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Implementation of a Nutrition-Oriented Clinical Decision Support System (CDSS) for Weight Loss during the COVID-19 Epidemic in a Hospital Outpatient Clinic: A 3-Month Controlled Intervention Study

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Abstract: Clinical Decision Support Systems (CDSSs) facilitate evidence-based clinical decision making for health professionals. Few studies have applied such systems enabling distance monitoring in the COVID-19 epidemic, especially in a hospital setting. The purpose of the present work was to assess the clinical efficacy of CDSS-assisted dietary services at a general hospital for patients intending to lose weight during the COVID-19 pandemic. Thirty-nine patients (28 men, 71.8%) comprised the intervention group and 21 patients (four men, 16%) of the control group. After a 3-month CDSS intervention, reductions in both body weight (mean ± standard deviation (SD): 95.5 ± 21.8 vs. 90.6 ± 19.9 kg, $p < 0.001$) and body mass index (BMI) (median, interquartile range (IQR): 35.2, 28.4–37.5 vs. 33.2, 27.4–35.4 kg/m^2, $p < 0.001$) were observed. Beneficial effects were also recorded for total body fat (44.9 ± 11.3 vs. 41.9 ± 10.5%, $p < 0.001$), glycated hemoglobin (5.26 ± 0.55 vs. 4.97 ± 0.41%, $p = 0.017$) (mean ± SD) and triglycerides (137, 115–152 vs. 130, 108–160 mg/dL, $p = 0.005$) (medians, IQR). Lean tissue was borderline decreased (25.4, 21.7–29.1 vs. 24.6, 21.8–27.9 kg, $p = 0.050$). No changes were documented in the control group. In multivariate linear regression models, serum triglycerides were inversely associated with % absolute weight loss (B = −0.018, standard error (SE) = 0.009, $p = 0.050$) in the CDSS intervention group. In women, a principal component analysis-derived pattern characterized by high BMI/lean tissue was positively related to % absolute weight loss (B = 20.415, SE = 0.717, $p = 0.028$). In conclusion, a short-term CDSS-facilitated intervention beneficially affected weight loss and other cardiovascular risk factors.

Keywords: clinical decision support system; CDSS; weight loss; COVID-19; nutrition intervention; Mediterranean diet

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1. Introduction

Clinical Decision Support Systems (CDSSs) constitute a useful tool in reducing human-related errors and facilitating evidence-based clinical decision making for medical doctors, pharmacists, and other health professionals [1,2]. Patients' characteristics are entered in the system, and they are compared to recommendations. Then, patient-specific evaluations are provided to the clinician, who makes the final decision [1]. Similarly, a nutrition-oriented CDSS helps dietitians to calculate patients' nutritional needs more quickly and easily compared to paper or simply computerized methods [3]. Such a system reduces the time required for data calculation and analysis during nutritional assessment [3]. Moreover, it ensures the implementation of a step-by-step nutrition care process (NCP) including nutritional assessment, diagnosis, intervention, monitoring and evaluation [4,5]. All records are standardized and are stored and accessible, allowing clinical dietitians and health professionals to conduct clinical research as well as to assess the improvement in patients with long-term nutritional care [1]. Indeed, the use of structured records and the incorporation of alerts/reminders have been shown to enhance the quality of medical records and provision of evidence-based care adherent to guidelines [6].

During the COVID-19 era in Greece, certified dietitian and nutritionist services were restricted during certain quarantine periods (between March and June of 2020), due to state measures to control the spread of COVID-19. Similar measures were also in force for hospital outpatients while the health system was "under pressure". In parallel, good nutritional status and obesity prevention was of outmost importance for COVID-19 prevention and management [7,8]. Hospital dietitians took care of hospitalized patients, and the special needs of whom were covered via menu modifications [9] and oral nutritional supplements [10]. During this difficult time, the use of electronic medical records [11] and tele-health were recommended to provide and monitor nutritional care [7]. Within this scope, the CDSS developed by our group, named Nutrinet®, aimed to provide distance lifestyle advice while avoiding visits to healthcare providers and minimizing the risk of COVID-19 infection [3]. The clinical efficacy of the CDSS used in the present study was recently demonstrated in patients with breast cancer [4], multiple sclerosis [12] and rheumatoid arthritis [13], as well as pregnant women [14]. Several programs based on tele-health and remote consultations were developed to assist patients with obesity during weight loss, especially during COVID-19 [15–17]. However, to our knowledge, there is no study using CDSS in a hospital setting to enable distance counseling and monitoring of overweight and obese patients.

The purpose of the present work was to assess the application and clinical efficacy of CDSS (Nutrinet®)-assisted dietary services for patients at a general hospital who were intending to lose weight during the COVID-19 era.

