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Impact of Telemonitoring and Telehealth Coaching on the General Nutrition Knowledge in Overweight and Obese Individuals: A Pilot Study

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Abstract: (1) Background: General nutrition knowledge is a fundamental pillar of well-being and healthy lifestyles. The aim of this study was to investigate the effect of a weight loss intervention supported with telemonitoring and telehealth coaching, on improving the general nutrition in overweight and obese individuals. (2) Methods: A total of 30 participants have completed the trial at the 3-month visit, and a total of 25 have completed the trial at the 6-month visit. All participants have enrolled in a randomized controlled trial (RCT) and received a hypocaloric tailored diet and 3 online nutrition education sessions over a 6-month period. Participants were randomly divided into two groups, where the intervention group were supported with weekly telemonitoring and monthly telehealth coaching vs. a control group. The Arabic validated General Nutrition Knowledge Questionnaire (GNKQ) was used, which covered 4 sections; dietary recommendations; food groups and nutrient sources; healthy food choices; associations between diet–disease and weight (3) Results: Findings showed that both intervention and control groups have improvements in GNKQ scores over time, with the intervention group demonstrating significant increases in overall nutrition knowledge and specific areas such as the diet-disease relationship and weight management at 3 months. In addition, changes in GNKQ scores had a significant negative association with BMI and visceral fat percentage. The findings underline the benefits of supporting nutrition interventions with telemonitoring and telehealth coaching suggesting that increased nutrition knowledge may relate to lower body fat metrics. Still, small sample size and high attrition rate of participants were considered a significant limitation in the current study, where large populations is required to confirm reliability of the obtained findings.

Keywords: general nutritional knowledge; obesity; telenutrition; telemonitoring; telehealth coaching; online nutrition education

1.Introduction

Health and nutrition knowledge has been previously identified as a global goal for all populations to develop healthy food relationships [1]. Research has proven that nutrition knowledge plays a major role in following healthier eating habits [2,3]. The main concerns identified previously are difficulties in reading food labels and choosing the healthiest food product options due to a lack of knowledge [4]. Globally, nutrition programs and resources are available to be implemented in

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schools, which is seen in the UK, USA, India and Singapore [5]. Yet, In Saudi Arabia there is lack of learning resources and nutrition education programs to support schools in implementing nutrition education. Moreover, teachers have shown great interests and positive attitudes towards delivering nutrition education for students [6], but several obstacles have been identified by Saudi schools, which are a lack of awareness and training, cost coverage and resistance [7]. In a cross-sectional study, Saudi women showed low scores in nutrition knowledge, particularly in portion size and my plate guidelines [8]. It has also been revealed that obesity continues to present a major health burden worldwide [9]. Sedentary lifestyles and poor eating habits have been identified to be associated with behavior towards food and lack of knowledge [10]. The World Health Organization (WHO) has predicted that by 2030, almost 30% of death cases worldwide will be associated with "lifestyle diseases", where strategies that target population behavior, attitude and knowledge are essential [11]. Ensuring that the population is fully aware of nutrition and health information is essential to improve eating habits and attitudes towards nutrition and health [12]. Meanwhile, eating habits refer to conscious, collective and repetitive behaviors that lead people to select, consume and use certain foods or diets in response to social and cultural influences [13]. This dynamic interplay between nutrition knowledge and eating habits profoundly influences various health aspects, especially weight. For instance, a well-informed understanding of nutrition often leads to wiser food choices, ultimately impacting overall diet quality and nutrient intake. These informed choices, in turn, have far-reaching implications for preventing chronic diseases resulting from obesity and overweight, such as diabetes, cardiovascular conditions and certain cancers [14]. Several factors influence the general nutrition knowledge of the population, including sex, education background, obesity and lifestyle [15]. According to research, nutritional knowledge sources vary; these are not only medical sources but also internet content, family members or friends and TV, which may be misleading [16]. According to a previous study on the General Nutrition Knowledge in the Austrian Population, 41.4% of the general population have misclassified sugar as the nutrient with the most calories, while only 29% of them have correctly classified fat to be the nutrient with the most calories [17]. Intervention studies have confirmed that improving nutrition education has a stronger impact on weight loss among obese populations [18]. Thus, dietetic consultations play a major role in improving nutrition knowledge, but the effectiveness of these consultations has been seen to vary due to practice being focused on diet planning and nutrition assessment, with minimal time given for nutrition education [19]. Thus suggested developing new strategies that can be integrated to dietetic consultations such as continuous monitoring and health coaching [20]. Therefore, it is important to introduce newly developed strategies that may enable dietitians to identify their patients' needs and wishes in a personalized approach or so called "patient-centered approach", which results in an increase in awareness, knowledge and lifestyles changes [21].

