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Factors of Weight Loss for Telemedically Supported Metabolic Syndrome Patients in a Controlled Trial

Brigitta Szálka [1,2], István Vassányi [1,*], Éva Máthéné Köteles [3], Lili Adrienn Szabó [4], Szilvia Lada [4], Tímea Bolgár [4], Andrea Korom [3], Judit Ábrahám [5], Vilmos Bilicki [6], Mária Barnai [3], Attila Nemes [4], Csaba Lengyel [7] and István Kósa [1,5]

1. Medical Informatics Research and Development Centre, University of Pannonia, 8200 Veszprém, Hungary; kosa.istvan@med.u-szeged.hu (I.K.)
2. Department of Dietetics and Nutritional Sciences, Semmelweis University, 1088 Budapest, Hungary
3. Department of Physiotherapy, University of Szeged, 6720 Szeged, Hungary; mathene.koteles.eva.szilvia@szte.hu (É.M.K.); barnaima@gmail.com (M.B.)
4. Directorate of Nursing Management and Professional Education, University of Szeged, 6720 Szeged, Hungary; szabo.lili.adrienn@med.u-szeged.hu (L.A.S.); lada.szilvia@med.u-szeged.hu (S.L.); bolgar.timea@med.u-szeged.hu (T.B.)
5. Department of Medical Prevention, University of Szeged, 6725 Szeged, Hungary
6. Department of Software Engineering, University of Szeged, 6727 Szeged, Hungary; bilickiv@inf.u-szeged.hu
7. Department of Medicine, University of Szeged, 6725 Szeged, Hungary

* Correspondence: vassanyi.istvan@mik.uni-pannon.hu

Abstract: Metabolic syndrome (MetS) is a complex of interrelated risk factors, associated with several serious chronic diseases like diabetes. The goal of this study was to find dietary factors of successful weight loss for MetS outpatients. We performed a 90-day dietary intervention in a telemedically supported, pre- and post-test, controlled trial in Hungary involving 132 MetS patients; 67 were in the intervention, and 65 were in the control group. Patients in the intervention group used wireless smart devices, a dietary logger, and a lifestyle app. During the trial, we recorded the patients' weight loss and diet composition. For analysis, *t*-tests were used, and the temporal trends of diet composition in the intervention group were analyzed between two sub-groups according to weight loss success. Correlation and regression models were used to find predictors of success. The intervention group achieved more weight loss, and the success in this group was linked with more consumption of raw fruits/vegetables, poultry and potato dishes, while age had a negative effect. We conclude that telemedically supported dietary coaching is an efficient alternative for interventions directed at weight loss. Future trials should investigate the therapeutic application of diets rich in raw fruits, especially apples, and vegetables, as well as poultry dishes.

Keywords: metabolic syndrome; weight loss; trend analysis; food sets; telemedicine

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1. Introduction

Metabolic syndrome (MetS) can be defined as a combination of interrelated risk factors for cardiovascular disease and diabetes, including elevated blood glucose and triglyceride levels, high blood pressure, low high-density lipoprotein cholesterol levels, and obesity, particularly central adiposity [1]. The qualifying factors are defined in the ATP III Panel as follows:

- Waist circumference above 102 cm in men and above 88 cm in women
- Proved Type 2 Diabetes Mellitus or fasting glucose level above 5.6 mmol/L
- Treated hypertension or spontaneous blood pressure $\geq$ 130/85 Hgmm
- Treated hypertriglyceridemia (HTG) or serum TG level above 1.7 mmol/L
- Serum HDL-C level under 1.03 mmol/L in men, under 1.3 mmol/L in women

A person is considered to have MetS if at least three of the above are satisfied [1,2]. The relevance of MetS for public health is due to its association with several serious chronic diseases and health conditions, including cardiovascular disease, type 2 diabetes, and stroke. Due to the high social and financial burden related to MetS [3], there are comprehensive efforts worldwide to introduce new methods for its management via medication, lifestyle intervention or bariatrics [4–6]. Since the development of MetS is highly influenced by the lifestyle, a promising current method is the application of Information Technology (IT)-supported telemedicine that builds on self-management and personalized advice.

Diet is one of the most important controllable factors of lifestyle, and there is also general scientific consensus on the fact that weight loss is the most important part of any dietary intervention therapy for MetS, as the other risk factors are expected to improve due to weight loss as a result. Yet weight loss is the goal that often proves the hardest to achieve. The literature and our own experience show that interventions based on just a few consultations are not effective for weight loss. Rather, a successful lifestyle change and weight loss can be supported only by comprehensive intervention schemes with at least one meeting per month [7,8], or even more than 14 meetings over a 6-month period for best results [9]. Such schemes require a large investment of time and money by both the health care staff and the patient. However, telemedicine can help maintain a high meeting number while keeping the scheme economically viable for the general public [9].

Works related to dietary intervention for MetS include several studies performed over the last decade to test the viability of IT supported dietary intervention in a telemedical setting. Most of these studies had a 3 to 6 month observation period and a cohort ranging from 40 to several hundreds, involving patients with a body mass index (BMI) above 30.

In a trial using the Fitbit mobile app, structured phone calls were used to maintain patients' motivation, which resulted in more weight loss and a significantly improved adherence to the protocol [10]. Similarly, the application of the My Meal Mate smartphone app combined with text messages helped with adherence to the calorie goals between 1200 and 1500 kcal/day in a study with more than 120 participants [11]. The effect of a mobile app vs. a wearable bite counter device was compared in the study of [12], while participants also received behavioral weight loss information via twice-weekly podcasts. The results were in favor of the mobile app method. Extensive use of wireless measurement technology was the cornerstone of another trial resulting in an impressive average weight loss of 7.8 kg over 3 months [13].

Perhaps the most similar in design to our study, [14] used detailed exercise and food diaries in a solution called the 'Mobile health behaviour change support system' in a trial of 6 months. The measured weight loss, however, somewhat falls behind the ca. 3% over 3 months reported in other studies. Some important parameters of these studies are summarized in Appendix A.

The dietary databases supporting the above apps are quite diverse. My Meal Mate has a comprehensive food database (2300 items), but only displays the energy content of the logged food in the user interface [11], while the Bodykey app also provides feedback on the macronutrient content of the logged items [13]. The scanning of barcoded foods is a feature that helped identify logged foods more accurately and to eliminate possible errors in the FatSecret app [12].

This paper presents the dietary-intervention-related results of a telemedical pilot trial performed in Hungary with MetS patients. The main hypothesis of the intervention can be stated as follows: There is a relationship between diet (quantity and composition) and weight loss, which along with the trends of changes in the patients' dietary behavior, can be observed over a 90-day period. The secondary (exploratory) hypothesis was that the use of a mobile app for dietary logging that gives instant feedback on the logged items improves the efficiency of weight loss in the telemedical dietary intervention program.

2. Materials and Methods

The study was originally planned and approved to follow a controlled design with a randomized control group. However, due to the emergent COVID-19 situation, true randomization of the group assignments was not possible. Patients were assigned to either the intervention or the control group consecutively, the control group starting only after some months of delay, when the COVID-19 restrictions were lifted again.

Based on previous studies on the primary outcome variable (weight loss or abdominal circumference), 116 patients′ data were estimated to suffice for performing the statistical tests with 80% power. With a 10% drop-out rate, this required a total of 130 patients; i.e., 65 patients in the telemedicine group as well as in the control group.

Both groups were educated for a lifestyle intervention at the start of the study. We used convenience sampling to recruit volunteers with MetS, defined by the presence of at least 3 ATP-III risk factors [1]. We included participants (men and women) aged between 25 and 70 years who practiced only very low level self-reported regular physical activity (less than 30 min a week). We did not include patients who were unable to give informed consent, had planned invasive cardiology procedures, had uncontrolled hypertension, Type 1 or Type 2 diabetes treated with more than one insulin dose per day, heart failure, renal impairment, tumor disease, severe cognitive dysfunction, or any known condition preventing physical exercise or seriously impairing the capacity to act.