2. Materials and Methods

2.1. Participants

The study was carried out at a general hospital from March 2020 to September 2021 and consisted mainly of patients who visited outpatient clinics or were hospitalized and needed nutritional intervention and follow-up. More particularly, participants screened for participating in the study were inpatients or outpatients being referred to the dietitian department. The inclusion criteria for the volunteers were (i) age equal to or over 18 years, (ii) ability to be systematically followed up by the dietitian in the time frame that was set and (iii) familiarization with computer systems. The exclusion criteria were (i) pregnancy or breastfeeding, (ii) presence of cancer, liver disease, kidney disease or celiac disease, (iii) alcohol abuse or specific dietary preferences, such as ketogenic or vegetarian diet, (iv) recent change in glucose and lipid-lowering therapy, (v) bariatric or other type of surgery, (vi) computer illiteracy (for the CDSS intervention group) and (vii) inability to read and understand the Greek or English language. In the intervention group, 28 men participated (71.8%). A control group was identified from the outpatients of the hospital's clinic and received only dietary advice (n = 4 men, 16%). All subjects gave their verbal informed consent for inclusion in the study. The study was performed according to the principles of the Helsinki Declaration (1964). Ethical approval was obtained from the hospital's Institutional Review Board (number f310519).

2.2. Study Design

A 3-month single-centered controlled intervention was performed. In the CDSS intervention group, the participants received a personalized eating plan based on the principles of the Mediterranean diet. The energy and macro-nutrient content of the dietary plan were created using a CDSS, as previously described [4]. An example of the dietary plan is given in Supplementary Table S1. The control group received simple lifestyle advice (dietary advice group). The CDSS was accessible to both patients and dietitians, so that bi-directional feedback was possible.

2.3. Anthropometric and Body Composition Measurements

Height was assessed with a stadiometer (Seca 216) in cm to the nearest 0.1 cm. Measurements were taken without shoes, with a straight back, relaxed shoulders and looking straight ahead at a horizontal Frankfurt imaginary line. Body weight was measured with the SOEHNLE Fitness Scale 7850 in kg to the nearest 0.1 kg. Waist circumference was measured with a GIMA tape measure (Gessate, Italy) in cm to the nearest 0.1 cm. All measurements were performed by the same researcher-dietitian.

The participants underwent a body composition analysis using the bioelectrical impedance method. Body composition analysis was performed with the digital scale-body fat analyzer (SOEHNLE Fitness Scale 7850) (Soehnle GmbH, Murrhardt, Germany) and included body fat (%) and fat free mass (% and kg). Measurements were taken without shoes and socks and with light clothing according to the manufacturer's recommendations. Lean mass index was then calculated as lean mass divided by squared height (kg/m^2).

2.4. Nutrition-Oriented CDSS

In the present study, the Nutrinet® CDSS was used. The system was initially launched in the pre-COVID era. However, the functions included facilitated a distance-based intervention and follow-up. Basic information (patient's name, date of birth, gender), anthropometric, medical, nutritional and pharmaceutical data were deposited in the database during the visit (Figure 1). More particularly, the CDSS assisted in the following procedures: medical and pharmaceutical history, dietary assessment, physical activity assessment, formulation of personalized tailored dietary plans, provision of guidelines, definition of nutritional and physical activity goals, and monitoring nutritional and physical activity goals.