Online nutrition education has recently been introduced as an alternative to in-person education, showing positive outcomes on obese and overweight patients in weight loss. A previous study has proved that digital nutrition education shows significant improvements in nutrition knowledge using the knowledge assessment questionnaire (KAQ). In that study, nutrition education was provided via a developed CD-ROMs and significant improvements in nutrition knowledge was seen on the total number of participants after the intervention ($p < 0.05$) [22]. A study carried in Peru on teachers showed that a telehealth intervention improved both the knowledge and BMI of participants [23]. Still, general nutrition knowledge needs to be improved worldwide [24,25]. Online nutrition education has shown to be effective and affordable in previous studies and has also shown positive outcomes in weight loss [26].

The alignment of both nutrition education and lifestyle health coaching is a new approach that has been investigated recently to have a strong impact on weight loss, which is worth investigating. A Previous Study have proved that long period of Digital health coaching and education had a significant impact on retaining participants in weight loss interventions for up to 24 months [27]. In consistent with our findings, participants from the intervention group have a lower attrition rate in comparison to the control group due to continuous health coaching and enforcement of the online education. The literature has confirmed the beneficial use of engagement strategies for digital

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education such as telemonitoring or so-called reminders and health coaching [28]. Interestingly combining telemonitoring and health coaching has been previously tested in overweight employees showing a significant long-term weight loss [29]. Still, lack of evidence is seen regarding the impact of combining telemonitoring and telehealth coaching on the general nutrition knowledge. Thus, the purpose of the present study is to investigate the effects of an integrative approach "weekly telemonitoring and monthly telehealth coaching" on the general nutrition knowledge in overweight and obese participants. In addition to examining the relationship between improvements in nutrition knowledge scores and various anthropometric measurements.

2. Materials and Methods

2.1. Study Population and Design

The current study is a 6-month pilot two-arm randomized controlled trial (RCT) carried out in Jeddah, Saudi Arabia, between January 2022 and August 2023. The study protocol was approved by the Research Ethics Committee (REC) at the Unit of Biomedical Ethics, Faculty of Medicine at King Abdulaziz University (HA-02-j-008). Thus, a detailed description of the study protocol has been published by same research group in the British Journal of Nutrition [30]. As mentioned in the protocol, inclusion criteria included obese or overweight participants based on the WHO Body Mass Index (BMI) criteria (a BMI of 25 or more is considered overweight and 30 or more is considered obese). Including, adults aged 20 to 50 years old from both genders. On the other hand, participants were excluded when they were not familiar with using online applications and/or had a history of chronic diseases such as diabetes or cardiovascular diseases, thyroid dysfunction, any other endocrine abnormality or/and were pregnant and lactating. In addition, those who joined weight loss programs or used medication for weight loss during the past 3 months were excluded. Participant recruitment took place via official online platforms of King Abdulaziz University and King Fahd Medical Research Center, Jeddah, Saudi Arabia. All recruited participants were invited to a screening visit for a medical assessment and a full anthropometric measurement. Measurements included systolic and diastolic blood pressure, weight, waist circumference, BMI and body fat percentage detected by the body composition analyzer. Eligible participants were randomly divided into two groups (Intervention and Control groups). Both groups have been provided with a hypocaloric diet and 3 nutrition education sessions via telenutrition (remotely). But the intervention group have been supported with weekly telemonitoring (total of 36 weeks of telemonitoring) and monthly telehealth coaching (Total of 6 sessions) by both registered dietitians (RDs) and integrative nutrition health coaches. Telemonitoring was conducted using what's app via smartphones, where health measures were collected weekly such as weight, weekly steps, and blood pressure. With regards to telehealth coaching, sessions were conducted via video conference Zoom platform. Sessions have included guidance and support to tackle different aspects of lifestyle to follow the dietary plan, which indirectly enforces awareness and general nutrition knowledge gained in the study. One participant was eligible to join the study, they were invited for 3 visits during the 6-month period of the trial: at baseline, after 3 months and after 6 months to measure the general nutrition knowledge and anthropometric measurements.

The sample size was obtained according to our study primary outcomes, which is weight loss and it has been published at the Clinical Nutrition ESPEN congress in Milan, 2024 [31]. Sample size was calculated on the basis on an intervention that implemented a similar strategy (telemonitoring and health coaching) and showed significant reductions in weight by a minimum of 35 participant to be able to achieve a significant difference between groups (3.7 kg (2.5 SD) in body weight. Calculations were based on 80% power with a 5% significance level and 25% dropout [29]. Indeed, our current study is a pilot study that has investigated a secondary outcome "the general nutrition knowledge" in overweight and obese participants. Thus, a total of 50 participants were enrolled in the study to ensure we have a representable sample considering possible attrition rate in both groups. Since the study is a pilot study, we recruited 10% to 30% of the calculated sample size [32]. So total number of enrolled participants were 50 but only 30 participants have completed the trial at the 3-

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month visit, and a total of 25 have completed the trial at the 6-month visit with variations in gender proportion in each group and in different time points (Table.1).

