

# Changes of dietary patterns during participation in a web-based weight-reduction programme

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Submitted 5 December 2014: Final revision received 14 July 2015: Accepted 7 September 2015: First published online 28 September 2015

## Abstract

**Objective:** To examine the weight-loss success associated with distinct dietary patterns and to determine changes of these dietary patterns during participation in a web-based weight-reduction programme.

**Design:** Factor analysis was used to identify the dietary patterns of twenty-two food groups that were administered in 14 d dietary protocols at baseline and after 3 months. Successful weight loss ( $\geq 5\%$  of initial weight) and BMI were calculated. Logistic regression analyses were used to assess the rates of weight-loss success from each dietary pattern and changing or remaining in the initial dietary pattern. A generalised linear mixed model was used to estimate the effects of changing or staying in a dietary pattern on change in BMI.

**Subjects:** Adults ( $n$  1635) aged 18–81 years.

**Setting:** Users of a web-based weight-reduction programme (2006–2012).

**Results:** Participants who aligned to a healthful dietary pattern at baseline (OR = 1.8; 95% CI 1.5, 2.3) and after 3 months (OR = 1.5; 95% CI 1.2, 1.9) had a greater chance of successfully losing weight. After adjusting for age, sex, initial dietary pattern and BMI, participants who started with or changed to the healthful dietary pattern had a greater chance of being successful (OR = 1.4; 95% CI 1.1, 1.7) and a higher BMI reduction of 0.30 (95% CI 0.2, 0.5) kg/m<sup>2</sup> compared with those who started with or changed to the energy-dense or high-carbohydrate dietary pattern.

**Conclusions:** A favourable healthful dietary pattern at the beginning and after 3 months was positively associated with anthropometry. However, successful weight loss was feasible in each dietary pattern.

**Key words**  
Dietary patterns  
Weight loss  
Factor analysis  
Online weight-reduction programme

In Europe, more than 50% of men and women are overweight<sup>(1)</sup>. A BMI above 30 kg/m<sup>2</sup> is present in 21% of women and 22% of men aged 20 years or older<sup>(2)</sup>. Moreover, worldwide, the prevalence of obesity has almost doubled between 1980 and 2008<sup>(1)</sup>. Obesity is an important health risk for diseases such as diabetes mellitus type 2, hypertension, CVD and others<sup>(3)</sup>. Nevertheless, weight is adjustable, and a moderate weight reduction of 5–10% is associated with enhanced health benefits<sup>(4)</sup>. Weight gain is the result of an imbalance between energy intake and expenditure; however, the effect of different dietary factors on weight gain or weight loss remains unclear<sup>(5)</sup>. Because of the complexity of the diet, dietary pattern analysis is useful because it simultaneously reflects various aspects of the diet, has the potential to capture interactions between food and nutrients<sup>(6,7)</sup> and is an alternative to traditional methods of examining single

foods or nutrients<sup>(8)</sup>. The dietary pattern approach has intuitive appeal because the human diet does not consist of a single nutrient or food, but instead represents a complex set of highly correlated dietary exposures<sup>(9–11)</sup>. Statistical methods, such as factor analysis, can be used to generate dietary patterns from food group data, by which various dietary factors can be reduced to a convincing set of dietary patterns describing how people actually eat. A few longitudinal studies have examined the association between changes in dietary patterns and a reduction in BMI<sup>(12–16)</sup>. There is evidence in the literature that several web-based weight-loss interventions are efficient at supporting weight loss<sup>(17–24)</sup>. In this regard, these programmes can support participants by identifying dietary patterns and can also be used for collecting precise long-term and comprehensive nutrition data<sup>(25)</sup>. Moreover, weight self-monitoring has been documented as an impactful

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tool for weight loss and control<sup>(26–28)</sup>. Additionally, recording dietary intake, physical activity and body weight is associated with successful weight loss and weight control<sup>(27,29–31)</sup>.

The aims of the present study were to: (i) characterise the dietary patterns of participants in a web-based weight-reduction programme; (ii) examine the weight-loss success associated with the distinct dietary patterns; and (iii) determine the changes in these dietary patterns over time.

## Methods

### Programme description

The web-based weight-reduction programme KiloCoach™<sup>(32)</sup> has the main goal of encouraging changes in lifestyle regarding nutrition and physical activity that lead to weight loss by using self-monitoring combined with information about dietary intake and tailored feedback<sup>(23)</sup>. Self-monitoring consists of a dietary protocol and height and weight records. The dietary protocol is an electronic version of the common written protocols for recording food intake<sup>(23)</sup>. In our study, height and weight were self-reported; however, it has previously been shown that self-reported weight data in online programmes are comparable to an in-person assessment<sup>(33)</sup>. Participants were advised to continuously document their behaviour regarding dietary intake and physical activity units for at least 5 d/week for sixty consecutive days and to update their body weight once weekly. Energy and nutrient intakes were calculated immediately by the programme after the participant electronically documented all of the food items and drinks, based on a food database of more than 40 000 items. Moreover, an upper threshold for daily energy intake (kcal), on the basis of self-reported data (sex, age, height and body weight) and energy expenditure (physical activity units), is automatically calculated by the programme<sup>(23)</sup> and therefore provides immediate feedback. The calculated energy expenditure is then subtracted from the energy intake and provides an individualised energy recommendation. The programme offers assistance regarding an individual's weight-loss goal so that the weight reduction should be equal to or less than 1 kg/week to be in accordance with the European Clinical Practice Guidelines; this rate of weight loss is realistic and desirable<sup>(34)</sup>. Therefore, the weight-loss programme fulfils this criterion. Additionally, the programme is based on a healthy diet and encourages participants to increase their physical activity. Recommendations for a healthy diet include achieving a balance in macronutrients<sup>(35)</sup>; for physical activity, the participants should undertake 150 or 75 min of respectively moderate-intensity or vigorous-intensity exercise per week and a muscle-strengthening activity for a minimum of 2 d/week<sup>(36)</sup>. Additionally, the web-based weight-reduction programme provides graphically displayed reports, e.g. on components

