is high, compared with a previous web-based survey.[33]

Limitations

Compared with conventional face-to-face interventions, the Internet-based design of the present study limited the number of collected measures. Furthermore, all data collected during the study were self-reported or derived from biological samples collected remotely. Thus, there is the potential for nondifferential information bias.[6]

CONCLUSIONS

Both Lower- and Higher-Frequency feedback interventions were efficacious in promoting health-related behavior changes. Higher-frequency interventions produced significant (but relatively small) improvements in overall diet quality and body weight loss compared with lower-frequency interventions at the 3-month follow-up. However, most of these advantages were not sustained at the 6-month follow-up, except for body weight and BMI, when the frequency of delivery of PN advice and feedback over Months 3 to 6 was identical between the two groups. In addition, attrition was significantly higher in participants in the Higher-Frequency group in the first 3 months. These results suggest that higher-frequency feedback may not be advantageous in improving public health using such Internet-delivered PN interventions.

ACKNOWLEDGMENTS

This work was supported by the European Commission under the Food, Agriculture, Fisheries and Biotechnology Theme of the 7th Framework Programme for Research and Technological Development (265494). The sponsor had no role in the study's design or conduct, data collection, management, analysis or interpretation, manuscript preparation, review, or approval. Author responsibilities were as follows: JCM was the Food4Me intervention study coordinator. ERG, LB, YM, IT, CAD, JAL, JAM, WHMS, HD, MG, and JCM contributed to the research design. CCM, SNC, RS-C, CBO, GM, CFMM, RF, ALM, MW, and JCM conducted the intervention. CCM performed the statistical analyses for the manuscript. CCM, KML, FPR, and JCM drafted the paper. All authors contributed to a critical review of the manuscript during the writing process and approved the final version to be published. None of the authors reported a conflict of interest related to the study.

No financial disclosures were reported by the authors of this paper.

Carlos Celis-Morales, PhD and Katherine M. Livingstone, PhD contributed equally to this work and are joint first authors.

SUPPLEMENTAL MATERIAL

Supplemental materials associated with this article can be found in the online version at https://doi.org/10.1016/j.amepre.2019.03.024.

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