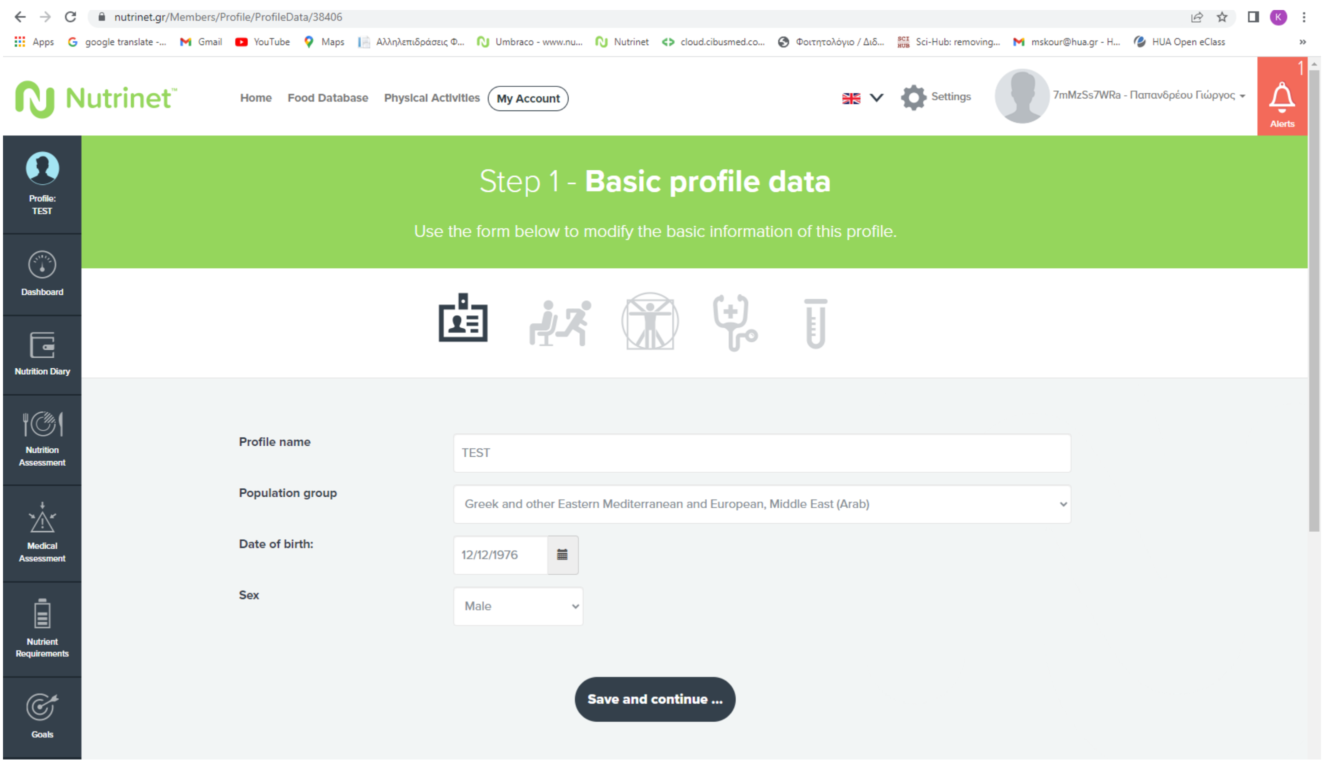

Figure 1. The Nutrinet® CDSS: basic profile data.

2.4.1. Medical and Pharmaceutical History

Regarding the medical history, information was recorded about health state and the presence of diseases or chronic conditions. A history of surgical procedures affecting nutrient absorption was also included. In addition, information was collected on smoking habits, drinking habits, and unintentional weight loss in the past 3–6 months. In the pharmaceutical history, the intake of medicines, herbal products and dietary supplements was recorded.

At the first session, the volunteers were asked to present their most recent laboratory tests performed in the last 4 months. Laboratory tests were repeated under the direction of the dietitian in order to detect possible differences at follow-up. The laboratory data requested and recorded were blood tests of fasting glucose (mg/dL), glycated hemoglobin (HbA1c), total-cholesterol, HDL-cholesterol, and triglycerides. LDL-cholesterol was calculated based on the Fridewald formula, provided that triglycerides were <400 mg/dL [18]. It is noted that with the aid of the CDSS the assessment of blood lipid and glucose values was automatically performed according to international standards. For lipids assessment, the NIH/NHLBI/NCEP (ATP III) 2002 criteria were used [19], and for the assessment of blood glucose levels, the American Diabetes Association (ADA) 2014 criteria were used [20].

2.4.2. Dietary Assessment

The assessment of the participants' dietary intake in terms of energy, macronutrients, micronutrients and eating habits was conducted using a 24 h recall method, by a dietitian. The 24 h recall was carried out on the day of admission to the study. Essentially, the volunteers were asked to describe all foods and beverages they consumed the previous day in detail, and their corresponding quantity. Data from the 24 h recall were immediately entered into the CDSS nutritional program to perform the analysis. The embedded nutrition database used by the CDSS uses data from the USDA database (Releases 27 and 28) [21], the food database created by Trichopoulou [22], and information provided by food manufacturers. The dietary reference intakes are used to assess and design personal dietary plans [23].

The ideal body weight was automatically calculated with the aid of the CDSS with the use of the Hamwi equation [24]. The body mass index was calculated by the division of weight with squared meters (in kg/m^2) for each person who participated in the study. Moreover, an assessment of waist circumference was provided based on the criteria of the International Diabetes Federation [25] (Figure 2).

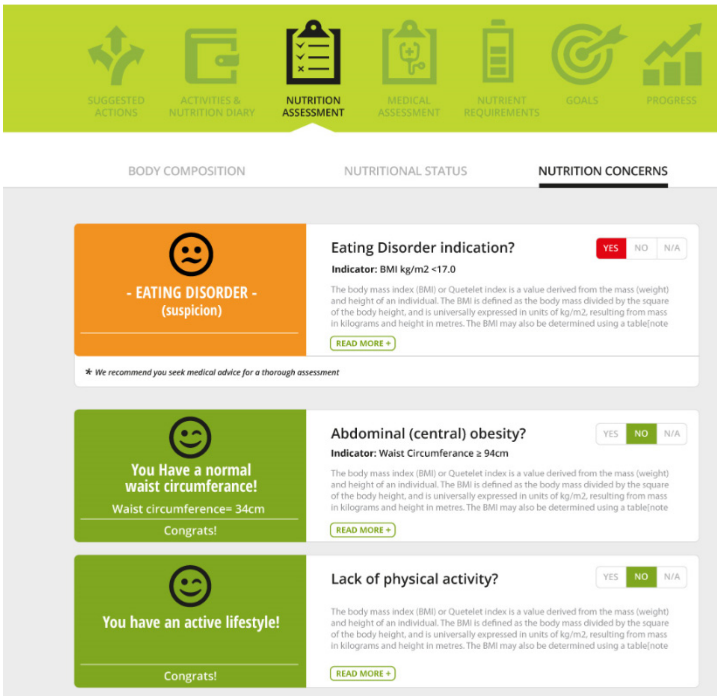

Figure 2. The Nutrinet® CDSS: Nutrition assessment.