2.2. Nutrition Education

A total of 3 nutrition education sessions were delivered by both registered clinical dietitians (RDs) and integrative nutrition health coaches who took part in the study via a Zoom link. At the end of each time point visit (baseline visit, 3-month visit and 6-month visit), research assistants created a Zoom meeting and sent invitations to all participants to attend on the same day of the visit. Sessions were a total of 45min focusing on tips related to grocery shopping, healthy food choices, reading food labels, healthy eating by using the healthy plate and understanding the relationship between diet and disease. An additional 15 min was provided for all participants for discussions.

2.3. The Arabic General Nutrition Knowledge Questionnaire (GNKQ)

The general nutrition knowledge was measured using the published Arabic version of the revised General Nutrition Knowledge Questionnaire [12]. In the year 2020, the method was previously evaluated for the reliability and validity to be used specifically for adults, which is suitable to be used for adults and in different middle eastern Arab countries. The GNKQ contained 4 sections; (1) recommendations and portion sizes for the main food groups; (2) specific types of food and their salt, fat, protein, and sugar contents; (3) Healthy food choices; (4) Food quality and associations with increasing/decreasing risk of chronic diseases and weight management. The questionnaire consists of 88 items covered distributed among the in 4 sections, with 18 questions in first section, 36 in second section, 13 questions in third section and 21 for the last section. Questions are designed as multiple-choices questions with only one answer is required to answer.

3.3. Statistical Analysis

Data were analyzed using the SPSS program version 26.0. Continuous data are reported as the mean and SD. Between-group differences in baseline continuous characteristics were examined using an independent t-test. Baseline categorical variables are reported as frequencies and percentages (%) and were examined using the Chi-square test. The general nutrition knowledge (GNK) scores are presented as mean and SD. Repeated measures Friedman test was conducted on all time-point completers as the primary analysis. The within-subjects factor was time (baseline, 3 months and 6 months) with pairwise comparisons between the time points. The between-subjects factor was intervention group (intervention and control). Bonferroni correction was used to adjust p-values for pairwise comparisons. Secondary analysis was done on completers at any time-point to maximize utilization of data. The Wilcoxon signed-rank test was used to assess differences in GNKQ scores between baseline and subsequent time points (3 months and 6 months) within each group due to the non-normal distribution of the data. The Mann–Whitney U test was utilized to compare the median change in knowledge scores between the intervention and control groups at both 3 and 6 months. A series of regression analyses were conducted to investigate the relationship between changes in nutrition knowledge scores and various anthropometric measurements. The dependent variables included ranked changes in weight, BMI, fat percentage, muscle percentage, visceral fat percentage and waist circumference after 3 months of intervention. The independent variable was the ranked change in nutrition knowledge score after 3 months of intervention. A p-value of less than 0.05 was considered statistically significant.

3. Results

3.1. Characteristics of Participants at Baseline

A total of 30 participants (18 and 12 in the intervention and control arms, respectively) completed the 3-month visit, and a total of 25 participants (16 and 9 in the intervention and control arms,

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respectively) completed the 6-month visit. Both arms were balanced as the baseline characteristics of the participants were not significantly different between the two study groups, as shown in Table 1.

Table 1. Baseline characteristics for all participants (GNKQ completers).

	3-month completers				6-month completers			
	Intervention n= 18 (Mean ± SD)		Control n=12 (Mean ± SD)		Intervention n= 16 (Mean ± SD)		Control n=9 (Mean ± SD)	
	Male n= 6	Female n= 12	Male n= 7	Female n= 5	Male n= 5	Female n= 11	Male n= 6	Female n= 3
Age (years)	27 (6)	34 (13)	37 (8)	33 (11)	29 (6)	36 (13)	39 (9)	40 (9)
Weight (kg)	107 (26.8)	84.3 (14.4)	99.9 (26.2)	80.2 (8.8)	107 (27)	82.8 (15.3)	102 (24)	75.3 (4.1)
BMI (Kg/m^2)	34.3 (6.99)	33.3 (5.9)	34.2 (7.1)	33.6 (3.9)	34.3 (7)	32.5 (6.6)	34.2 (7)	31.9 (3.7)
Fat %	37 (7)	48.9 (5.6)	36.7 (7.4)	49.2 (5.7)	37 (7)	47.6 (6.5)	36.8 (7.4)	47.7 (6.5)
Muscle %	30 (3.7)	22 (2.3)	29.2 (3.4)	22 (2.8)	30 (4)	22.6 (2.7)	29 (3.1)	22.4 (3.4)
Visceral fat %	15.4 (4.6)	9 (4)	17 (6)	9 (2)	15 (5)	9 (4)	17 (6)	9 (3)
WC (CM)	112.1 (18.8)	90.7 (11.7)	113.7 (16.8)	90 (6.3)	112.1 (19)	89.8 (12)	114 (16.4)	88 (7.8)
Sys BP	126 (12.7)	135 (18)	132 (16)	133 (19)	126 (13)	130 (17)	130 (17)	135 (26)
Dias BP	80 (11.9)	78 (15)	86 (5)	92 (14)	80 (12)	75 (14)	84 (6)	92 (18)