In the intervention group, patients took part in an individual dietetic consultation at the start of the trial in order to plan the dietetic intervention. The intervention adhered to the accepted principles of medical nutrition therapy [15,16]. During the consultation, a detailed dietary history was taken with insights into patients' lifestyle, habits, dietary preferences, frequency and quantity of consumption of various food types, beverages, meal settings, timing, and other pertinent factors. Based on this information, the patients' nutritional plans were developed collaboratively including short-term as well as long-term goals. These goals were discussed during the follow-up consultations and modified as necessary. Long-term objectives included, for example, defining the extent of weight loss, while short-term goals entailed the implementation of specific daily tasks, such as increasing vegetable intake to half a plate or eliminating sugar from coffee. In general, the plans did not include any strict dietary restrictions.

In the rest of the trial, volunteers lived their everyday life with telemedical support. For this they received a wireless body weight scale and a connected smart watch supporting automated exercise logging. They also received a smart phone with a pre-installed copy of a dietary logger and lifestyle app developed in a previous project [17]. Patients were instructed to weigh themselves every day and precisely log their daily meals on as many full days as possible. The app generates instant visual feedback on the energy nutrient contents (calorie, fat, carbohydrate, protein) of the logged item and its contribution to the daily totals, in comparison to the personalized recommended values. All logged and measured data were stored in a cloud database with web-based user interfaces for the supervising dietitians to track the recorded diet, exercise and weight values [18]. A weekly personal tele-consultation was scheduled when the patient could talk with the supervisor over results achieved (e.g., weight loss) and dietary changes (e.g., introduction of new vegetable-based foods), and they received advice on common situations (e.g., eating out, holidays, eating before/after exercise, shopping or cooking). In general, patients were regularly encouraged to practice self-care; e.g., packing healthy and easily transportable snacks to work.

The control group followed a similar protocol, with the exception that the participants were not provided with wireless devices and access to the dietary logger and lifestyle app. Therefore, no detailed dietary or body weight logs were available for this group, only the demographic data and the body weights taken before and after the trial. Nevertheless, this group also took part in the startup consultation, and the participants were offered one personal consultation a month, in line with the regular treatment protocol for MetS patients.

Aside from the daily measurement of the body weight, the blood pressure, plasma blood glucose level, LDL/HDL-cholesterol levels, and waist circumference values were also recorded at the startup and the end of the trial. The compilation of these clinical outcomes is still under way and will be published later. However, it is the weight loss outcome for which the most remarkable change could be expected, according to similar studies [19], and also the parameter for which detailed daily measurement data were available. Therefore, this paper focuses on the success of the dietary interventions based on the weight loss.

The cornerstone of the dietary logging and analysis was an **expert database** that has been manually compiled by dietitian experts to match the target Hungarian culture. The database contains all popular dishes, foods and snacks with several natural units, along with their nutrient contents. The database also contains the weight equivalents of all natural units to support a weight-based dietary analysis. The source of the nutrient data was the public national database on the dietary content of foods, and the contents of dishes were calculated according to the recipe and the contents of the food ingredients. Missing nutrition data for ingredients were imported from the public USDA database [20] after a manual alignment of the food items.

All database items have been manually assigned to one of 35 sets based on their content and dietary characteristics. Nine sets contained foods and dishes which were identified as dietary protective factors according to the relevant literature [8,15,16,21,22]. An example of such a set is 'Raw fruits'. Twelve of the sets were linked with dietary risk factors (e.g., 'High fat processed meat products, fast food'). The remaining 14 sets characterized items whose expected effect on nutritional therapy mainly depended on the amount consumed (e.g., 'pasta', or 'rice dishes'). For a complete list of the sets, see Appendix B.

Due to the lack of detailed timeline data for the control group, the **data analysis** used the control group only for group-level comparisons to check the validity of the secondary hypotheses, and focused more on the primary hypothesis of the study; i.e., the exploration of temporal trends and sub-groups within the intervention group.

As a first step, the dietary logs were systematically cleaned to filter out incomplete or erroneous entries, according to the following ordered scheme.

1. If the log contained an entry that was too general to be identified reliably, the whole day that contained the entry was excluded from the analysis
2. If the total energy logged for a day exceeded 2500 kcal, the logged items for the day were manually checked and corrected by a supervising experienced dietitian. Similarly, any single entries with a quantity above 9 (like e.g., 10 platefuls of spaghetti) were considered a possible typo. Such entries were verified and corrected manually. A similar procedure was followed for repeated identical entries.
3. Incompletely logged days were excluded from further analysis. A logged day was considered incomplete if it had a total energy below 500 kcal, if it contained only one meal, or it contained only two meals and a total energy below 1000 kcal.
4. Outlier days were excluded due to a high probability of a logging error. A day was considered an outlier if its total energy differed more than 50% from the average of the two preceding and two succeeding days.
5. We excluded those patients from the analysis who had less than 14 valid logged days after all the above steps have been executed.

We defined the 90-day weight change percentage (WCP) as

$$WCP = \frac{(final\ body\ weight - initial\ body\ weight) * 90}{initial\ body\ weight * duration\ of\ observation\ in\ days} * 100\ [\%]$$

In line with accepted dietary guidelines [8,15,22–24] and similar studies [13,14,25], we considered a person a successful weight loser (SWL) if their weight loss percentage exceeded 3%, and unsuccessful (UWL) otherwise. Belonging to the success group was treated as the main dependent variable in the statistical analysis. Aside from the SWL, we computed the weight ratios of all dietary sets for each patient for the whole observation period.

The initial independent variables included the patients' age and gender. In order to characterize the patients' compliance, an additional adherence ratio was computed as the ratio of the number of fully logged days with respect to all days. Finally, we also used the average daily weight ratios of the various dietary sets as independent variables in the analysis.

The data analysis posed two questions: first, is there a significant change or trend (either positive or negative) in the body weight of the patients during the trial; second, can we relate any independent variables to an observed significant change or trend.

To answer these questions, we first performed a paired-samples T-test and Wilcoxon signed rank test using the initial and 90-day body weights of all patients to check whether there was a significant change at the group level.

We also performed a Mann-Kendall trend test for each patient to check if there is a significant temporal trend in the change of their body weight during the observation. This test can handle missing days, does not assume a particular distribution, and delivers an estimated slope of the trend-line by the Theil-Sen method that is quite robust for outliers [26]. If the trend was significant for a patient, the weight-loss slope (WL-slope) was also treated as a dependent variable. We note that a higher negative slope denotes more rapid weight loss. In order to track the changes in patients' preferences, we also computed the trends of the average weight ratios for the most important sets separately for the SWL and UWL sub-groups in the first 90 days of the observation.

In order to find a connection between therapeutic success and nutrition, we computed the Pearson correlation between the WL-slope and the important dietary set weight ratios in the cohort of those patients with a significant WL trend, either positive or negative.

As a last step in the analysis of the main hypothesis, we built Ordinary Least Squares linear regression models to find any significant predictors of the two dependent variables; i.e., WCP and WL-slope, using the age, gender, logging adherence, the averaged ratio of the raw fruit/vegetable set, and the daily average dietary fiber consumption as independent variables. We used the forward likelihood model selection method. The linear regression method approximates the dependent variable as the linear combination of the independent variables plus a constant. The coefficient computed for each independent variable carries information on the role and importance of the variable [27].

The secondary hypothesis about the effect of more telemedical support was checked using two-sample *t*-tests.