2.4.3. Physical Activity Assessment

Four physical activity categories were available to select through the CDSS: (i) mildly active, (ii) moderately active, (iii) active, and (iv) intensely active or athlete. Physical activity intensity was evaluated based on the corresponding metabolic equivalents (MET) [26]. Moreover, an assessment of physical activity status was provided (Figure 2).

2.4.4. Formulation of Personalized Tailored Dietary Plans

In the intervention group, patients were prescribed a CDSS-generated individualized daily dietary plan (food portions in grams, recipes, etc.) based on the Mediterranean diet. Moreover, the presence of gastro-intestinal issues, in which medical nutrition therapy is indicated for long with other therapies (such as constipation, diarrhea or gastroesophageal reflux) was considered in the formulation of CDSS diet plans.

2.4.5. Dietary Monitoring and Evaluation

The ability to track patient progress per session was also provided by the CDSS. The application allowed the dietitian to see the metrics of previous meetings in a graphical way and to evaluate progress. Depending on the case and health problem, the dietitian was able to focus on different points each time. Moreover, login passwords were provided to patients in the intervention group to allow remote access to the CDSS. In this way, patients had the opportunity to also self-track their progress relating to body weight, physical activity, fruits consumption, etc. It is noted that Nutrinet® helped people focus on enhancing self-awareness, being confident and understanding behavioral patterns, through small steps.

2.5. Statistical Analysis

The Kolmogorov–Smirnov test was used to test for data normality. Continuous normal variables were expressed as mean ± standard deviation (SD), and continuous non normal variables were expressed as median, interquartile range (IQR). Dichotomous variables were expressed as counts and frequencies (n, %). To assess the differences between control and experimental groups, the Student's *t*-test or Mann–Whitney U-test was used for normally distributed and non-normally distributed variables, respectively. The paired samples *t*-test or the Wilcoxon test was performed to test pre- and post-intervention differences within groups, for normally distributed and not-normally distributed variables, respectively. Principal component analysis (PCA) was performed to identify body weight and body composition patterns. To choose the number of components to keep from the PCA analysis, the eigenvalues derived from the correlation matrix of the standardized variables were assessed, and the scree plot was checked for confirmation. Components with eigenvalue higher than one were retained for data analyses. Based on the concept that the component scores are interpreted as correlation coefficients (i.e., higher absolute scores indicate that the variable characterizes most to the component), the bodyweight and body composition patterns were defined in relation to variables that correlated most with the component (absolute factor loadings > 0.45). Moreover, the orthogonal varimax rotation was used to derive optimal patterns, which were non-correlated.

Spearman coefficients were calculated in order to identify the factors that correlated mostly with % weight loss. Then, linear regression analysis was carried out to identify the factors that can "predict" weight loss after taking into account basic confounders. More particularly, the absolute % weight loss was set as dependent variable and several variables were set as independent ones, such as age, body weight patterns and blood exams. Sex-specific analysis was also performed. All analyses were carried out with the SPSS statistical software (Version 21.0, SPSS, Inc., IBM, Chicago, IL, USA). Statistical significance was set at p-value < 0.05.

3. Results

In Table 1, the general characteristics of participants are shown as well as the pre- and post-intervention differences in the CDSS intervention group versus dietary advice group. It is noted that the CDSS intervention group consisted mainly of males (~70%). The mean age and body mass index (BMI) of the CDSS intervention group was 48.9 years and 35.2 kg/m^2, respectively. The percentage of overweight subjects was similar between the two groups (30.8% in the CDSS intervention group vs. 32.3% in the dietary advice group, p = 0.153), while the intervention group consisted of more obese subjects (17.9% in the CDSS intervention group vs. 9.5% in the dietary advice group). The levels of several biochemical markers of glucose and lipid metabolism were not different between the CDSS-intervention group and the control group. Moreover, it is noted that the pre- and post-effects in the CDSS intervention and dietary advice groups are seen in Table 1. In the CDSS intervention arm, body weight, BMI, total body fat, glycated hemoglobin and triglycerides were significantly decreased at follow-up. Lean tissue was borderline decreased, and lean mass index was decreased, while glucose and cholesterol (total, LDL- and HDL-cholesterol) did not change. No difference was observed in the dietary advice group. It is noted that grouped results for both genders may be misleading, since anthropometric and body composition measurements are different in men and women. For this reason, sex-specific analysis was also conducted. In sex-specific analysis, body weight, BMI and total body fat were reduced in both sexes (Table 2). More particularly, body weight was reduced from 87.9 ± 14.9 kg to 83.3 ± 13.9 kg in men and from 114.6 ± 25.4 kg to 109.2 ± 21.4 kg in women. BMI was reduced from 35.2 (28.4–37.5) kg/m^2 to 33.2 (27.4–35.4) kg/m^2 in men and from 26.4 (22.4–28.5) kg/m^2 to 24.9 (21.7–27.4) kg/m^2 in women. Total body fat was reduced from 46.9 ± 9.8% to 43.7 ± 9.7% in men and from 39.9 ± 13.8% to 37.3 ± 11.5% in women. Lean tissue and lean mass index remained unchanged in both men and women. In addition, beneficial changes were documented in glucose, total cholesterol and triglycerides in male participants (Table 2). No sex-specific analysis was conducted in the dietary advice group, since a low number of men were recruited.