3.2. Weight, BMI, and WC at All Time-Points for All Time-Point Completers

While the primary focus of this manuscript is on the general nutrition knowledge outcomes, a summary of the weight-related outcomes is provided in Table 2. Briefly, participants in the intervention group only showed significant reductions in weight, BMI, WC and fat % and a significant increase in muscle % at 3 months from baseline but not at 6 months. The effect of intervention on weight loss and anthropometric measurements was reported in the Clinical Nutrition ESPEN congress in Milan [31].

Table 2. Mean, SD and statistical significance for within and between-group differences in weight, BMI and WC at all time-points for all time-point completers.

	Baseline Mean (SD)	3 months Mean (SD)	6 months Mean (SD)	Within-group analysis Baseline vs. 3 months P-value	Within-group analysis Baseline vs. 6 months P-value	Between group analysis Intervention vs. control
Weight						
Intervention	91.5 (22.3)	87.3 (20.7)	88.5 (22.9)	0.015	0.227	0.620
Control	94.7 (23.9)	94.2 (25)	93.4 (24.5)	1	0.696	
BMI						
Intervention	33.6 (6.5)	32 (6.6)	32.4 (7.5)	0.012	0.253	0.624
Control	34.4 (5.7)	34.1 (6)	33.8 (5.7)	1	0.528	
WC						
Intervention	97 (18)	92 (16)	93 (16)	0.002	0.112	0.23
Control	106 (20)	103 (19)	101 (20)	0.081	0.217	
Fat%						
Intervention	44.7 (8.3)	41.6 (8.8)	43 (9.7)	0.004	0.199	0.634
Control	41.9 (8)	40.8 (8.2)	41.2 (7.9)	0.27	1	

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Muscle%						
Intervention	25 (5)	26.9 (5.3)	25.5 (6.5)	0.016	1	0.805
Control	26 (4.1)	26.7 (4.6)	26.5 (4.2)	0.212	0.662	
Visceral fat%						
Intervention	11.4 (4.7)	10.3 (4.2)	10.5 (4.5)	0.071	0.181	0.11
Control	14.8 (6.2)	14.8 (6.4)	14.4 (6.3)	1	0.239	

Data is expressed as mean (SD) for DASS-21 scores for completers of the study (n=15) in the intervention and (n=8) in the control group. P-values were obtained through repeated measures analysis of variance (ANOVA) with pairwise comparisons between the time points. Bonferroni correction was used to adjust p-values for pairwise comparisons.

3.3. General Nutrition Knowledge Scores

3.3.1. GNKQ Scores at All Time-Points for All Time-Point Completers

Overall, the GNKQ results showed modest improvements in both the intervention and control groups over time with no significant between-group differences in the change from baseline at 3 months or 6 months. In the intervention group, scores generally increased from baseline to 3 and 6 months, particularly in overall nutrition knowledge and the diet-disease relationship and weight management sections ($p < 0.05$ for the overall effect of time for both, table 3), with a near-significant within-group difference in at 3 months only when compared with baseline ($p = 0.055$ and 0.098 respectively; table 3) and no significant differences at 6 months. In the control group, GNKQ scores did not significantly change at 3 months nor at 6 months post intervention.

Table 3. Mean, SD and statistical significance for within and between-group differences in GNKQ scores within each study group (intervention and control) as well as for all participants combined at all time-points for all time-point completers.