For each statistical test, the relevant assumptions, such as missing values, normality of distributions, univariate/multivariate outliers, multicollinearity, homoscedasticity, etc., were checked, and the appropriate corrections were performed. Throughout the analysis, *p*-values $p < 0.05$ were regarded as statistically significant.

The data analysis was performed with the Python Statsmodels ver. 0.14, Python Scipy ver. 1.13 and IBM SPSS Statistics ver. 29.0.0 software packages. For the cleaning, transforming and storing of the anonymized trial data, Microsoft SQL Server ver. 2019 database technology was used.

3. Results

3.1. Data Exploration

In the control group, 65 volunteers gave informed consent between January 2022 and February 2023. A total of 62 started the trial, and 51 finished it successfully (27 women and 24 men). The main reasons for dropouts were the COVID-19 pandemic and a lack of motivation. Patient recruitment took place in the municipal district of the city of Szeged, Hungary. The flow of participants is summarized in Figure 1.

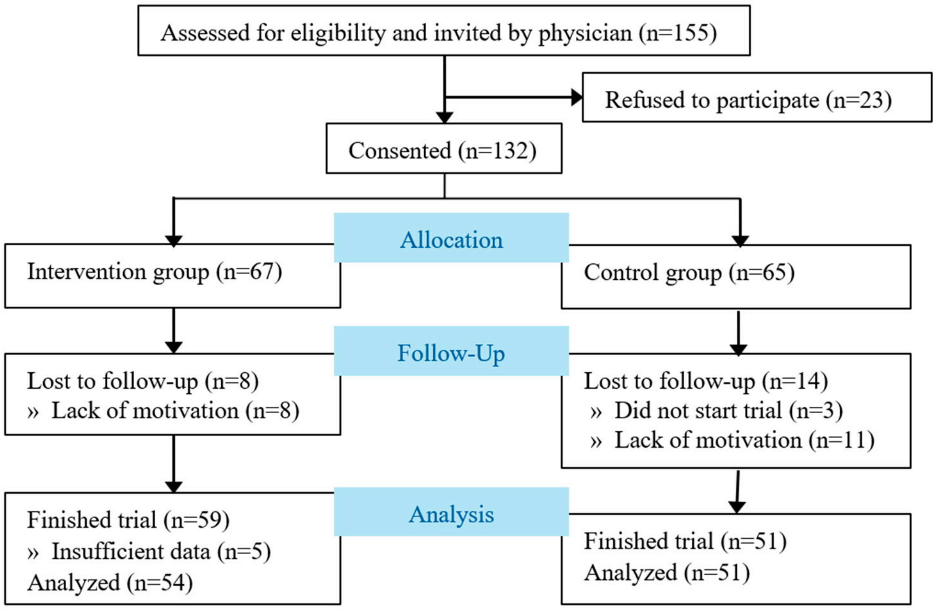

Figure 1. Flow of patients in the trial. The control group received medical treatment according to the regular protocol for metabolic syndrome patients.

In the intervention group, 67 volunteers signed the informed consent between July 2021 and March 2023, out of whom 59 could actually finish the trial according to the protocol. Similarly to the control group, the main reasons for the dropouts were the lack of motivation and the COVID-19 situation. During data cleaning, a total of 108 patient days were dropped due to overly general logged items and 85 days for other reasons detailed above. After data cleaning, 54 patients (26 women and 24 men) had at least 14 fully logged days, applicable for further analysis. Table 1 shows an overview of the relevant demographic and weight loss parameters in this cohort (n = 54).

Table 1. Summary demographic and weight loss data for the intervention group, ±standard deviation (n = 54).

Variable	Women	Men
Group size	26	28
Age at startup (year), average	58.1 ± 9.12	49.8 ± 11.37
Total number of logged days	1590	2135
Number of logged days, average	61.2 ± 27.84	76.3 ± 36.84
Initial body weight (kg), average	100.8 ± 22.26	129.3 ± 30.61
90-day weight change percentage (%), average	−4.5 ± 3.10	−5.6 ± 4.62
Number of successful weight losers	17 of 26	18 of 28

Table 2 compares the successful vs. unsuccessful sub-groups with respect to demography, adherence and 90-day weight loss. While there are no substantial differences in demography, the unsuccessful sub-group falls behind in all other respects. Similarly, Table 3 shows how some key factors have changed during the trial, with the most notable difference in the daily energy intake decreasing in the SWL sub-group and increasing in the UWL sub-group.

The average daily energy intake for the whole observation period was 1470.8 kcal for the successful weight loser sub-group and 1536.9 kcal for the unsuccessful one; however, the difference was not statistically significant in our sample, nor were the differences between the periods shown in Table 3.

The focus of our study is on nutrition, so we analyzed the food composition of the two sub-groups with respect to the food sets. The weight percentages of the first 10 dietary sets are shown in Figure 2. There are slight but notable differences, particularly with respect to raw fruits, vegetables and pastries.

Table 2. Summary trial related data for the successful and unsuccessful weight loser sub-groups, group averages ± standard deviation (n = 54).

Variable	Successful WL	Unsuccessful WL
Group size	35	19
Gender	17 women, 18 men	9 women, 10 men
Age at startup (year), average	54.2 ± 11.90	52.9 ± 9.62
Number of logged days, average	73.2 ± 35.74	61.3 ± 27.81
Adherence (Number of fully logged days/all days) (%), average	79.6 ± 17.05	72.9 ± 21.84
Initial body weight (kg), average	120.5 ± 32.02	106.6 ± 25.17
90-day weight loss percentage (%), average	−7.2 ± 3.18	−1.13 ± 1.38
Weight ratio of raw fruits and vegetables (%), average	22.9 ± 10.33	19.3 ± 10.11

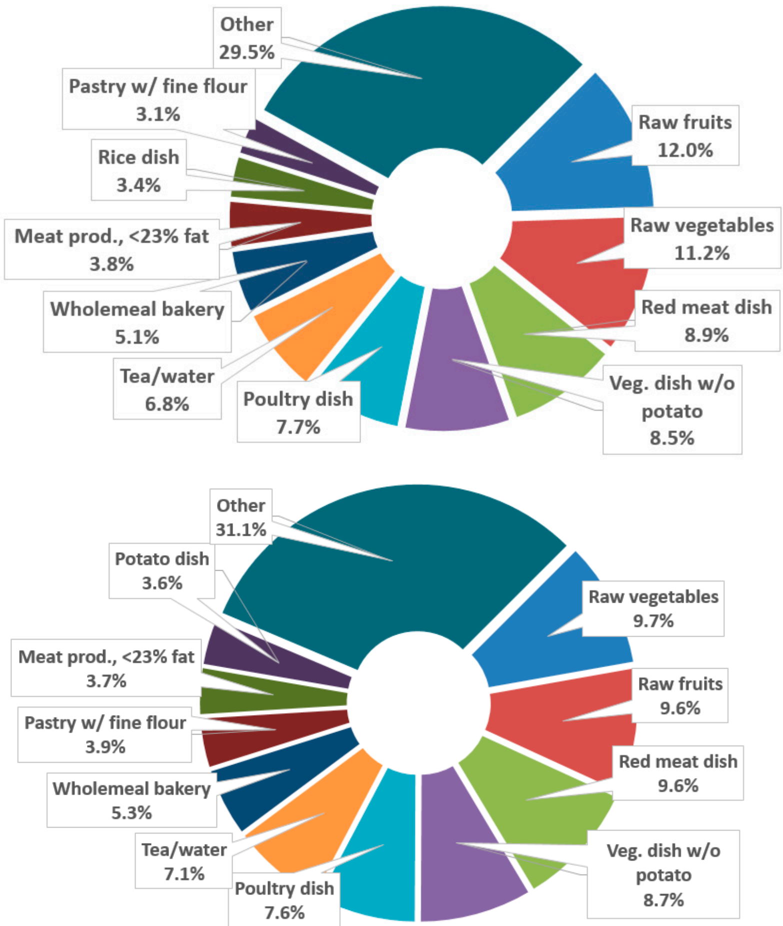

Figure 2. Weight ratios of the 10 most relevant food sets of the successful weight loser (**top**) and the unsuccessful weight loser groups (**bottom**), according to the cleaned dietary logs. Percentage values are group averages.