Table 1. Baseline and follow-up measurements of the patients in the CDSS intervention and dietary advice group.

	CDSS Intervention Group (n = 39)			Dietary Advice Group (n = 21)			
	Baseline	**Follow-Up**	***p*-Value §**	**Baseline**	**Follow-Up**	***p*-Value ‡**	***p*-Value ∫**
Age (y)	48.9 ± 13.4	NA	NA	67.0 ± 16.4	NA	NA	<0.001
Sex (men), n (%)	28 (71.8%)	NA	NA	4 (16%)	NA	NA	<0.001
Body weight (kg)	95.5 ± 21.8	90.6 ± 19.9	<0.001	73.4 ± 10.1	72.8 ± 11.3	0.563	<0.001
BMI (kg/m^2)	35.2 (28.4–37.5)	33.2 (27.4–35.4)	<0.001	26.4 (22.4–28.5)	24.9 (21.7–27.4)	0.434	<0.001
Total body fat (%)	44.9 ± 11.3	41.9 ± 10.5	<0.001	35.7 ± 5.7	35.6 ± 5.9	0.469	0.001
Lean tissue (kg)	25.4 (21.7–29.1)	24.6 (21.8–27.9)	0.050	NA	NA	NA	NA
Lean mass index (kg/m^2)	9.31 ± 1.29	8.98 ± 1.31	0.048	NA	NA	NA	NA
Glucose (mg/dL) †	89 (80–97)	87 (85–97)	0.478	91 ± 12.4	91.2 ± 15.6	0.612	0.733
Glycated hemoglobin, HbA1c (%)	5.26 ± 0.55	4.97 ± 0.41	0.017	5.10 ± 0.84	NA	NA	0.573
Total-cholesterol (mg/dL)	186 ± 45	164 ± 37	0.628	193 ± 38	197 ± 40	0.582	0.554
LDL-cholesterol (mg/dL)	111 (91–120)	108 (77–118)	0.919	107 (100–143)	109 (83–135)	0.748	0.638
HDL-cholesterol (mg/dL)	55 (46–67)	50 (40–65)	0.569	49 (56–64)	53 (65–74)	0.125	0.552
Triglycerides (mg/dL)	137 (115–152)	130 (108–160)	0.005	95 (65–155)	97 (70–121)	0.808	0.554

Data are presented as mean ± standard deviation or as median and interquartile range. † Values logarithmized prior to statistical comparison to achieve normality. NA: Not available or not applicable. § Comparison between baseline and follow-up values in the CDSS intervention group. ‡ Comparison between baseline and follow-up values in the dietary advice group. ∫ Comparison of baseline values between CDSS intervention and dietary advice group.

Body weight patterns identified using PCA analysis are shown in Table 3. More particularly, two distinct patterns were identified: a high BMI–high % body fat pattern explaining 60.4% of the total variance and a high BMI–high lean tissue pattern explaining 38.4% of the total variance. The total variance explained was as high as 98.9%. In Table 4, Spearman correlation coefficients are shown between the absolute % weight loss and several variables of body composition (raw data or body weight patterns), as well as several biochemical variables. In detail, lean mass, lean mass index and a high BMI–high

% body fat pattern were positively related to % weight loss in women. Baseline glucose levels were inversely related to % weight loss in women. In men, as well as in the total sample, baseline triglyceride levels were inversely related to % weight loss. Furthermore, multiple linear regression models were created to identify the factors that can independently "predict" weight loss (Table 5). As can be seen in the total sample, serum triglycerides were inversely associated with the magnitude of weight loss, irrespective of age, gender, physical activity at baseline and identified body weight patterns. In women, a pattern with high BMI and high lean tissue was consistently positively related to the % weight loss irrespectively of age, physical activity and triglyceride levels (Table 5).

Table 2. Differences pre- and post-CDSS intervention stratified by sex.