of the participant's diet (macronutrient balance of proteins, carbohydrates and fats) and the most consumed food groups.

The programme's food database consists of food groups that are based on the nutrient profile (e.g. high in carbohydrates) and type of food (e.g. fruit or vegetables). These food groups contain basic products (e.g. plain vegetables), dishes prepared using the main food components (e.g. vegetable dishes) and types of dishes (e.g. bakery products and pastries). Twenty-two food groups were formed: 'bakery products and pastries', 'bread and buns', 'diet products and food supplements', 'eggs and pasta', 'convenience products', 'fish and seafood', 'meat', 'vegetables, mushrooms, soya and herbs', 'alcoholic beverages', 'non-alcoholic beverages', 'cereals', 'spices and condiments', 'milk and dairy products', 'nuts and seeds', 'fruits and fruit products', 'oils and fats', 'salads', 'soups and soup garnishes', 'candies and sweets', 'sweet dishes', 'poultry, venison and offal' and 'sausages, spreads and spicy snacks'. The total consumption for each food group was determined by summing the total amount of each item (in grams) within the group.

### Study design

The design is a pre-and-post intervention study without a control group, investigating users within a web-based weight-loss programme. The programme contains self-monitoring of diet and body weight, combined with information about dietary intake and tailored feedback to change lifestyle regarding nutrition and physical activity. Data sets of users were available between 2006 and 2012.

### Study participants

The duration of the weight-loss period was defined by the chosen membership length (at least 3 months) for each participant. Six thousand seven hundred and seventeen data sets were available from participants who signed up for the weight-reduction programme between 7 February 2006 and 8 January 2012. The inclusion criteria for the present analysis were age  $\geq 18$  years (leaving a sample size of  $n$  6715), available self-reported weight records after 3 months of participation ( $n$  1987) and continuous daily dietary records over a period of 60 d ( $n$  1635). The act of continuously recording dietary intake for more than 60 d has a significant impact on weight loss; this impact was previously described by Longin *et al.*<sup>(21)</sup>. Therefore, we excluded participants with less than 60 d of continuous dietary recording. These selection criteria yielded a study sample size of 1635 participants. All of the data sets included individual age, sex, height and body weight.

### Factor analysis

To derive dietary and food patterns, the twenty-two main food groups at two time points, baseline and after

3 months, were entered separately into a principal component analysis (PCA) with orthogonal rotation (varimax) as the absolute weight in grams<sup>(7)</sup>. We calculated the daily food intake for each individual at both time points from the average dietary intake of each food group over two weeks of dietary records. The extraction of the number of components was determined by applying the following criteria: eigenvalue >1, identification of a break in the scree plot and interpretability of the components<sup>(37)</sup>. Furthermore, food items with absolute factor loadings that were  $\geq 0.25$  accounted for each component. These items correlated intensely with the identified component. This fact is in accordance with the previous literature<sup>(38–40)</sup>. Food groups were not included if they had an absolute loading of <0.25. We labelled the dietary patterns according to the food items. Hence, foods that did not fit in a category or did not load on any factor were not used for further analysis, such as 'diet products and food supplements', 'eggs and pasta', 'convenience products', 'spices and condiments', 'nuts and seeds', 'oils and fats' and 'soups and soup garnishes'.

The factor score coefficients at baseline and after 3 months were calculated by summing the amount of daily intake at each time point for each food group and were weighted by the loading factor determined by PCA at baseline<sup>(37,41–43)</sup>. Each participant was given a factor score coefficient for each defined dietary pattern. The purpose of this calculation was to describe the initial dietary patterns and the change of dietary patterns after 3 months<sup>(41–43)</sup>.

### **Anthropometrics**

Total body weight loss was calculated as a percentage based on the initial weight. A cut-off of 5% weight loss was used to classify all of the participants as either successful ( $\geq 5\%$ ) or unsuccessful ( $< 5\%$ ). We have chosen this classification because a weight reduction of lower than 5% is considered to be insignificant<sup>(34)</sup>. BMI was calculated from height and weight as  $[\text{weight (kg)}]/[\text{height (m)}]^2$ . Normal weight, overweight and obesity were classified according to the cut-off points from the WHO<sup>(2)</sup>.