Table 3. Dietary composition data for the successful and unsuccessful weight loser sub-groups in the first and second period of the observation (n = 54).

Variable	Successful WL		Unsuccessful WL	
	Period 1	Period 2	Period 1	Period 2
Daily energy intake [kcal], average	1502.0	1439.8	1496.8	1577.0
Energy ratio, dietary fibers [%], average	3.7	3.6	3.1	3.1
Weight ratio, raw fruits and vegetables [%], average	22.8	23.7	19	19.7

3.2. Statistical Analysis Results—Main Hypothesis

In the intervention group, the average body weight was 115.6 ± 30.29 (min. 66.5, max. 224.7) kg, the average BMI was 38.9 ± 8.78, while the average 90-day body weight was 109.3 ± 27.24 (min. 67.4, max. 217.2) kg. After removing an extreme outlier, (the person with the maximal weight), the samples passed the Shapiro-Wilk test for normality, and a paired samples t-test found that there was a significant weight decrease (weight loss) of 6.3 ± 6.01 kg; i.e., 5.06% of the startup weight (95% CI 4.60–7.94), $p < 0.001$. This result was confirmed by a Wilcoxon signed-rank test performed on the whole cohort, including the outlier ($p < 0.001$).

The Mann-Kendall test returned a significant trend for 31 out of 35 patients in the SWL sub-group, and 14 out of 19 patients in the UWL sub-group. The average slope of the linear trend line was −95 ± 69.7 g/day in the SWL and −23 ± 22.4 g/day in the UWL sub-group, respectively. Therefore, the Pearson correlation analysis between the WL-slope and the relevant set weight ratios was carried out for n = 45 patients. We found three significant correlations, as shown in Table 4.

Table 4. Significant correlations between the weight loss slope and the most relevant dietary set weight ratios, for the patients in the intervention group with a significant temporal trend (n = 45).

Set Name (Avg. Weight Ratio)	Correlation Coefficient	p
Raw fruits and vegetables (21.7%)	−0.33	0.03
Poultry dishes (7.7%)	−0.3	0.04
Potato dishes (3.1%)	−0.33	0.03

The negative correlation coefficients mean that a higher value of consumption of these sets is associated with a steeper negative slope value i.e., more weight loss.

As for the changes in patient preferences, we computed the significant trends of weight ratios of the most important sets (i.e., those with a weight ration over 3%) over the first 90 days, separately in the SWL vs. UWL sub-groups, with a slope > 1%/90 days. The results are shown in Table 5.

Table 5. Significant temporal trends of weight ratios of the most important dietary sets, in the successful weight loser (SWL) and the unsuccessful weight loser (UWL) sub-groups.

Set Name (Avg. Weight Ratio)	Sub-Group	Trend Slope (/90 Days)	p
Raw fruits and vegetables (21.7%)	SWL	3.51	<0.001
Raw or cooked/steamed vegetables (19.2%)	UWL	3.15	0.02
Raw fruits (11.1%)	SWL	2.97	<0.001
	UWL	−3.42	<0.001
Processed meat products with fat content < 23% (3.7%)	SWL	−1.44	<0.001

Please note that the set 'Raw or cooked/steamed vegetables' is the union of the sets 'Raw vegetables' and 'Cooked/steamed vegetables' and the set 'Raw fruits and vegetables' is the union of the sets 'Raw vegetables' and 'Raw fruits', so these two sets are overlapping. A negative trend slope in Table 5 marks a decreasing trend.

As an example, the weight ratio of the most important raw vegetable/fruit set is illustrated in Figure 3, averaged for the SWL (with a significant trend) and UWL (with no significant trend) sub-groups, in the function of the time.

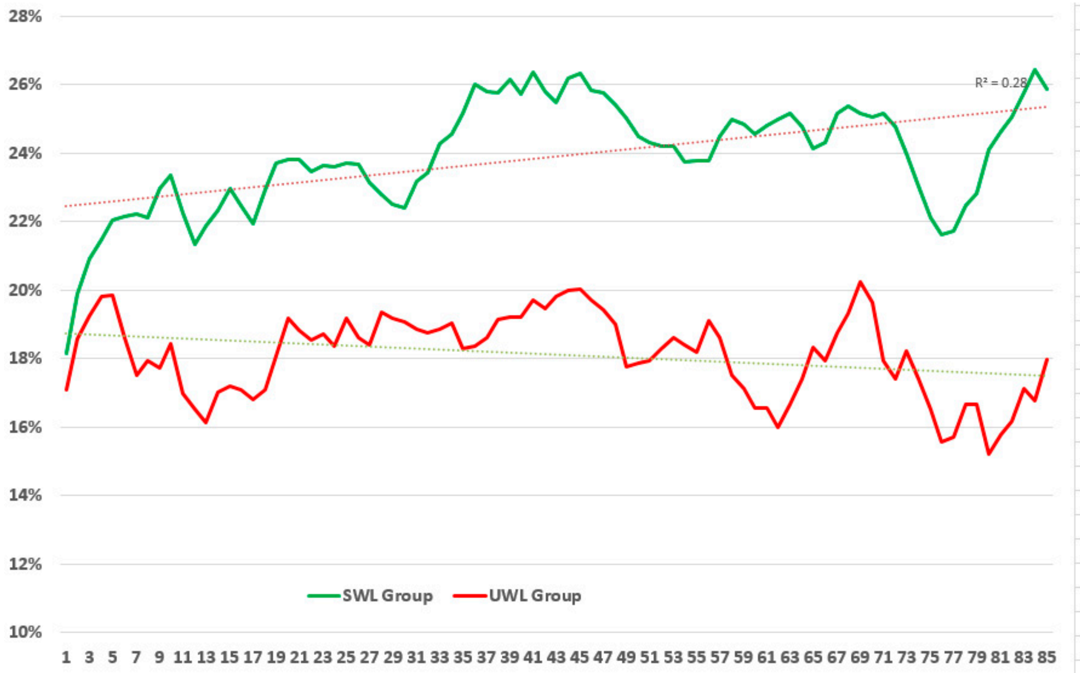

Figure 3. Averaged weight ratio in daily consumption of the 'Raw fruits and vegetables' set, in the successful weight loser (green line) vs. unsuccessful weight loser (red line) sub-groups. The horizontal axis shows observation days.

As for linear regression results, due to the high level of correlation (66%) between the dietary fiber ratio and the raw fruits and vegetables ratio, only the latter was included among the independent variables. For WCP, we could not build a meaningful model due to the low level of explained variability. For the WL slope, the best model included the age, adherence rate and the raw fruits and vegetables ratio as independent variables with an adjusted explained variance R^2 = 41%. The coefficient of the age was 0.34 ($p < 0.001$, relative importance 64%), while the coefficient of the raw fruits and vegetables was −0.20 ($p = 0.016$, relative importance 24%). The effect of the adherence ratio was not significant and the gender was not selected into the model. These results prove a strong negative effect of the patients' age on weight loss success, a higher age being linked with a less steep WL slope (due to the positive coefficient), and a weaker, but substantial positive effect of fruits and vegetables consumption on the rate of weight loss.

We note that the WL slope model used only the data of the 45 patients with a significant WL trend, and an extreme outlier was also omitted from the model to conform to the assumptions of the regression test, resulting in $n = 44$. However, repeated tests also including the outlier confirmed the results.