	Men (n = 28)			**Women (n = 11)**		
	Baseline	**Follow-Up**	***p*-Value**	**Baseline**	**Follow-Up**	***p*-Value**
Body weight (kg)	87.9 ± 14.9	83.3 ± 13.9	<0.001	114.6 ± 25.4	109.2 ± 21.4	<0.001
BMI (kg/m^2)	31.9 (28.3–36.2)	30.3 (26.7–34.6)	<0.001	36.2 (28.8–40.1)	35.1 (29.4–36.5)	0.021
Total body fat (%)	46.9 ± 9.8	43.7 ± 9.7	<0.001	39.9 ± 13.8	37.3 ± 11.5	<0.001
Lean tissue (kg)	22.4 (21.5–26.1)	23.5 (19.9–25.9)	0.167	35.4 (29.1–41.6)	32.8 (28.0–38.5)	0.109
Lean mass index (kg/m^2)	8.83 (8.03–9.22)	8.80 (7.64–9.16)	0.178	10.83 (9.92–11.67)	9.90 (9.30–11.76)	0.091
Glucose (mg/dL) †	89 (80–93)	87 (85–97)	0.010	75 (92–98)	88 (85–96)	0.220
Glycated hemoglobin, HbA1c (%)	5.25 ± 0.44	5.06 ± 0.46	0.151	5.31 ± 0.83	4.83 ± 0.29	0.077
Total-cholesterol (mg/dL)	182 ± 38	164 ± 39	<0.001	197 ± 61	164.2 ± 38.9	0.069
LDL-cholesterol (mg/dL)	111 (91–119)	109 (35–121)	0.237	109 (87–138)	107 (99–130)	0.109
HDL-cholesterol (mg/dL)	55 (45–67)	50 (40–52)	0.343	59 (45–68)	57 (41–65)	0.705
Triglycerides (mg/dL)	137 (110–144)	130 (108–138)	0.018	135 (116–189)	140 (107–194)	0.109

Data are presented as mean ± standard deviation or as median and interquartile range. † Values logarithmized prior to statistical comparison to achieve normality.

Table 3. Factor loadings using principal component analysis for the identification of body weight patterns in the CDSS intervention group.

	Pattern 1: High BMI–High % Body Fat	**Pattern 2: High BMI–High Lean Tissue**
BMI at baseline (kg/m^2)	**0.873**	**0.473**
Lean mass at baseline (kg)	0.014	**0.997**
Body fat at baseline (%)	**0.975**	−0.195
% variance explained	60.4%	38.4 %
Total variance explained 98.9%		

The factor loadings (component scores) are interpreted as correlation coefficients (r). Higher absolute values of the loadings indicate that the variable is correlated with the respective component. Numbers in bold indicate absolute loadings greater than 0.45.

Table 4. Spearman correlation coefficients between % weight loss and several variables in the CDSS intervention group for the total sample and separately for men and women.

		% Weight Loss (r)	
	Total (n = 39)	**Women (n = 11)**	**Men (n = 28)**
Age (y)	0.092 (p = 0.576)	0.050 (p = 0.884)	0.130 (p = 0.511)
BMI (kg/m^2)	0.292 (p = 0.072)	0.400 (p = 0.223)	0.222 (p = 0.256)
Body fat (%)	0.118 (p = 0.473)	0.127(p = 0.709)	0.191 (p = 0.332)
Lean mass (kg)	0.108 (p = 0.514)	0.618 (p = 0.043)	0.079 (p = 0.690)
Lean mass index (kg/m^2)	0.158 (p = 0.337)	0.618 (p = 0.043)	0.147 (p = 0.456)
High BMI–high % body fat pattern	0.164 (p = 0.318)	0.200 (p = 0.555)	0.185 (p = 0.346)
High BMI–high lean tissue pattern	0.166 (p = 0.313)	0.618 (p = 0.043)	0.149 (p = 0.450)
Glucose (mg/dL)	−0.270 (p = 0.128)	−0.714 (p = 0.047)	−0.154 (p = 0.462)
Glycated hemoglobin, HbA1c (%)	−0.145 (p = 0.428)	−0.143 (p = 0.736)	−0.139 (p = 0.518)
Total-cholesterol (mg/dL)	−0.150 (p = 0.377)	0.231 (p = 0.521)	−0.218 (p = 0.274)
HDL-cholesterol (mg/dL)	−0.026 (p = 0.877)	−0.588 (p = 0.074)	0.199 (p = 0.321)
Triglycerides (mg/dL)	−0.410 (p = 0.012)	−0.067 (p = 0.855)	−0.601 (p = 0.001)

Spearman correlation coefficients (r) are shown. p-value is shown in parenthesis. BMI: body mass index; HDL: high-density lipoprotein; y: years.

Table 5. Linear regression analysis with % weight loss after a CDSS intervention as dependent variable in the total sample, men and women.