### **Definition of under-reporters of energy intake**

The average daily energy intake (EI; kcal/d) was assessed within the weight-loss programme. The BMR was not measured and therefore was calculated with the Schofield equation<sup>(44)</sup>. Moreover, EI:BMR was determined to evaluate the under- and over-reporters of energy intake by using the values defined by Goldberg *et al.*<sup>(45)</sup>. For estimating energy expenditure, the programme considered the minimum energy requirement and coefficients for physical activity levels that were suggested by FAO/WHO/United Nations University<sup>(46)</sup>. EI:BMR < 1.35 was considered under-reporting<sup>(47)</sup> and EI:BMR  $\geq 2.4$  suggested over-reporting<sup>(48)</sup> as the maximum for a sustainable lifestyle<sup>(47)</sup>. Nevertheless, these cut-offs fail to take the true energy expenditure of each individual

into account. Therefore, in the current analysis, an EI:BMR range of 1.35 to 2.39 is categorised as plausible reporting regarding energy intake.

### **Statistical analyses**

Statistical analyses were performed with the statistical software package IBM® SPSS® Statistics for Windows, Version 22. *P* values <0.05 were considered statistically significant and all tests were two-sided. Data are presented as means and standard deviations for continuous variables or as percentages for categorical variables, as appropriate. All of the results are stratified by sex.

The *t* test and the Mann–Whitney *U* test for continuous variables and the  $\chi^2$  test for categorical variables were used to detect differences between groups.

To ensure consistency, the Pearson product-moment correlation (*r*) was used to cross-check factor score coefficients after 3 months against the dietary pattern results at baseline, which is in agreement with the previously published literature<sup>(41,42)</sup>.

The predictive value of each dietary pattern on weight-loss success was assessed by logistic regression analysis. Three 0–1 dummy variables were constructed for each dietary pattern; the first dummy variable was 1 for a healthful pattern and 0 for an energy-dense and high-carbohydrate pattern. The second dummy variable was 1 for an energy-dense pattern and 0 for a healthful and high-carbohydrate pattern, and the third dummy variable was 1 for a high-carbohydrate pattern and 0 for a healthful and energy-dense pattern. Success in the programme was defined as the dependent variable and the dummy variables for the dietary patterns were defined as the independent variables adjusted for age and initial BMI.

Logistic regression analyses were used to assess the predictive value of changing or staying in the initial dietary pattern on the successful group. Success in the programme was defined as the dependent variable and changing or staying in the initial dietary pattern as the independent variable. This procedure provides odds ratios for the effect of changing or staying in the dietary pattern on successful weight loss that are adjusted for age, sex, initial BMI and initial dietary pattern.

Furthermore, changes in the initial BMI were obtained by calculating the difference between the BMI after 3 months and at baseline. The predicted value of the change in BMI, as the dependent variable, on changing or maintaining the dietary pattern was assessed by a univariate generalised linear mixed model and was adjusted for age, sex, initial BMI and initial dietary pattern.

## **Results**

### **Characteristics of the study participants**

A total of 1108 women and 527 men, aged 18–81 years, were included in the present analysis. At baseline, women

**Table 1** Characteristics of participants included in the analysis; adults (*n* 1635) aged 18–81 years, users of a web-based weight-reduction programme, Austria, 2006–2012

| Characteristic                                | Women ( <i>n</i> 1108) | Men ( <i>n</i> 527) | <i>P</i> † | Total ( <i>n</i> 1635) |
|---|------------------------|---------------------|------------|------------------------|
| Age (years), mean                             | 43.7                   | 47.9                | <0.001     | 45.1                   |
| SD  | 11.9                   | 11.8                |            | 12.0                   |
| Height (cm), mean                             | 166.9                  | 179.5               | <0.001     | 171.0                  |
| SD  | 6.0                    | 6.9                 |            | 8.6                    |
| Initial body weight (kg), mean                | 82.0                   | 100.8               | <0.001     | 99.0                   |
| SD  | 16.2                   | 16.8                |            | 18.6                   |
| Initial BMI (kg/m <sup>2</sup> ), mean        | 29.4                   | 31.3                | <0.001     | 30.0                   |
| SD  | 5.5                    | 4.8                 |            | 5.4                    |
| Weight change after 3 months (%), mean        | −4.7                   | −5.6                | <0.001     | −5.0                   |
| SD  | 4.2                    | 4.3                 |            | 4.2                    |
| Initial BMI classification (%)                |                        |                     |            |                        |
| Normal weight (18.5–24.9 kg/m <sup>2</sup> )  | 20.5                   | 4.2                 | <0.001     | 15.2                   |
| Overweight (25.0–29.9 kg/m <sup>2</sup> )     | 41.7                   | 43.6                | <0.001     | 42.3                   |
| Obese class I (30.0–34.9 kg/m <sup>2</sup> )  | 23.3                   | 33.6                | <0.001     | 26.6                   |
| Obese class II (35.0–39.9 kg/m <sup>2</sup> ) | 9.0                    | 13.7                | <0.001     | 10.5                   |
| Obese class III (≥40.0 kg/m <sup>2</sup> )    | 5.5                    | 4.9                 | <0.001     | 5.3                    |
| Weight change after 3 months (%)              |                        |                     |            |                        |
| Weight gain >10 %                             | 0.5                    | 0.0                 | <0.001     | 0.3                    |
| Weight gain 5–10 %                            | 0.4                    | 0.4                 | <0.001     | 0.4                    |
| Weight stable 0–5 %                           | 47.7                   | 41.9                | <0.001     | 45.8                   |
| Weight loss 5–10 %                            | 43.4                   | 43.5                | <0.001     | 43.4                   |
| Weight loss >10 %                             | 8.1                    | 14.2                | <0.001     | 10.1                   |

†Independent-samples *t* test or Mann–Whitney *U* test, as appropriate.

had a statistically significant lower initial BMI than men ( $P < 0.001$ ; Table 1).