GNKQ sections	Baseline	3 months	6 months	Difference at 3 months from baseline	Difference at 6 months from baseline	Within-group analysis Baseline vs. 3 months P-value	Within-group analysis Baseline vs. 6 months P-value	Overall time effect	Between group P-value Intervention vs. control at 3 months	Between group P-value Intervention vs. control at 6 months
Dietary recommendations										
Intervention	8.73 (2.89)	9.33 (2.72)	9.4 (2.75)	0.6 (2.1)	0.67 (4.03)	NP	NP	0.133	0.506	0.728
Control	9.63 (3.29)	10.87 (2.17)	10.5 (1.41)	1.25 (2.82)	0.88 (2.9)	NP	NP	0.497		
Combined groups	9.04 (2.99)	9.87 (2.6)	9.78 (2.39)	0.83 (2.33)	0.74 (3.61)	NP	NP	0.12		
Food groups										
Intervention	21.5 (6.8)	21.9 (7.5)	21.9 (8.2)	0.33 (2.06)	0.33 (3.7)	NP	NP	0.942	0.265	0.591
Control	21.5 (4.4)	23.3 (2.7)	22.3 (3.2)	1.75 (3.11)	0.75 (4.71)	NP	NP	0.629		
Combined groups	21.5 (5.99)	22.4 (6.2)	22 (8.8)	0.83 (2.5)	0.48 (3.98)	NP	NP	0.846		
Healthy food choices										
Intervention	5.67 (2.09)	5.8 (1.97)	6.13 (2.17)	0.13 (1.64)	0.47 (1.85)	NP	NP	0.365	0.728	0.428
Control	5.75 (0.89)	5.5 (1.31)	5.75 (1.28)	-0.25 (1.04)	0 (1.31)	NP	NP	0.961		
Combined groups	5.7 (1.74)	5.7 (1.74)	6 (1.88)	0 (1.45)	0.3 (1.66)	NP	NP	0.5		
Diet–disease relationship and weight management										
Intervention	13.7 (4.8)	15.5 (3.4)	15.3 (4.5)	1.8 (2.18)	1.53 (2.39)	0.107	0.134	**0.034***	0.265	0.169
Control	13.9 (1.5)	14.4 (2.6)	13.4 (4.2)	0.5 (2.78)	-0.5 (3.51)	NP	NP	0.725		
Combined groups	13.8 (1.46)	15.1 (3.11)	14.6 (4.4)	1.35 (2.42)	0.83 (2.92)	0.098 [a]	0.196	**0.042***		
Overall nutrition knowledge										
Intervention	51.2 (15.8)	53.9 (14.4)	54.2 (15.7)	2.67 (5.42)	3 (8.72)	0.053 [a]	0.134	**0.034***	0.975	0.466
Control	51.9 (8.4)	55.6 (5.8)	53.3 (8)	3.75 (6.34)	1.38 (6.91)	NP	NP	0.177		
Combined groups	51.4 (13.5)	54.5 (5.8)	53.9 (13.3)	3.04 (5.64)	2.43 (8.01)	0.055 [a]	0.314	**0.048***		

Data is expressed as mean (SD) for GNKQ scores for completers of the study (n=15) in the intervention and (n=8) in the control group. P-values were obtained through Friedman test with pairwise comparisons between the

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time points. Bonferroni correction was used to adjust p-values for pairwise comparisons. NP, multiple comparisons are not performed as the overall effect of time was not significant. Significant P-values are bold (P-values: [a] P > 0·05 and * P < 0·05).

3.3.2. GNKQ Scores for All Time-Points for Any Time-Point Completers

Changes in GNKQ scores from baseline to 3 and 6 months across different sections for the intervention and control groups, and all participants combined who completed assessments at any time point (n=30 at 3 months; n=25 at 6 months) are described in Table 4. Significant improvements in GNKQ scores were observed in certain areas and time points across the study groups. At 3 months, significant increases were noted in the combined groups for dietary recommendations (P = 0.035), food groups (P = 0.027), diet–disease relationship and weight management (P = 0.014), and overall nutrition knowledge (P = 0.003). Additionally, at this timepoint, the intervention group showed a significant improvement in the diet–disease relationship and weight management nutrition knowledge (P = 0.007), while the control group demonstrated a significant increase in food groups (P = 0.028) and overall nutrition knowledge (P = 0.019). At 6 months, significant improvements in nutrition knowledge were limited to the diet–disease relationship and weight management section for the intervention group (P = 0.026), with a near-significant trend in the combined groups (P = 0.055) (Table 4).

The change in knowledge scores between the pre-intervention and post-intervention periods was analyzed using the Mann–Whitney U test to compare the effectiveness of the intervention and control groups. There was no significant difference in the change in knowledge scores between the intervention and control groups at both 3 months and 6 months (data not shown).

Table 4. Changes in GNKQ scores from baseline to 3 and 6 months across different sections for the intervention and control groups, and all participants combined who completed assessments at any time point.