3.3. *Statistical Analysis Results—Secondary Hypothesis*

In the control group, the average weight at startup of those who finished the trial was 96.1 ± 20.17 (min. 64.6, max. 138.4) kg, the average BMI was 34.1 ± 5.67, and the average 90-day weight loss was 1.8 ± 2.94 kg (1.72% of the startup body weight). A paired samples *t*-test found that the weight decrease was significant ($p < 0.001$).

A two-sample *t*-test found that there was a significant difference in the 90-day weight loss percentages between the control group and the intervention group ($p < 0.001$); i.e., we observed more weight loss (5.06% of the startup weight) in the intervention group.

4. Discussion

We experienced a statistically significant 90-day weight loss of 6.3 kg (5.06% of the startup weight) over the whole intervention group, significantly more than in the control group (1.78%), which is a very clear and positive result, showing the added value of more intensive coaching combined with dietary logging supported by information technology. Compared to similar studies, this result is close to the 7.8 kg reported by [13], over a 12-week intervention period and using a smartphone app—which is also quite similar to our study design. Other studies reached this weight loss range only after a 6-month-long intervention period [10–12,14]. Weight loss is usually attributed primarily to the reduced energy intake. Though we observed a difference between the average energy intake of the successful and the unsuccessful groups, this difference was not statistically significant in our sample, nor were the differences between the two time periods. However, we did observe the significant effect of food composition on weight loss success.

Though the weight loss results are similar, a distinguishing feature of our study is a detailed and cleaned dietary log for the whole observation period in the intervention group, which made it possible to analyze relationships between diet composition and success in this group. We found the following dietary food groups to influence weight loss in a statistically significant way.

Raw fruit and vegetable consumption is the best success predictor. The raw fruit and vegetable food set is the one of all sets that has been consumed the most by the participants (21.7%, see Tables 4 and 5). It also proved to be the best predictor of success. This is shown by its correlation with the WL slope in the whole cohort (Table 4) and its increasing volume over the trial within the SWL sub-group. Moreover, this set was also selected in the linear regression model that successfully predicted the WL slope as a positive factor. This finding is in line with our expectations and confirms the study hypotheses. Consumption of vegetables and fruits is generally recommended as a dietary component for weight loss, healthy balanced nutrition, and various therapeutic diets, including weight loss, dietary therapy for diabetes, and cardio-protective diets [16,28]. Nutritional guidelines recommend consuming approximately 400–500 g of vegetables and fruits daily, equivalent to 4–5 servings, to ensure optimal dietary intake [28,29].

A subset of this set, the raw fruit set, was also identified as a contrast between the SWL and UWL sub-group, with significantly increasing volumes in the former group and decreasing volumes in the latter (Table 5). Clinical experience suggests that obese patients and individuals with diabetes often avoid consuming fruits, influenced by outdated educational materials, although fruits in their raw, unprocessed form are considered a food with low-energy density and low to medium glycemic index [30]. Consumption of fruits in unprocessed form results in slower gastric emptying, thus helping to maintain a feeling of fullness, as it was also proven in a study using MRI scans after raw apples, apple puree and apple juice [31], confirmed by [32]. The fact that supplementing the diet with raw fruit can support weight-loss success in low energy diets was also reported by a 12-week-long study in which obese women consumed a dietary supplement three times a day on an energy-restricted diet, as the best results were linked with the consumption of raw fruits; i.e., apples or pears [33]. The detailed analysis of the dietary logs in our study also revealed that the most often recorded raw fruit was apples, which, besides having low energy content, also possess a favorable carbohydrate composition. It should be noted that according to related studies, the anti-obesity effect of fruit consumption can be influenced by various mechanisms, such as the water and fiber contents facilitating satiety [34].

As for the specific effects of food composition on MetS management, most of the evidence reported so far is also related to fruits and vegetables. Fibers in vegetables and fruits are known to have a beneficial physiological effect by slowing down the absorption of carbohydrates, resulting in a more favorable glycemic response [8]. More recently, research focused on the effect of fibers on the microbiota. A high fiber diet increases the diversity and volume of the microbiome, including probiotics that produce short-chain fatty acids (SCFA) during fiber fermentation [27,35]. With respect to MetS management, butyrate is the most remarkable SCFA, as it seems to be effective in the treatment of obesity and insulin resistance by several mechanisms: it increases insulin sensitivity, pancreatic insulin secretion and leptin secretion, and it has also anti-inflammatory effects [36,37].

Processed meat products and poultry dishes. According to Table 5, we recorded a significantly decreasing trend of processed lean meat products in the SWL group. Though we limited the fat content of foods assigned to this set to 23% in line with national recommendations, this set can still contain relatively fatty items. Such foods have been shown to increase the risk of cardiovascular and cancerous diseases in several studies [15,16,38]. Current research also suggests that the consumption of processed meat foods increases the risk of obesity, attributed not only to the overall fat content and consequently high energy content of these products, but also to their high saturated fatty acid content and other components as well [39–41]. Since our study also involved MetS patients, we must mention a recent study involving obese women, in which participants were divided into two groups: metabolically healthy obesity phenotypes (MHO) and metabolically unhealthy obesity phenotypes (MUHO) [42]. The study reported that those consuming more processed meat foods showed a higher likelihood of MUHO phenotypes. Therefore, we can conclude that in this respect, our study generally confirmed the findings of other recent studies.

Nevertheless, we also found that the consumption of poultry dishes was correlated with a steeper weight loss slope (Table 4). We can explain this phenomenon if we consider poultry as an alternative to red meats, which, either processed or unprocessed, have been associated with an increased risk of MetS in related studies [15,16,28,43], while poultry, with its low fat and high protein content, was found to support weight loss [43].

Finally, potato dishes. We found the same strength of correlation between the potato dishes set and the WL slope as for the Raw fruits and vegetables set. It is a well-known phenomenon in clinical practice that patients, in their pursuit of weight loss, eliminate starchy side dishes, particularly "the evil potato". Our findings corroborate the recommendations of the American Diabetes Association's plate method, which suggests consuming 25% of starchy foods in main meals [1,44]. Recent studies also suggest that the resistant starch content of potatoes is beneficial for the microbiota, thereby supporting weight loss [45]. Finally, the evaluation of data from the Framingham Offspring Study concluded that potato consumption (including fried and non-fried types) did not increase cardio-metabolic risk in middle-aged and older adults [46], further confirming our results.

The role of age is substantial. Our study found a statistically significant and strong connection between the age and the slope of the WL trend: higher age was a predictor of less successful weight loss. According to the Harris Benedict equation, energy requirements decrease with advancing age for both genders [47]. In general, clinical experience suggests that older obese patients typically face greater challenges in weight loss due to mobility issues resulting from musculoskeletal conditions associated with excess body weight, which often restrict their physical activity and thereby limit their energy expenditure. There are, however, quite contradictory results published in the literature from similar studies. In a multi-center, randomized controlled clinical trial involving 1685 participants who self-monitored their physical activity, followed a reduced-energy diet in accordance with the Dietary Approaches to Stop Hypertension (DASH) guidelines and participated in behavioral therapy interventions, surprisingly, individuals aged 60 and above exhibited significantly greater initial weight loss compared to younger groups, and this trend persisted throughout the additional 3 years of the study [48]. In another 400-participant observational, open, prospective study, participants engaged in a 12-month online weight loss program where energy intake was reduced by 15% and physical activity was increased. The program resulted in the same weight loss across age groups [49]. Compared to these studies, our study confirms the general clinical expectation, with a distinctive feature that we applied linear regression analysis.

Dietary intervention involves behaviour changes which in old age can be hindered by lack of peer support, motivation, health literacy and financial resources [50]. As nutrition is part of our identity [51], changing it in old age is particularly difficult and challenging for both the dietitian and the patient. Therefore, the intervention designed for older adults should be more personalised, offering low-cost, seasonal food recipes and group dietetic education sessions, as well as implement any change in very small steps, with dietary suggestions adapted to the patient's preferences.