### Weight change after 3 months

After 3 months of participation in the web-based weight-reduction programme, women had a mean BMI of 28.9 (SD 5.3) kg/m<sup>2</sup> and men had a mean BMI of 29.5 (SD 4.5) kg/m<sup>2</sup> ( $P < 0.001$ ). Overall, 25 % of the population had a normal weight after 3 months (32 % of women and 11 % of men;  $P < 0.001$ ), representing a change of 10 %. Twenty-eight per cent of women and 36 % of men were obese at follow-up, representing an overall change of 12 %. More than half of the participants (52 % of women and 58 % of men) lost 5 % or more of their initial weight and thus were considered to be successful in the programme (Table 1). Significantly more women changed from the overweight to the normal weight group after 3 months of participation in the web-based weight-reduction programme compared with men (27.3 % *v.* 15.7 %;  $P < 0.001$ ).

### Under-reporters

At baseline, 68 % were under-reporters (EI:BMR < 1.35) and 1 % were over-reporters (EI:BMR ≥ 2.4). Compared with plausible reporters, under-reporters had significantly higher mean BMI (28.2 (SD 4.5) *v.* 30.9 (SD 5.5) kg/m<sup>2</sup>;  $P < 0.001$ ) and the majority were overweight or obese (89 %). Regarding weight change after 3 months, there was no significant difference between under-, plausible and over-reporters. Participants who over-reported their energy intake demonstrated a significantly lower BMR.

Regarding the dietary pattern, both time points (at baseline and after 3 months) showed significantly higher proportions of under-reporters in the energy-dense pattern (at baseline: 41 % under-reporters, 18 % plausible reporters, 21 % over-reporters,  $P < 0.001$ ; after 3 months: 45 % under-reporters, 22 % plausible reporters, 21 % over-reporters,  $P < 0.001$ ). The distribution of under-, plausible and over-reporters in the three dietary patterns remained constant over time (e.g. healthy dietary pattern at baseline: 30 % under-reporters, 38 % plausible reporters, 33 % over-reporters; after 3 months: 30 % under-reporters, 32 % plausible reporters, 46 % over-reporters).

### Dietary patterns

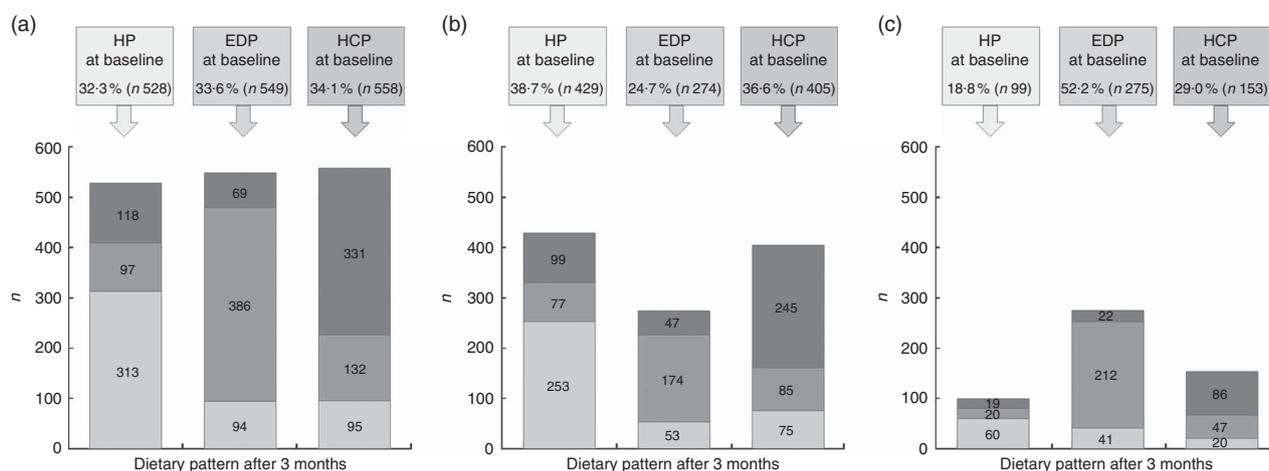
At baseline and after 3 months, PCA revealed three dietary patterns (Table 2). The first pattern was characterised as healthful (HP) and included the food groups 'vegetables, mushrooms, soya and herbs', 'cereals', 'milk and dairy products', 'fruits and fruit products' and 'salads'. The second pattern, which included the food groups 'fish and seafood', 'meat', 'alcoholic beverages', 'poultry, venison and offal' and 'sausages, spreads and spicy snacks', was called energy-dense pattern (EDP). The third pattern was considered to be a high-carbohydrate pattern (HCP) and contained 'bakery products and pastries', 'bread and buns', 'non-alcoholic beverages', 'candies and sweets' and 'sweet dishes'. All three patterns explained 36 % and 42 % of the variation of food intake at baseline and after 3 months, respectively. PCA after 3 months revealed similar dietary patterns to those identified at baseline with respect to component loadings for each food group