GNKQ section	Time point comparison	Groups	n	GNKQ score		P-Value for Change
				Baseline GNKQ Score Mean (SD)	Post-Time Point GNKQ Score Mean (SD)	
Dietary Recommendations	3-Month Comparison	Intervention	18	8.5 (2.8)	9.4 (2.6)	0.131
		Control	12	9.8 (2.9)	10.9 (2)	0.124
		Combined groups	30	9 (2.8)	10 (2.5)	**0.035***
	6-Month Comparison	Intervention	16	9 (3)	9.4 (2.7)	0.173
		Control	9	9.2 (3.3)	10.2 (1.6)	0.339
		Combined groups	25	9.1 (3)	9.7 (2.3)	0.103
Food Groups	3-Month Comparison	Intervention	18	20.3 (7.5)	21.2 (7.2)	0.31
		Control	12	21.8 (3.6)	23.7 (2.3)	**0.028***
		Combined groups	30	20.9 (6.2)	22.2 (5.8)	**0.027***
	6-Month Comparison	Intervention	16	21.6 (6.6)	21.8 (7.9)	0.68
		Control	9	19.9 (6.4)	21.3 (4)	0.674
		Combined groups	25	21 (6.4)	21.6 (6.7)	0.59
Healthy Food Choices	3-Month Comparison	Intervention	18	5.5 (2)	5.8 (1.9)	0.47
		Control	12	5.7 (1.3)	6.2 (1.7)	0.286
		Combined groups	30	5.6 (1.7)	6 (1.8)	0.208
	6-Month Comparison	Intervention	16	5.6 (2)	6.1 (2.1)	0.161
		Control	9	5.1 (2.1)	5.2 (2)	0.792
		Combined groups	25	5.4 (2)	5.8 (2.1)	0.18
Diet–Disease Relationship and Weight Management	3-Month Comparison	Intervention	18	13.2 (4.6)	14.8 (3.5)	**0.007****
		Control	12	14.6 (2.4)	14.9 (2.6)	0.558
		Combined groups	30	13.8 (3.8)	14.9 (3.1)	**0.014***
	6-Month Comparison	Intervention	16	13.8 (4.7)	15.3 (4.3)	**0.026***
		Control	9	13.1 (2.7)	13.3 (3.9)	0.723
		Combined groups	25	13.6 (4)	14.6 (4.2)	0.055

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Overall Nutrition Knowledge	3-Month Comparison	Intervention	18	48.8 (16)	52.4 (13.5)	**0.055**[a]
		Control	12	53 (7.6)	57.5 (6.1)	**0.019***
		Combined groups	30	50.5 (13.3)	54.5 (11.3)	**0.003****
	6-Month Comparison	Intervention	16	51.6 (15.4)	54.2 (15.1)	0.103
		Control	9	48.3 (13.2)	51.3 (9.5)	0.475
		Combined groups	25	50.4 (14.4)	53.2 (13.2)	0.071

Data are expressed as mean (SD) for GNKQ scores. Significant differences between baseline and subsequent time points (3 months and 6 months) in GNKQ score within each group was obtained using Wilcoxon paired test and are shown in bold (P-values: [a] P > 0·05, * P < 0·05 and ** P < 0·01).

3.4. The Relationship Between Changes in Nutrition Knowledge Scores and Various Anthropometric Measurements

The current analysis aimed to identify the relationship between changes in nutrition knowledge scores and various anthropometric measurements. There was no significant association between the change in nutrition knowledge scores and changes in weight, muscle percentage or waist circumference after 3 months of intervention. However, a significant negative association was observed between changes in nutrition knowledge scores and both BMI (β = -0.746, SE = 0.320, 95% CI [-1.405, -0.087], r = 0.415, P = 0.028; Table 3) and visceral fat percentage (β = -0.839, SE = 0.245, 95% CI [-1.344, -0.333], r = 0.573, P = 0.002; Table 3). Additionally, there was a marginally significant trend indicating that increased nutrition knowledge might be associated with a reduction in fat percentage (β = -0.620, SE = 0.331, 95% CI [-1.301, 0.061], r = 0.345, P = 0.073; Table 3 [SE1]).

Table 5. Regression analyses examining the relationship between changes in GNKQ scores and anthropometric measurements after 3 months of intervention.

Variable	β	SE	95% CI	r	P-value
Change in Weight	-0.263	0.19	[-0.653, 0.127]	0.263	0.177
Change in BMI	-0.746	0.32	[-1.405, -0.087]	0.415	**0.028***
Change in Fat %	-0.62	0.331	[-1.301, 0.061]	0.345	0.073[a]
Change in Muscle %	0.509	0.316	[-0.143, 1.160]	0.312	0.12
Change in Visceral Fat	-0.839	0.245	[-1.344, -0.333]	0.573	**0.002****
Change in WC	-0.476	0.336	[-1.166, 0.215]	0.268	0.169

Dependent variables include ranked changes in weight, BMI, fat percentage, muscle percentage, visceral fat percentage, and waist circumference. The independent variable is the ranked change in Overall Nutrition Knowledge score. Regression coefficients (β), standard errors (SE), 95% confidence intervals (CI), correlation coefficients (r), and P-values are reported. (P-values: [a] P > 0·05, * P < 0·05 and ** P < 0·01).