	Total (n = 39)			Women (n = 11)			Men (n = 28)		
	B	SE	*p*	B	SE	*p*	B	SE	*p*
Basic Model (R^2 = 0.2%, W: 0%, M: 0.1%)									
Age (y)	0.005	0.041	0.903	0.004	0.086	0.967	0.006	0.047	0.908
Gender (men vs. women *)	0.320	1.208	0.792	NA	NA	NA	NA	NA	NA
Model 1 (R^2 = 1.1%, W: 18.6%, M: 2%)									
Age (y)	0.002	0.042	0.967	−0.009	0.083	0.913	0.007	0.049	0.888
Gender (men vs. women *)	0.228	10.232	0.854	NA	NA	NA	NA	NA	NA
Physical activity at baseline §	−0.393	0.724	0.591	−1.915	10.419	0.214	0.160	0.849	0.852
Model 2 (R^2 T: 13.5%, W: 83.6%, M: 4.6%)									
Age (y)	0.004	0.041	0.928	−0.069	0.049	0.207	0.023	0.053	0.665
Gender (men vs. women *)	2.757	1.804	0.136	NA	NA	NA	NA	NA	NA
Physical activity at baseline §	−0.017	0.785	0.983	−2.568	1.093	0.057	0.524	0.941	0.583
Pattern 1: High BMI–high% fat	0.282	0.628	0.657	−0.469	0.738	0.549	0.522	0.869	0.554
Pattern 2: High BMI–high lean tissue	1.611	0.803	0.050	3.353	0.692	0.003	0.769	1.167	0.517
Model 3 (R^2 T: 20.6%, W: 88.5%, M: 18.6%)									
Age (y)	−0.006	0.040	0.887	−0.040	0.044	0.424	0.003	0.054	0.949
Gender (men vs. women *)	2.579	1.734	0.147	NA	NA	NA	NA	NA	NA
Physical activity at baseline §	−0.290	0.762	0.706	−30.416	0.979	0.025	0.248	0.915	0.789
Pattern 1: High BMI–high % fat	0.128	0.610	0.835	−10.245	0.703	0.151	0.411	0.840	0.630
Pattern 2: High BMI–high lean tissue	10.307	0.818	0.121	20.415	0.717	0.028	0.727	10.123	0.524
Triglycerides (mg/dL)	−0.018	0.009	0.050	−0.005	0.009	0.618	−0.022	0.011	0.069

T: Total sample, M: Men, W: Women, NA: Not applicable; y = years, * Men = 1, Women = 0, § 1 = mildly active, 2 = moderately active, 3 = active, 4 = intensely active or athlete.

4. Discussion

The present study documented that a 3-month nutrition-oriented CDSS intervention during the COVID-19 period reduced body weight, body fat, glucose and lipid biomarkers, with borderline reductions in lean body mass. In multivariate linear regression models, serum triglycerides (total sample) were inversely associated to % weight loss, while a pattern characterized by high BMI/lean tissue (women) was positively related to % weight loss.

The importance of our findings lies in the fact that a hospital-based weight loss intervention during the COVID-19 epidemic was possible with the use of new technologies and evidence-based procedures, such as those ensured by the use of CDSS. Indeed, several programs based on tele-health and remote consultations were developed to assist patients with obesity during weight loss, especially during COVID-19 [15–17]. However, the present study firstly reports the use of a CDSS in a hospital setting for distance counseling in obesity. In parallel, electronic medical records have been useful so far to screen individuals for obesity [27] and CDSS-created alerts have been used to further refer patients to professionals for obesity management [28]. Several CDSS programs have been also created for childhood obesity prevention and treatment [29–31]. In parallel, through the use of CDSS, cost and time are reduced, and thus, more time can be dedicated to each patient [32]. However, as recently reviewed, many contemporary CDSS are still focused on alerts and reminders [33], and only ~24% of them include patient education features, dietary advice and other lifestyle recommendations [33]. It has been suggested that future CDSS should target screening, diagnosis and management of multiple chronic diseases and that user-friendly interfaces on top of alerts should be developed [33]. Hopefully, the Nutrinet® CDSS used in the present study fulfills the aforementioned aspirations. Indeed, it ensures the implementation of all the steps of the NCP including nutritional assessment, diagnosis, intervention, monitoring and evaluation [4,5]. It facilitates dietary assessment, physical activity assessment, formulation of personalized tailored dietary plans, provision of guidelines, definition of nutritional and physical activity goals and monitoring of nutritional and physical activity goals [4,5]. It thus aims at assisting nutritional care provision at all stages and is not only centered on alerts. Moreover, the Nutrinet® CDSS can be used by both the dietitian and the patient (after appropriate training), since it "allows" patients to visit their personal profile and record/track their personal progress, e.g., weight goals, physical activity goals, etc. [4,12]. The tracking feature of the present CDSS also enables a "continuous treatment model" approach, which is crucial to combat a chronic condition, such as obesity [34]. In parallel, the Nutrinet® CDSS endorses patient stimulation, a powerful mechanism for addressing health inequalities. The use of CDSS tools by patients themselves has shown promising results in a hospital-based intervention [35]. Similarly, an electronic nutritional assessment tool improved dietary habits, as well as motivation and self-efficiency, when used by patients [36]. A bi-directional communication of the patient and health provider can be achieved through the Nutrinet® CDSS, which is particularly important in the COVID-19 era [4].