**Table 2** Factor-loading matrix for the three dietary patterns and their foods or food groups

| Food or food group                    | HP†      |                | EDP†     |                | HCP†     |                |
|---------------------------------------|----------|----------------|----------|----------------|----------|----------------|
|                                       | Baseline | After 3 months | Baseline | After 3 months | Baseline | After 3 months |
| Bakery products and pastries          | –        | –              | –        | –              | 0.69     | 0.71           |
| Bread and buns                        | –        | –              | –        | –              | 0.50     | 0.52           |
| Diet products and food supplements    | –        | –              | –        | –              | –        | –              |
| Eggs and pasta                        | –        | –              | –        | –              | –        | –              |
| Convenience products                  | –        | –              | –        | –              | –        | –              |
| Fish and seafood                      | –        | –              | 0.39     | 0.31           | –        | –              |
| Meat                                  | –        | –              | 0.64     | 0.72           | –        | –              |
| Vegetables, mushrooms, soya and herbs | 0.72     | 0.72           | –        | –              | –        | –              |
| Alcoholic beverages                   | –        | –              | 0.64     | 0.69           | –        | –              |
| Non-alcoholic beverages               | –        | –              | –        | –              | 0.34     | 0.35           |
| Cereals                               | 0.33     | 0.32           | –        | –              | –        | –              |
| Spices and condiments                 | –        | –              | –        | –              | –        | –              |
| Milk and dairy products               | 0.60     | 0.59           | –        | –              | –        | –              |
| Nuts and seeds                        | –        | –              | –        | –              | –        | –              |
| Fruits and fruit products             | 0.69     | 0.74           | –        | –              | –        | –              |
| Oils and fats                         | –        | –              | –        | –              | –        | –              |
| Salads                                | 0.43     | 0.55           | –        | –              | –        | –              |
| Soups and soup garnishes              | –        | –              | –        | –              | –        | –              |
| Candies and sweets                    | –        | –              | –        | –              | 0.53     | 0.61           |
| Sweet dishes                          | –        | –              | –        | –              | 0.51     | 0.47           |
| Poultry, venison and offal            | –        | –              | 0.42     | 0.53           | –        | –              |
| Sausages, spreads and spicy snacks    | –        | –              | 0.51     | 0.47           | –        | –              |

HP, healthful pattern; EDP, energy-dense pattern; HCP, high-carbohydrate pattern.

†Food items and groups with an absolute component loading  $\geq 0.25$  comprised the dietary patterns at baseline and after 3 months; only these are included in the analysis.



**Fig. 1** Assignment changes of dietary patterns (□, healthful pattern (HP); ▒, energy-dense pattern (EDP); ■, high-carbohydrate pattern (HCP)) after 3 months compared with baseline for (a) the total population, (b) women and (c) men; adults (n 1635) aged 18–81 years, users of a web-based weight-reduction programme, Austria, 2006–2012

(HP:  $r=0.594$ ,  $P<0.001$ ; EDP:  $r=0.606$ ,  $P<0.001$ ; HCP:  $r=0.622$ ,  $P<0.001$ ). The factor score coefficients compared with baseline were statistically significantly lower after 3 months in all participants and in males and females, which could be attributed to a decreased food intake ( $P<0.001$ ). Supplemental Table 1 (see online supplementary material) illustrates all food groups in grams per day at baseline and after 3 months.

As shown in Fig. 1, these dietary patterns were similarly distributed at the start of the programme, with 32% in the HP, 34% in the EDP and 34% in the HCP. However, there was a marked difference between men and women.

Whereas the HP and the HCP were the most prominent dietary patterns in women, it was the EDP for men. Sixty-three per cent of the total population remained in their baseline dietary pattern during the observation period of 3 months. Fifty-nine per cent of participants with an initial HP, 70% with an EDP and 59% with an HCP stayed in their initial dietary pattern. Fifty-nine per cent of women and 61% of men with an initial HP stayed in the HP. Furthermore, men were more likely to remain in the EDP than women (77% v. 64%). In addition, 17% of all participants changed from the EDP or the HCP to the HP (Fig. 1).