4. Discussion

The present study aimed to examine general nutrition knowledge using the validated Arabic General Nutrition Knowledge Questionnaire GNKQ [12] in all participants who participated in the telenutrition randomized controlled trial. The results have shown a significant increase in the GNKQ scores in different sections of the questionnaires when compared to the baseline visit (Table 2). The overall nutrition knowledge score at the 3-month visit increased significantly, from 50.5 (13.3) to 54.5 (11.3) (p = 0.003; Table 2). Consistent with our study, a cross-sectional study was conducted on nursing students living in the UAE to assess their general nutrition knowledge using the GNKQ. The results revealed that the overall nutrition knowledge score was 53.86 (19.44), which is very similar to the overall nutrition knowledge of our participants after receiving the nutrition education sessions [33]. This means that our participants successfully gained a similar level of nutrition-related information to students specialized in health care. Our findings were also consistent with a study that was carried out on students living in both the UAE University and Hashemite University in Jordan. Students with a nutrition background had higher scores of GNKQ 66·0 (10·6), whereas those without a nutrition background had low scores (38·0 (10·7), P < 0·001; d = 2·6) [12]. To compare the study's participants with university students living in the UK, the overall nutrition knowledge score among

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UK students was 64·0; this was similar the previous study, confirming that a nutrition background improves general nutrition knowledge significantly [34]. It should be taken into account that the characteristics of populations are different, and it is expected that university students with a nutrition background will have a higher nutrition knowledge level in comparison with Saudi participants There are several factors that may have influenced the variations in participant characteristics, including age, gender and nutrition literacy, which were not studied in the present study [35]. GNKQ was investigated among young men without tertiary education, where they had the lowest GNKQ scores [36]. Nutrition knowledge has also been examined via different tools among the Saudi population, and there is still a lack of knowledge and awareness regarding the correct identification of portion size and my plate guidelines [8]. As mentioned earlier, nutrition education is still not implemented in Saudi schools [6] due to a lack of awareness and the required training [7]. Thus, it is essential to highlight the importance of nutrition education and its impact on consumers' behavior and healthy eating patterns. The current study proved that education sessions focused on food choices, food labels and healthy eating nutrition education sessions have an impact in increasing general nutrition knowledge scores.

In the current study, data were also analyzed in each of the study arms, where significant improvements were seen in different sections of the questionnaire (Table 3). The results taken from both groups showed that significant improvements at 3 months (median increase from 54 to 56, $p = 0.055$; Table 2) and in the control group (median increase from 53 to 57, $p = 0.019$; Table 2). By the end of the intervention, the median scores reached 58.9 (meaning that 67% of the 88 questions had been answered correctly). Thus, the initial trend toward higher scores in the intervention group at 3 months may reflect early effects of the intervention. However, the lack of significant differences at 6 months suggests that the improvements may not have been sustained, possibly due to diminishing engagement with the intervention or other external factors. Interestingly, at the 3-month follow-up, participants in the control group who received telenutrition and nutrition education still showed significant improvements in "overall nutrition knowledge" and "food groups knowledge" compared to their scores before joining the program. This may have happened due to online nutrition education sessions which were provided for both the control and the intervention group. On the other hand, participants in the intervention group who were supported with weekly telemonitoring, and monthly health coaching showed a significant improvement in "diet–disease and weight management knowledge" at the 3- and 6-month follow-ups. All participants in both the intervention and control groups received the same three nutrition education sessions which explains the improvements in overall nutrition knowledge in both groups. This might explain the increase in overall nutrition knowledge and food groups knowledge among the control group participants as well; participants who were only receiving their nutrition information from these education sessions might have mostly relied on them as a primary source of health-related information and might have therefore been more committed to comprehending and utilizing the learnt information. Furthermore, participants in the intervention group who had access to personalized health coaching had an additional channel for acquiring health-related information, which might explain the increase seen in diet–disease relationship and weight management knowledge among these participants over the entire 6-month period. On the contrary, a study carried among Chinese university students showed 60% correct answers for the GNKQ, but improvements were still needed regarding their understanding of the relationship between diet and disease [37]. While previous work has shown that health coaching can contribute to improving chronic diseases, including reducing cardiovascular disease risk and hemoglobin A1c and normalizing blood pressure [38–40]. our study was the first to establish the effect of health coaching alongside telenutrition and telemonitoring on increasing diet–disease relationship and weight management knowledge among individuals with overweight/obesity over a longer period of six months. This finding is in line with previous reports that health coaching improved diabetes knowledge among individuals with diabetes [41]. This also proves that online nutrition education may be an effective tool to enhance the overall nutrition knowledge among a population, and one that is believed to be accessible and convenient [42]. A randomized controlled trial among students mentioned that using a game-based e-program in nutrition knowledge was