In a wider perspective, new technology-assisted dietary assessment has been connected to higher acceptability, self-adherence and self-monitoring compared to paper records in persons with obesity [16,37–39] or type 2 diabetes [40,41]. In line with our results suggesting a decrease in body weight and body fat, website-assisted interventions combining nutrition intervention and dietary self-monitoring have shown higher rates of weight loss and body fat loss compared to standard treatment [37,38], although not all studies agree [42]. A borderline reduction of lean mass was observed in the present study. Of note, in sex-specific analysis, lean mass remained unchanged. This issue is important, since the loss of lean mass can lower resting metabolic rate, cause fatigue and increase injury risk [43,44]. Moreover, it can increase the risk of sarcopenia, which worsens quality of life and prognosis, especially in disease states [45]. It is possible that the Mediterranean diet pattern followed, along with enhancement of physical activity through the CDSS, minimized the risk of lean mass loss [46].

Reductions in HbA1c and triglycerides were also documented in the present work, underlying the importance of Mediterranean diet adherence in glycemia management [47], cardiovascular disease prevention [48], and the contribution of technology to the same direction [49]. Indeed, a diet rich in antioxidants, fiber and mono-unsaturated and unsaturated fatty acids and low in saturated fatty acids, as in the Mediterranean dietary pattern [50], exerts anti-inflammatory actions by targeting several mediators, such as the Platelet Activating Factor (PAF) [51,52] and can improve glycemia [53,54]. Several CDSS have been used for glucose management in a hospital setting and for cardiovascular disease prevention and management, as recently reviewed elsewhere [33,55]. However, the Nutrinet® CDSS was administered by a professional dietitian, while most CDSS were administered by medical doctors and nurses [55], even if they were directly related to food consumption, such as "MyFood" [35].

In addition, the identification of weight loss predictors may assist in ascertaining the probable outcomes of lifestyle interventions [56]. Paying attention to baseline subjects' characteristics affecting weight loss is thus important, and possibly population- and situation-specific. A recent review identified that several patient-related variables affect weight loss, such as male gender, older age, presence of cardiometabolic diseases and low fat intake [56]. Although sex-specific predictors of weight loss have been reported [57], in most studies, sex is only included as a covariate in models and sex-specific models are not applied [58], with some exceptions [59,60]. In the present study, sex-specific analysis was performed in both pre- and post-intervention results as well as in the models for prediction of weight loss. However, age and gender were not identified as predictors of % weight loss. A pattern characterized by increased BMI and lean mass was positively related to the extent of weight loss in women. In another study, pre-treatment fat mass was related to weight loss in males [59]. It is thus possible that high BMI is connected to high lean mass and increases energy expenditure, facilitating weight loss [61]. Serum triglycerides were inversely related to % weight loss in the total sample and men as a possible trend. This finding is in line with data suggesting that triglycerides changes have a positive relationship with weight change (r = 0.82) [62]. In addition, sex differences have been reported in the relationship of weight and lipoproteins [63], with triglyceride kinetics being affected mostly in men than women [64,65], which is in line with the trend observed in the present work.

In addition, the present study was conducted in the COVID-19 pandemic, which has been per se associated with weight changes. According to a recent meta-analysis, self-reported body weight increased in 11.1–72.4% of individuals and decreased in 7.2–51.4% of individuals [66]. Moreover, predictors of body weight may be different during COVID-19 compared to other periods, since emotional stress, telework and confinement took place [67]. For example, a study in Greek volunteers showed that sleep impairment was present during the lockdown, and it was related to changes in dietary and physical activity habits [68]. In addition, health issues affecting food intake and activity patterns following acute or long COVID-19 infection are not to be excluded.

A major limitation of the present study was the fact that several differences between the control and experimental group existed, including age and sex of the participants. This was partially due to the fact that during COVID-19 a low number of patients were treated in the out-patient clinic. It is also possible that the younger individuals in the intervention group were more used to technology and computer environment. Moreover, in the control group, several measurements, such as lean mass, were not available. The sample size and the duration of the study were relatively small. However, changes were documented in weight, body fat and biochemical measurements. In addition, biochemical exams were undertaken in several laboratories. However, all laboratories were licensed by state, which assures the accuracy of measurements. Regarding LDL-cholesterol, it was not measured but estimated, which may be related to differentiated cardiovascular risk at the individual level [69]. Regarding "predictors" of weight loss, several variables were not recorded, such as previous weight loss interventions, socio-economic history, marital status and motivation level.

5. Conclusions

In conclusion, a short-term CDSS-facilitated intervention beneficially affected weight loss and other cardiovascular risk factors, such as glucose and lipid indices. Further research is required in larger samples and with longer intervention periods and follow-ups to identify if the beneficial results persist over time. Moreover, several issues should be addressed in the future, such as the interoperability of health-related systems and the use of artificial intelligence or complex networks to optimize and tailor-cut nutritional advice.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/app13169448/s1, Supplementary Table S1: Diet plan for weight loss.

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