**Table 3** Success of weight loss (>5% of initial weight after 3 months) in relation to dietary patterns either at baseline or after 3 months; adults (*n* 1635) aged 18–81 years, users of a web-based weight-reduction programme, Austria, 2006–2012

| Dietary pattern at baseline | Successful (%) | <i>P</i> † | Dietary pattern after 3 months | % of group | % of total | Successful (%) | <i>P</i> † |
|-----------------------------|----------------|------------|--------------------------------|------------|------------|----------------|------------|
| HP ( <i>n</i> 528)          | 63.3           | <0.001     | HP                             | 59.3       | 19.1       | 65.5           | 0.014      |
|                             |                |            | EDP                            | 18.3       | 5.9        | 50.5           |            |
|                             |                |            | HCP                            | 22.3       | 7.2        | 67.8           |            |
| EDP ( <i>n</i> 549)         | 47.4           | <0.001     | HP                             | 17.1       | 5.7        | 50.0           | 0.773      |
|                             |                |            | EDP                            | 70.3       | 23.6       | 46.4           |            |
|                             |                |            | HCP                            | 12.5       | 4.2        | 49.3           |            |
| HCP ( <i>n</i> 558)         | 50.4           | <0.001     | HP                             | 17.0       | 5.8        | 53.7           | 0.016      |
|                             |                |            | EDP                            | 23.6       | 8.1        | 39.4           |            |
|                             |                |            | HCP                            | 59.3       | 20.2       | 53.8           |            |

HP, healthful pattern; EDP, energy-dense pattern; HCP, high-carbohydrate pattern.

†Significant differences tested between successful and unsuccessful weight-loss groups using the  $\chi^2$  test for categorical variables.

**Table 4** Association between successful weight loss (>5% of initial weight after 3 months) and the dietary pattern (0–1 dummy variables) at baseline and after 3 months; adults (*n* 1635) aged 18–81 years, users of a web-based weight-reduction programme, Austria, 2006–2012

|                                | Women ( <i>n</i> 1108) |            | Men ( <i>n</i> 527) |            | Total ( <i>n</i> 1635) |            |
|--------------------------------|------------------------|------------|---------------------|------------|------------------------|------------|
|                                | OR†                    | 95 % CI    | OR†                 | 95 % CI    | OR†                    | 95 % CI    |
| Dietary pattern at baseline    |                        |            |                     |            |                        |            |
| HP                             | 1.88***                | 1.47, 2.41 | 2.35**              | 1.44, 3.84 | 1.84***                | 1.48, 2.28 |
| EDP                            | 0.66**                 | 0.50, 0.87 | 0.56**              | 0.39, 0.80 | 0.68***                | 0.55, 0.83 |
| HCP                            | 0.73*                  | 0.57, 0.94 | 1.11                | 0.75, 1.65 | 0.82                   | 0.67, 1.01 |
| Dietary pattern after 3 months |                        |            |                     |            |                        |            |
| HP                             | 1.41**                 | 1.10, 1.82 | 2.10**              | 1.35, 3.27 | 1.52***                | 1.22, 1.88 |
| EDP                            | 0.56***                | 0.43, 0.73 | 0.50***             | 0.35, 0.71 | 0.58***                | 0.47, 0.71 |
| HCP                            | 1.21                   | 0.94, 1.56 | 1.29                | 0.85, 1.97 | 1.21                   | 0.98, 1.49 |

HP, healthful pattern; EDP, energy-dense pattern; HCP, high-carbohydrate pattern.

\**P*<0.05, \*\**P*<0.01, \*\*\**P*<0.001.

†Odds ratio of successful weight loss (dependent variable) for dietary patterns with 0–1 dummy variables (independent variables) adjusted for age and initial BMI. The reference group for the 0–1 dummy variables is the relevant dietary pattern (e.g. HP dummy variable: 1 = having an HP, 0 = having an EDP or an HCP).

### Dietary patterns and weight loss

Table 3 shows the proportion of successful participants in relation to their initial dietary pattern or change in their dietary patterns. Sixty-three per cent of all participants who showed an HP at baseline were successful in losing weight (*P*<0.001; Table 3). Participants in the EDP and in the HCP groups were quite similar in successfully losing weight (47%, *P*<0.001 *v.* 50%, *P*<0.001) compared with those who failed to be successful.

Participants who changed to or remained in the HP (31%) had a greater chance of being successful (OR=1.4; 95% CI 1.1, 1.7). Participants who aligned with the HP lost a statistically significant greater amount of weight compared with those who changed to the EDP and HCP (6.3 (SD 4.5) *v.* 5.2 (SD 5.3) and 6.1 (SD 3.7) %; *P*=0.032) and had a significantly higher BMI reduction of 6.3 (SD 4.5) % (*P*=0.034) compared with those participants with an EDP or HCP at baseline or who changed to those patterns (data not shown). This analysis was adjusted for age, sex, initial BMI and initial dietary pattern.

Furthermore, we observed significant sex differences; in all three dietary patterns, men lost more weight than did women (HP: 7.5 (SD 4.6) *v.* 5.2 (SD 4.0) %, *P*<0.001; EDP: 4.7 (SD 4.2) *v.* 3.9 (SD 4.5) %, *P*=0.022; HCP: 5.7 (SD 3.5) *v.* 4.9 (SD 3.9) %, *P*=0.029). Seventy-one per cent of men and

57% of women who were in the HP after 3 months were successful, with a statistically significant difference between sexes (*P*<0.001).

### Success ratios

On the one hand, participants who aligned to an HP at baseline (OR=1.8; 95% CI 1.5, 2.3) and after 3 months (OR=1.5; 95% CI 1.2, 1.9) had a greater chance at successfully losing weight. Moreover, the odds of successful weight loss were greater in men compared with women (Table 4). On the other hand, in those participants who complied with the EDP at baseline (OR=0.7; 95% CI 0.6, 0.8) and after 3 months (OR=0.6; 95% CI 0.5, 0.7), we observed a lower chance of successfully losing weight (Table 4). Female participants in the HCP at baseline had lower odds to be successful (OR=0.7; 95% CI 0.6, 0.9). There were no significant odds ratios in all of the other distributions of the HCP (Table 4).