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interesting and easy to understand [43]. However, digital programs can also reach populations with low income and those living in distanced areas [44]. There is a clear shift in health care services towards adopting Telehealth, which has been introduced in the past years due to the widespread of coronavirus globally. In fact, hospitals all around the world have provided an opportunity for health professionals to practice telehealth in nutrition care process, which is also called telenutrition, where positive outcomes have been revealed [45]. In the Arab world, a cross-sectional study have revealed that dietitians are now adopting alternative telenutrition approaches through social/mass media [46]

There is still a lack of studies that have investigated effectiveness of telemonitoring and health coaching in improving nutrition education among different populations. Thus, our study is a pilot trial that have used an Arabic version of the GNKQ for the first time to investigate the impact of telemonitoring and health coaching on improving nutrition education. A study protocol was recently published on Coaching and/or education intervention for obese parents with their children, but research is still ongoing [47]. Like our study design and findings, The Smarter Pregnancy mHealth coaching program have been seen to improve women lifestyle and nutrition education via mobile health coaching [48]. In addition The Healthy Supermarket Coach program have shown that health coaching and nutrition peer education in supermarkets improves nutrition knowledge and attitudes toward healthy eating patterns [49]. Health coaching has been evident to have an impact on lifestyle and behavior changes, but little was conducted to assess nutrition knowledge. Thus, our study is considered the first study that have explored how continuous guidance via weekly telemonitoring and monthly telehealth coaching to increase awareness and nutrition knowledge.

A significant correlation between nutrition knowledge scores and various anthropometric measurements was revealed at the 3-month visit, such as improving the BMI and visceral fat percentage. Despite this, nutrition knowledge has been proven to have an impact on food choices and eating behavior. A study confirmed that dancers with eating disorders have lower nutritional knowledge, which has an impact on body weight and BMI [50]. Greater reductions in BMI and visceral fat might have been driven by behavioral changes rather than increases in knowledge due to the integration of both telemonitoring and health coaching among the intervention group. The intervention group showed only a trend towards significant improvement in overall nutrition knowledge ($p = 0.055$), yet experienced significantly greater reductions in weight, BMI and fat percentage. These findings suggest that while improvements in nutrition knowledge may not significantly influence weight, muscle percentage or waist circumference, they are likely to contribute to reductions in BMI and visceral fat percentage, with a potential effect on overall fat percentage**.** This suggests that the telemonitoring intervention may have directly influenced behavior changes (e.g., improved diet or physical activity) leading to weight loss without necessarily requiring a significant boost in overall nutrition knowledge. In this case, telemonitoring might have encouraged behavioral compliance through regular feedback, monitoring and personalized support, which could be more effective in short-term weight management than pure knowledge gains. The control group, on the other hand, showed significant improvements in nutrition knowledge but did not experience as much weight reduction. This may be because increased knowledge might not have translated into practical, sustained behavior changes as effectively as telemonitoring. Knowledge alone is not enough to drive behavioral changes, especially if it lacks direct and continuous support, which can be offered by telemonitoring. It would be fair to say that the special feature of the present study is that it is a multiple-component program, which enabled us to assess the effects of online nutrition sessions, telemonitoring and health coaching on nutrition knowledge and anthropometric measurements. However, this study was implemented on a small number of participants due to dropouts and questionnaire non-completers. Taking in consideration that the current study is a pilot study, the sample size was small which is considered one of the main limitations and this suggests the importance of implementing the study on a larger population for more reliable results.

5. Conclusions

The current study is a pilot study that examined the effects on supporting dietary weight loss programs with weekly telemonitoring and monthly telehealth coaching on the general nutrition

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knowledge, using the Arabic validated GNKQ in an RCT design. To sum up findings demonstrate Improvements in Nutrition Knowledge in all participants that have enrolled to the intervention over time, with the intervention group demonstrating significant increases in overall nutrition knowledge and specific areas such as the diet-disease relationship and weight management at 3 months ($p < 0.05$), but no significant differences between groups at either 3 or 6 months. In addition to Significant association with Anthropometric Measurements, which propose that an increase in nutrition knowledge may be related to weight loss. Still, more investigations are required to assess how telemonitoring and health coaching can be utilized to improve nutritional knowledge as part of programs aiming to improve chronic diseases such as obesity through modifying knowledge and behaviors. Although previous work showed that online health coaching is as effective as in-person health coaching in weight reduction [51], the influence of health coaching modality on health and nutrition knowledge needs to be further established. Furthermore, it is unknown whether participants' readiness to change at the start of the program influences the effectiveness of health coaching in improving health and nutrition knowledge. Future intervention studies that incorporate qualitative data analysis are needed to further understand the strengths and limitations of telemonitoring and health coaching in improving knowledge and translating acquired health and nutrition information into action and behavior change from the participants' perspective.

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