After 90 days, the volunteers were offered to extend their participation in the trial to six months or more, and ca. 40% of them accepted this offer. These volunteers could preserve their weight loss success. However, currently we do not yet have enough data to assess the long-term sustainability of the results. In the future, we plan to introduce this kind of rehabilitation in routine clinical practice with a long term (some years) follow-up period. Other studies also suggest that the longer the intervention, even with a low or gradually decreasing effort, the lower the chance is for a relapse [52].

A *strength* of our approach is the classification of logged items into elaborate food set hierarchies, which was made possible by a sophisticated dietary expert database. Compared to other studies, another unique feature is the analysis of significant temporal trends in weight loss and in food set preferences.

A *limitation* of our study is that due to COVID-19 restrictions, we could not randomize the selection of the control group, which decreases the reliability of the control-intervention comparison. However, by the formation of the successful vs. unsuccessful weight loser subgroups within the intervention group, we could still perform meaningful and statistically relevant group level comparisons. This can be regarded as added value aside from within-subject trend analysis results.

We also think that the moderate sample size (cf. Table 1) of our study is somewhat counterbalanced by the longer and more detailed dietary logs; i.e., we have more data per patient.

The differences between the control and the intervention group consisted of more intensive coaching, telemedicine and dietary logging; however, our study design did not make it possible to separate these effects. Similarly, we have not measured the patient or expert satisfaction with the specific features of the telemedical platform, though we believe that the effective and intuitive graphical user interface is the key to success. Comparing our solution to similar studies reported in the literature is also very hard because the available information is scarce, and the related studies were using a variety of apps and telemedical designs, cf. the intervention summary of related studies in Appendix A. A recent guideline on rehabilitation also underlines the lack of standardization of telemedical solutions [53]. In the future, more and specifically designed studies are needed to identify the most effective solutions.

The dietary database needs continuous extension by adding new foods as they appear on the market. Similarly, new cooking technologies such as hot air frying may influence the dietary features of standard recipes in the database, leading to a bias in the dietary logs. These issues were identified during the follow-up consultations, and the proper logging alternatives were recommended to the patient.

5. Conclusions

Our positive results justify the viability of new, telemedically supported treatment protocols for diet-based therapy for chronic non-communicable diseases. The short dietary coaching sessions in the intervention group proved an efficient and low cost method to support weight loss, and, together with the instant feedback features built in the mobile app, contributed to the continuous education of the patients.

The strong evidence in favor of the raw fruits and vegetables in our study calls for more, larger-scale randomized controlled trials focusing on this food group, especially the raw, seasonal products instead of extracts or juices, in order to yield more robust therapeutic evidence. More specific results on other, less frequently consumed food groups, or the efficiency of specific telemedical features could be expected from follow-up studies with more participants over a longer observation period.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of the National Institute of Pharmacy and Nutrition of Hungary 13 August 2020 (Approval Code No. OGYÉI/46241/2020). The trial is registered No. NCT05117580 in the ClinicalTrials.gov database.

Informed Consent Statement: Informed consent was obtained in writing from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The detailed dietary log data are not publicly available due to the risk of identification; however, summary data can be released on specific requests after the approval of the Ethical Committee of the National Institute of Pharmacy and Nutrition of Hungary.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Summary weight-loss-related data of relevant studies.

Study	(*n*)	Duration (Months)	Baseline BMI (kg/m^2, in the Weight Loss Group)	Intervention	Weight Loss
Carter et al., 2013 [11]	128	6	33.7	My Meal Mate mobile app for meal and activity monitoring, feedback via weekly text messages	−5.0 kg CI −6.7 to −3.3
Martin et al., 2015 [13]	40	3	30.2 ± 2.66	Bodykey mobile app, wireless body weight scale and accelerometer	−7.8 ± 0.46 kg
Turner et al., 2017 [12]	81	6	33.4 ± 4.8	FatSecret mobile app, wearable Bite Counter device, behavioral advice in twice-weekly podcasts	−6.8 ± 0.8 kg
Ross et al., 2016 [10]	80	6	27–40	Fitbit mobile app, 14 structured phone calls	−6.4 ± 1.2 kg
Markkanen et al., 2023 [14]	200	6	34.4 ± 2.8	Weight monitoring, food and exercise logs, free text reports	−2.5%, 95% CI −3.4 to −1.6

CI = 95% Confidence Interval, BMI = Body Mass Index.

Appendix B

Table A2. Food and dish sets used in the study.

Category		Set	Dietary Effect
Foods	Plant-based foods	Raw vegetables	+
		Raw fruits	+
		Unsalted nuts and seeds	+
		White bread and bakery products	
		Whole grain bread and bakery products	+
		Whole grain cereals (oats, rye flakes)	+
	Bread spreads	Margarine	
		High SFA content fats (butter, lard)	–
	Milk and dairy products	Milk	
		Kefir, yogurt	
		Cottage cheese	
		Cheese	
	Processed meat	<23% fat content	–
		>23% fat content	–
	Sweets, salty snacks	Sugar sweetened	–
		Sugar fee (with artificial sweetener)	
		Salty snack (chips, crackers)	–
	Beverages	Sugary drinks	–
		Zero calory drinks: top water, mineral water, zero cola	
		Alcoholic drinks	–
	Added sugar		–
Dishes	Plant-based dishes	Vegetable dishes (soups, stews)	+
		Legume (soups, stews)	+
		Processed fruit (soups, sauces)	
		Potato sides	
		Rice sides	
		Noodles, pasta	
		Low GI sides (brown rice, buckwheat)	+
	Animal-source dishes	Fish dishes (except fried fish) and canned fish	+
		Egg	
		Poultry	
		Red meat	–
		Offal (liver, heart, bone marrow)	–
	Fast food restaurant meals		–
	Fried foods (French fries, fried cheese, fried chicken)		–