### Discussion

Our results revealed that more than half of the participants successfully lost weight ( $\geq 5\%$  of their initial weight after 3 months) during participation in the web-based

weight-reduction programme. Using twenty-two food groups, we identified three major dietary patterns derived from PCA, which we labelled healthful (HP), energy-dense (EDP) and high-carbohydrate (HCP). Deriving the amount of food from dietary records represents the 'gold standard' for dietary assessments. In our investigation, we used web-based food records for assessing energy intake; this method appears to be consistent with other published methods<sup>(49)</sup>. Alignment to the HP, reflecting high intakes of vegetables, fruits, grains, dairy products and salads, was associated with a higher chance of being successful and a significantly higher BMI reduction. In contrast, alignment to the EDP was associated with lower odds of successfully losing weight.

With high accessibility to the Internet, a rising number of web-based weight-reduction programmes are available and have been shown to produce significant weight loss<sup>(17,20–23)</sup>. To date, three studies have reported that early weight loss, as in the present study at 3 months, is favourably associated with the final weight loss amount<sup>(23,50–52)</sup>.

Very frequently in weight-reduction programmes, the participation rates of men and women are disproportional because more females participate<sup>(53,54)</sup>. The reason for this unequal distribution of participants might be an enhanced lifestyle and health triggers to lose weight for women<sup>(55)</sup>. In our investigation, we analysed men and women separately because other trials have found sex differences in using web-based programmes and in factors associated with successfully losing weight<sup>(56)</sup>. We observed a higher average weight loss in men compared with women (6.3 kg *v.* 4.3 kg). This might be caused by a higher BMI at baseline, fewer prior weight-loss attempts compared with women, or greater self-efficacy regarding weight loss<sup>(57)</sup>.

More than two-thirds of the participants were classified as under-reporters, while less than 2% were considered over-reporters; under-reporters demonstrated a higher BMI<sup>(58)</sup>. The under-reporting of energy intake was not uniformly distributed among the three dietary patterns and might be higher among participants within the rather unfavourable dietary pattern (EDP). Nevertheless, under- and over-reporting have been shown to be subject specific<sup>(59)</sup>. However, the focus of the current analysis is weight-loss success and therefore the bias may be attenuated because there was no significant difference between under- and over-reporters.

The frequency of the HP in our study population is in agreement with other studies on dietary patterns in other populations<sup>(15,60–64)</sup>. Additionally, in agreement with previous studies<sup>(64–67)</sup>, alignment to the HP from our study was associated with both a significantly higher chance to be successful and a greater weight reduction. Both women and men eating the HP lost more weight compared with those eating unhealthy dietary patterns, such as the EDP and HCP. Noticeably, men lost more weight in spite of the dominant EDP, and men in the HP lost more weight

than women. This is in agreement with another study among adult cohorts<sup>(68)</sup>. Schulze *et al.*<sup>(68)</sup> described that strong adherence to a Western pattern (derived by PCA), characterised by a high intakes of refined grains, sweets and desserts, was associated with greater weight gain in women.

In two recent randomised controlled intervention trials regarding diet quality and weight loss<sup>(25,69)</sup>, a higher diet quality was associated with greater weight loss. In our investigation, the high number of participants in the HP may be trying to adopt a healthier eating pattern to lose weight or prevent further weight gain<sup>(70)</sup>. These individuals might also implement healthier foods but may not adopt recommended portion sizes. Further research will be needed to determine whether these dietary patterns are consistent and maintain the same associations with weight over a longer time period.

To the best of our knowledge, the majority of studies involving dietary patterns use data from an FFQ or 24 h dietary recalls<sup>(71,72)</sup>; a minimal number of studies have used dietary records<sup>(67,73)</sup>. Furthermore, dietary assessment tools will most likely always face some level of error and the ability of individuals to precisely self-report their dietary intake may be challenging<sup>(74,75)</sup>. However, applied factor analyses propose that derived dietary patterns account for a modest part of the total variance of whole food intake<sup>(76)</sup>. Our three strongest dietary patterns accounted for only 36% of the total variance in food intake with all types of reporters (under-, over- and plausible reporters), which is in the range of previous reports<sup>(77,78)</sup> and is comparable to other studies<sup>(76)</sup>. The variance explained by individual factors is a function of both the number of variables included in the analysis and the correlation matrix itself<sup>(79)</sup> and might be expected to vary across investigations. Moreover, considering only plausible reporters, dietary patterns accounted for 43% of the total variance in food intake.

The key finding of our study implicates the consistency of dietary patterns over time because approximately two-thirds stayed in their initial dietary pattern. An explanation for this finding might be the relatively short observation period of 3 months. Nevertheless, according to participants who successfully lost weight, a change of a rather unfavourable dietary pattern to a healthful pattern might be challenging, especially for overweight and obese individuals and with respect to the short duration. Accordingly, the best diet for those persons might depend on taste preference and ease of adherence<sup>(80)</sup>.

Moreover, most programmes rely on changes in diet and physical activity with the aim of energy intake reduction and energy expenditure increase<sup>(81,82)</sup>. According to the literature, studies have proposed that a change in behaviour (dietary patterns) or in the principles of social learning, such as goal-setting and self-monitoring, can improve the efficacy of weight-loss approaches<sup>(83–85)</sup>. Moreover, these factors, particularly behavioural changes

and self-monitoring, have been found to be associated with weight-loss success<sup>(86,87)</sup>. Studies of persons who successfully maintain weight loss after self-directed or weight-loss programmes showed that long-term self-monitoring is a crucial component of weight-loss maintenance<sup>(88,89)</sup>. Therefore self-monitoring may serve as an effective behavioural intervention.

Some limitations and strengths of the present study need to be mentioned. First, the weight-change outcomes are based on self-reports, and weight is generally under-reported from overweight and obese individuals and women in particular<sup>(90)</sup>. However, it has been found that self-reported weight recorded online<sup>(91)</sup> and by web-based weight-loss programme participants<sup>(33)</sup> is accurate compared with measured weight<sup>(33,91)</sup>. The consumption of food is self-reported, and diet reporting is generally under-reported. These findings could lead to non-random misclassifications and can either underestimate or overestimate the association between dietary exposure and weight-loss success<sup>(58,59)</sup>. A possible factor for under-reporting the diet could be the general climate of knowledge about food and health<sup>(58)</sup>. There is evidence that the act of self-monitoring is more important than the particular approach and is beneficial for weight control. Electronic and paper diaries seem to be comparable<sup>(92)</sup> with regard to the level of entry details<sup>(93)</sup> or whether the programme participants have received training on accurately recording their dietary intake<sup>(94)</sup>. Second, there might be a potential bias associated with weight loss regarding follow-up and attrition. We only analysed the 'completers' who recorded their diet for a minimum of 60 d. Third, the use of PCA to identify dietary patterns involves some subjectivity in the criteria employed to retain factors. Fourth, it is not clear whether the patterns that we derived would have a different biological effect in individuals with altered educational levels or ethnicities. Dietary patterns might differ by sex<sup>(95–98)</sup> because women tend to have healthier dietary patterns compared with men<sup>(99–102)</sup>. Fifth, physical activity levels were not taken into account in the present analysis, and activity levels might be closely related to weight loss. Physical activity might therefore be a confounder regarding outcome parameters, such as the success of weight loss and dietary intake. Sixth, the study is a pre-and-post intervention study without a control group; therefore this might be a possible bias. The changes of dietary pattern after 3 months could be attributed to participating in the weight-loss programme. Furthermore, an association may exist between dietary pattern and weight loss, due to an intervention effect of self-monitoring.

The present study also has several strengths, including its prospective nature covering a participation period of 3 months with assessments of detailed dietary and anthropometric data and thus our ability to describe changes in the diet. To characterise habitual dietary intake, it is necessary to record dietary intake for more than 8 d to

minimise the effect of random errors (day-to-day variation in dietary intake) in a cohort of overweight and obese men and women<sup>(103)</sup>; the dietary intake was recorded for over 14 d. Additionally, the effects of paying for a weight-loss programme, as was the case for participants in the present analysis, are not particularly obvious. Regarding previous trials, it is reasonable that paying for a weight-loss programme might affect motivation and outcomes<sup>(18,104)</sup>. Nevertheless, our findings were strengthened by adjusting for the many potential confounders in our regression models, such as sex, age, initial BMI and initial dietary pattern. Furthermore, individual feedback and information about nutrition and physical activity within the web-based weight-loss programme could be ascribed as an advantage of the programme<sup>(49)</sup>.

## Conclusion

In summary, more than half of the participants successfully lost weight during their 3-month participation in the web-based weight-reduction programme. In the current investigation, alignment to the healthful dietary pattern was related to a higher chance of being successful and a significant BMI reduction compared with other unfavourable dietary patterns. Nevertheless, the majority of the participants remained in their initial dietary pattern, which could be related to the duration of the observation period or the fact that changing from a rather unfavourable dietary pattern to a healthful pattern might be challenging.

## Acknowledgements

*Financial support:* This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors. *Conflict of interest:* R.A. is the co-owner of the commercial programme KiloCoach™. R.A. provided the study team with user data and declares that the submitted data have been unselected and unmodified. R.L. is an employee of KiloCoach Internetportale GmbH. KiloCoach Internetportale GmbH will not have direct financial benefit from publication. No author has any conflict of interest. *Authorship:* T.E.D. designed the research. E.L., M.L. and T.E.D. analysed the data and performed statistical analyses. T.E.D. supervised the statistical analysis. E.L., M.L. and T.E.D. drafted the manuscript. E.L. had prime responsibility for the final manuscript content. A.R., R.A. and R.L. provided critical input on all versions of the manuscript. All authors read and approved the final manuscript. Language and quality control editors of the Elsevier Editing Service have revised the manuscript. *Ethics of human subject participation:* This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving subjects were approved by the ethics committee at the Medical University of Vienna (EC 1021/2012).

## Supplementary material

To view supplementary material for this article, please visit <http://dx.doi.org/10.1017/S1368980015002852>

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