References

1. Alberti, K.G.M.M.; Eckel, R.H.; Grundy, S.M.; Zimmet, P.Z.; Cleeman, J.I.; Donato, K.A.; Fruchart, J.C.; James, W.P.T.; Loria, C.M.; Smith, S.C. Harmonizing the Metabolic Syndrome: A Joint Interim Statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International. *Circulation* **2009**, *120*, 1640–1645. [CrossRef] [PubMed]
2. Grundy, S.M.; Cleeman, J.I.; Daniels, S.R.; Donato, K.A.; Eckel, R.H.; Franklin, B.A.; Gordon, D.J.; Krauss, R.M.; Savage, P.J.; Smith, S.C.; et al. Diagnosis and Management of the Metabolic Syndrome. *Circulation* **2005**, *112*, 2735–2752. [CrossRef] [PubMed]
3. Devaux, M.; Vuik, S. *The Heavy Burden of Obesity: The Economics of Prevention*; OECD Publishing: Paris, France, 2019.
4. Wang, H.H.; Lee, D.K.; Liu, M.; Portincasa, P.; Wang, D.Q.-H. Novel Insights into the Pathogenesis and Management of the Metabolic Syndrome. *Pediatr. Gastroenterol. Hepatol. Nutr.* **2020**, *23*, 189. [CrossRef] [PubMed]
5. Martin, K.A.; Mani, M.V.; Mani, A. New Targets to Treat Obesity and the Metabolic Syndrome. *Eur. J. Pharmacol.* **2015**, *763*, 64–74. [CrossRef]
6. Aguilar-Salinas, C.A.; Viveros-Ruiz, T. Recent Advances in Managing/Understanding the Metabolic Syndrome. *F1000Research* **2019**, *8*, 370. [CrossRef]
7. Lindström, J.; Louheranta, A.; Mannelin, M.; Rastas, M.; Salminen, V.; Eriksson, J.; Uusitupa, M.; Tuomilehto, J. The Finnish Diabetes Prevention Study (DPS): Lifestyle Intervention and 3-Year Results on Diet and Physical Activity. *Diabetes Care* **2003**, *26*, 3230–3236. [CrossRef]
8. ElSayed, N.A.; Aleppo, G.; Aroda, V.R.; Bannuru, R.R.; Brown, F.M.; Bruemmer, D.; Collins, B.S.; Hilliard, M.E.; Isaacs, D.; Johnson, E.L.; et al. 5. Facilitating Positive Health Behaviors and Well-Being to Improve Health Outcomes: Standards of Care in Diabetes—2023. *Diabetes Care* **2023**, *46*, S68–S96. [CrossRef]
9. Raynor, H.A.; Champagne, C.M. Position of the Academy of Nutrition and Dietetics: Interventions for the Treatment of Overweight and Obesity in Adults. *J. Acad. Nutr. Diet.* **2016**, *116*, 129–147. [CrossRef]
10. Ross, K.M.; Wing, R.R. Impact of Newer Self-Monitoring Technology and Brief Phone-Based Intervention on Weight Loss: A Randomized Pilot Study. *Obesity* **2016**, *24*, 1653–1659. [CrossRef]
11. Carter, M.C.; Burley, V.J.; Nykjaer, C.; Cade, J.E. Adherence to a Smartphone Application for Weight Loss Compared to Website and Paper Diary: Pilot Randomized Controlled Trial. *J. Med. Internet Res.* **2013**, *15*, e32. [CrossRef]
12. Turner-McGrievy, G.M.; Wilcox, S.; Boutté, A.; Hutto, B.E.; Singletary, C.; Muth, E.R.; Hoover, A.W. The Dietary Intervention to Enhance Tracking with Mobile Devices (DIET Mobile) Study: A 6-Month Randomized Weight Loss Trial. *Obesity* **2017**, *25*, 1336–1342. [CrossRef] [PubMed]
13. Martin, C.K.; Miller, A.C.; Thomas, D.M.; Champagne, C.M.; Han, H.; Church, T. Efficacy of SmartLossSM, a Smartphone-Based Weight Loss Intervention: Results from a Randomized Controlled Trial. *Obesity* **2015**, *23*, 935–942. [CrossRef] [PubMed]
14. Markkanen, J.O.; Oikarinen, N.; Savolainen, M.J.; Merikallio, H.; Nyman, V.; Salminen, V.; Virkkula, T.; Karppinen, P.; Oinas-Kukkonen, H.; Hukkanen, J. Mobile Health Behaviour Change Support System as Independent Treatment Tool for Obesity: A Randomized Controlled Trial. *Int. J. Obes.* **2023**, *48*, 376–383. [CrossRef]
15. Visseren, F.L.J.; Mach, F.; Smulders, Y.M.; Carballo, D.; Koskinas, K.C.; Bäck, M.; Benetos, A.; Biffi, A.; Boavida, J.-M.; Capodanno, D.; et al. 2021 ESC Guidelines on Cardiovascular Disease Prevention in Clinical Practice. *Eur. Heart J.* **2021**, *42*, 3227–3337. [CrossRef]
16. Lichtenstein, A.H.; Appel, L.J.; Vadiveloo, M.; Hu, F.B.; Kris-Etherton, P.M.; Rebholz, C.M.; Sacks, F.M.; Thorndike, A.N.; Van Horn, L.; Wylie-Rosett, J. 2021 Dietary Guidance to Improve Cardiovascular Health: A Scientific Statement From the American Heart Association. *Circulation* **2021**, *144*, e472–e487. [CrossRef] [PubMed]
17. Vassanyi, I.; Kosa, I.; Karim, R.A.H.; Nemes, M.; Szalka, B. Effectiveness of Mobile Personal Dietary Logging. In Proceedings of the 13th International Conference on e-Society, Madeira, Portugal, 14–16 March 2015; pp. 288–292.
18. Máthéné Köteles, É.; Kiszely, I.; Szabó, L.A.; Lada, S.; Bolgár, T.; Szálka, B.; Korom, A.; Ábrahám, E.J.; Szűcs, M.; Rafael, B.; et al. Telerehabilitáció Hatásossága Metabolikus Szindrómás Személyek Rizikótényezoire (Effectiveness of Tele-Rehabilitation on the Risk Factors of Persons with Metabolic Syndrome). *Cardiol. Hung.* **2022**, *52*, 292–300. [CrossRef]
19. Pattyn, N.; Cornelissen, V.A.; Eshghi, S.R.T.; Vanhees, L. The Effect of Exercise on the Cardiovascular Risk Factors Constituting the Metabolic Syndrome. *Sport. Med.* **2013**, *43*, 121–133. [CrossRef]
20. Fukagawa, N.K.; McKillop, K.; Pehrsson, P.R.; Moshfegh, A.; Harnly, J.; Finley, J. USDA's FoodData Central: What Is It and Why Is It Needed Today? *Am. J. Clin. Nutr.* **2022**, *115*, 619–624. [CrossRef]
21. American Heart Association What Is a Healthy Diet? Recommended Serving Infographic. Available online: https://www.heart.org/en/healthy-living/healthy-eating/eat-smart/nutrition-basics/what-is-a-healthy-diet-recommended-serving-infographic (accessed on 24 October 2024).
22. Virani, S.S.; Newby, L.K.; Arnold, S.V.; Bittner, V.; Brewer, L.C.; Demeter, S.H.; Dixon, D.L.; Fearon, W.F.; Hess, B.; Johnson, H.M.; et al. 2023 AHA/ACC/ACCP/ASPC/NLA/PCNA Guideline for the Management of Patients with Chronic Coronary Disease. *J. Am. Coll. Cardiol.* **2023**, *82*, 833–955. [CrossRef]
23. Leigh Perreault, L.M.D. Obesity in Adults: Dietary Therapy. Available online: https://medilib.ir/uptodate/show/5375 (accessed on 24 October 2024).

24. Zentai, A. A Belügyminisztérium Egészségügyi Szakmai Irányelve a Metabolikus Szindróma Dietoterápiájáról (Ministry of Internal Affairs Health Professional Guideline on Dietary Therapy for Metabolic Syndrome); 2023; Volume LXXIII. Available online: https://mdosz.hu/hun/wp-content/uploads/2024/04/bm-iranyelv-ujabb-szempotok-felnott-betegek-taplaltsagi-allapotanak-felmereserol-es-a-taplalsagi-zavarok-taplalasterapiaval-torteno-kezeleserol.pdf (accessed on 24 October 2024).
25. Wing, R.R.; Lang, W.; Wadden, T.A.; Safford, M.; Knowler, W.C.; Bertoni, A.G.; Hill, J.O.; Brancati, F.L.; Peters, A.; Wagenknecht, L. Benefits of Modest Weight Loss in Improving Cardiovascular Risk Factors in Overweight and Obese Individuals with Type 2 Diabetes. *Diabetes Care* **2011**, *34*, 1481–1486. [CrossRef]
26. Sen, P.K. Estimates of the Regression Coefficient Based on Kendall's Tau. *J. Am. Stat. Assoc.* **1968**, *63*, 1379. [CrossRef]
27. Harrell, F. *Regression Modeling Strategies*; Springer Series in Statistics; Springer: Berlin/Heidelberg, Germany, 2015; ISBN 978-3-319-19424-0.
28. Cámara, M.; Giner, R.M.; González-Fandos, E.; López-García, E.; Mañes, J.; Portillo, M.P.; Rafecas, M.; Domínguez, L.; Martínez, J.A. Food-Based Dietary Guidelines around the World: A Comparative Analysis to Update Aesan Scientific Committee Dietary Recommendations. *Nutrients* **2021**, *13*, 3131. [CrossRef] [PubMed]
29. World Health Organization. Diet, Nutrition, and the Prevention of Chronic Diseases. Report of a Joint WHO FAO Expert Consultation by World Health Organization 2003. Available online: https://www.who.int/publications/i/item/924120916X (accessed on 24 October 2024).
30. Atkinson, F.S.; Foster-Powell, K.; Brand-Miller, J.C. International Tables of Glycemic Index and Glycemic Load Values: 2008. *Diabetes Care* **2008**, *31*, 2281–2283. [CrossRef]
31. Krishnasamy, S.; Lomer, M.C.E.; Marciani, L.; Hoad, C.L.; Pritchard, S.E.; Paul, J.; Gowland, P.A.; Spiller, R.C. Processing Apples to Puree or Juice Speeds Gastric Emptying and Reduces Postprandial Intestinal Volumes and Satiety in Healthy Adults. *J. Nutr.* **2020**, *150*, 2890–2899. [CrossRef]
32. Flood-Obbagy, J.E.; Rolls, B.J. The Effect of Fruit in Different Forms on Energy Intake and Satiety at a Meal. *Appetite* **2009**, *52*, 416–422. [CrossRef] [PubMed]
33. Conceição De Oliveira, M.; Sichieri, R.; Sanchez Moura, A. Weight Loss Associated with a Daily Intake of Three Apples or Three Pears among Overweight Women. *Nutrition* **2003**, *19*, 253–256. [CrossRef]
34. Sharma, S.; Chung, H.; Kim, H.; Hong, S. Paradoxical Effects of Fruit on Obesity. *Nutrients* **2016**, *8*, 633. [CrossRef]
35. Facilitating Behavior Change and Well-Being to Improve Health Outcomes: Standards of Medical Care in Diabetes—2022. *Diabetes Care* **2022**, *45*, S60–S82. [CrossRef]
36. Coppola, S.; Avagliano, C.; Calignano, A.; Berni Canani, R. The Protective Role of Butyrate against Obesity and Obesity-Related Diseases. *Molecules* **2021**, *26*, 682. [CrossRef]
37. Cronin, P.; Joyce, S.A.; O'Toole, P.W.; O'Connor, E.M. Dietary Fibre Modulates the Gut Microbiota. *Nutrients* **2021**, *13*, 1655. [CrossRef]
38. WHO World Health Organization. *Red and Processed Meat in the Context of Health and the Environment: Many Shades of Red and Green: Information Brief*; World Health Organization: Geneva, Switzerland, 2023; p. 56.
39. Khodayari, S.; Sadeghi, O.; Safabakhsh, M.; Mozaffari-Khosravi, H. Meat Consumption and the Risk of General and Central Obesity: The Shahedieh Study. *BMC Res. Notes* **2022**, *15*, 339. [CrossRef] [PubMed]
40. Zandvakili, A.; Shiraseb, F.; Hosseininasab, D.; Aali, Y.; Santos, R.D.; Mirzaei, K. The Association between Consumption of Red and Processed Meats with Metabolic Syndrome and Its Components in Obese and Overweight Women: A Cross-Sectional Study. *BMC Womens Health* **2024**, *24*, 93. [CrossRef]
41. Rouhani, M.H.; Salehi-Abargouei, A.; Surkan, P.J.; Azadbakht, L. Is There a Relationship between Red or Processed Meat Intake and Obesity? A Systematic Review and Meta-Analysis of Observational Studies. *Obes. Rev.* **2014**, *15*, 740–748. [CrossRef] [PubMed]
42. Mohamadi, A.; Shiraseb, F.; Mirzababaei, A.; Barekzai, A.M.; Clark, C.C.T.; Aali, Y.; Mirzaei, K. Inflammatory Markers May Mediate the Relationship between Processed Meat Consumption and Metabolic Unhealthy Obesity in Women: A Cross Sectional Study. *Sci. Rep.* **2023**, *13*, 9261. [CrossRef]
43. Guo, H.; Ding, J.; Liang, J.; Zhang, Y. Association of Red Meat and Poultry Consumption With the Risk of Metabolic Syndrome: A Meta-Analysis of Prospective Cohort Studies. *Front. Nutr.* **2021**, *8*, 691848. [CrossRef]
44. Camelon, K.M.; Hådell, K.; Jämsén, P.T.; Ketonen, K.J.; Kohtamäki, H.M.; Mäkimatilla, S.; Törmälä, M.-L.; Valve, R.H. The Plate Model. *J. Am. Diet. Assoc.* **1998**, *98*, 1155–1158. [CrossRef]
45. Liang, D.; Zhang, L.; Chen, H.; Zhang, H.; Hu, H.; Dai, X. Potato Resistant Starch Inhibits Diet-Induced Obesity by Modifying the Composition of Intestinal Microbiota and Their Metabolites in Obese Mice. *Int. J. Biol. Macromol.* **2021**, *180*, 458–469. [CrossRef] [PubMed]
46. Yiannakou, I.; Pickering, R.T.; Yuan, M.; Singer, M.R.; Moore, L.L. Potato Consumption Is Not Associated with Cardiometabolic Health Outcomes in Framingham Offspring Study Adults. *J. Nutr. Sci.* **2022**, *11*, e73. [CrossRef]
47. Bendavid, I.; Lobo, D.N.; Barazzoni, R.; Cederholm, T.; Coëffier, M.; de van der Schueren, M.; Fontaine, E.; Hiesmayr, M.; Laviano, A.; Pichard, C.; et al. The Centenary of the Harris–Benedict Equations: How to Assess Energy Requirements Best? Recommendations from the ESPEN Expert Group. *Clin. Nutr.* **2021**, *40*, 690–701. [CrossRef]
48. Svetkey, L.P.; Stevens, V.J.; Brantley, P.J.; Appel, L.J.; Hollis, J.F.; Loria, C.M.; Vollmer, W.M.; Gullion, C.M.; Funk, K.; Smith, P.; et al. Comparison of Strategies for Sustaining Weight Loss: The Weight Loss Maintenance Randomized Controlled Trial. *JAMA* **2008**, *299*, 1139–1148. [CrossRef] [PubMed]

49. Woźniak, J.; Woźniak, K.; Wojciechowska, O.; Wrzosek, M.; Włodarek, D. Effect of Age and Gender on the Efficacy of a 12-Month Body Weight Reduction Program Conducted Online—A Prospective Cohort Study. *Int. J. Environ. Res. Public Health* **2022**, *19*, 12009. [CrossRef] [PubMed]
50. Bardach, S.H.; Schoenberg, N.E.; Howell, B.M. What Motivates Older Adults to Improve Diet and Exercise Patterns? *J. Community Health* **2016**, *41*, 22–29. [CrossRef] [PubMed]
51. Blake, C.E.; Bell, B.A.; Freedman, D.A.; Colabianchi, N.; Liese, A.D. The Eating Identity Type Inventory (EITI). Development and Associations with Diet. *Appetite* **2013**, *69*, 15–22. [CrossRef]
52. Gong, Q.; Zhang, P.; Wang, J.; Ma, J.; An, Y.; Chen, Y.; Zhang, B.; Feng, X.; Li, H.; Chen, X.; et al. Morbidity and Mortality after Lifestyle Intervention for People with Impaired Glucose Tolerance: 30-Year Results of the Da Qing Diabetes Prevention Outcome Study. *Lancet Diabetes Endocrinol.* **2019**, *7*, 452–461. [CrossRef]
53. Schwaab, B.; Rauch, B. S3-Leitlinie Zur Kardiologischen Rehabilitation Im Deutschsprachigen Raum Europas. *DMW-Dtsch. Med. Wochenschr.* **2021**, *146*, 171–175. [CrossRef]