Title	Theoretical examination of behavioral feedback in the application of teledietetics to weight reduction
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Theoretical examination of behavioural feedback in the application of teledietetics on weight reduction

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Abstract

Introduction: Behavioural feedback can be attained through electronic self-monitoring with teledietetics. This study examined the theoretical framework of the theory of planned behaviour, which suggests that behavioural feedback contributes to the intention to initiate and maintain weight loss.

Methods: A quasi-experiment involving adults aged 20–50 years with a body mass index greater than 23 kg/m^2 was conducted. The experimental group (EG) comprised 25 participants who used electronic dietary records for self-monitoring. The control group (CG) comprised 25 participants who used paper-format dietary records for self-monitoring. Data pertaining to the theory of planned behaviour were obtained using a self-administered questionnaire. After an initial measurement, each participant's body weight was measured again at Week 12 and at Week 24, following a 12-week observation period. Hierarchical regression analyses of planned behaviour components were conducted for each power to predict the participants' intentions to lose 10% of their body weight. Logistic regression analysis was performed to investigate the odds ratio of intention, perceived behavioural control (PBC), and the group effect (CG vs. EG) for predicting the initiation and maintenance of 10% weight loss.

Results: At Week 12, the odds ratios for intention, the PBC, and the group effect were 2.154, 0.330, and 0.654, respectively, and those at Week 24 were 3.255, 0.499, and 24.592, respectively. The group effect contributed significantly to weight-loss maintenance at Week 24.

Discussion: Behavioural feedback through electronic self-monitoring improved the intention to achieve weight-loss maintenance, which may indicate the importance of behaviour reflection in weight-loss maintenance.

Keywords: behavioural feedback, self-monitoring, weight loss maintenance, the theory of planned behaviour (TPB), electronic dietary records

Introduction

Both initial and sustained weight loss are challenging, and people commonly lose a certain amount of body weight before reaching a plateau.[1] Although many treatments have exhibited high efficacy in facilitating weight loss, the rates of weight regain are high.[2-4] Scholars have explained how continued weight loss influences the body's lean mass, reducing its energy expenditure and triggering hormone mechanisms that alter appetite. This process consists of a sequence of physiological alterations that promote adverse behaviour in weight loss maintenance.[5-8] Sciamanna [9] suggested that people who achieve initial weight loss and those who consistently maintain weight loss exhibit different clusters of behaviour. People who engage in consistent physical activity or who choose low-fat protein were more likely to achieve weight loss maintenance but not necessarily weight loss. On the contrary, people who participate in a variety of exercises or earlier planning of meals were more likely to achieve weight loss but not weight loss maintenance. Therefore, the key component to maintaining weight loss is the establishment of self-management, which transforms weight maintenance into autonomic and habitual behaviour.[8]

Electronic self-monitoring has been applied to improve the consistency of dietary changes made during the weight loss process. [10-12] The benefits of such monitoring outweigh the inconvenience of using paper-based self-monitoring because an electronic dietary recording system could be easily accessed by the users with mobile devices or handheld tablet computers. With the current highly connected infrastructure of wireless technology, users can record their diet using their smartphones, which are directly connected to the web-based system. The input of dietary records can occur from anywhere and at anytime. It is more common for people to bring smartphones and tablets with them than to bring a pen and pencil during daily activities; a web-based dietary recording system thus fosters higher accessibility for users. In addition, various forms of support can be tailored to reinforce the motivation required to achieve changes in eating behaviour and to provide the user with

instantaneous, individual feedback. Such electronic self-monitoring and feedback facilitate transforming temporary eating behaviour into permanent eating habits. [13] Chung, Law, Fong et al.[14] defined individual feedback as behavioural feedback. This refers to an individual's previous eating behaviour as recorded and evaluated by experts as well as feedback to the individual that can inform them to adjust their present eating behaviour according to the provided feedback. Behavioural feedback enables people to establish an adaptive cycle of eating behaviour by adjusting their eating behaviour progressively, thereby reducing the difficulty of adopting healthy food choices and proper portion sizes in a short period of time. Eating habits are not modified through counselling sessions or seminar-led nutrition education[15,16]; instead, people must correct their behaviour based on repeated trial and error.

Applications of electronic dietary monitoring in teledietetics are migrating from the stage of clinical trials to community practices due to the benefits of its convenience and cost-effectiveness in weight reduction maintenance.[17] However, the innovative application of teledietetics still lacks theoretical support; therefore, this study aimed to examine the evidence of behavioural feedback in weight loss and weight loss maintenance by applying teledietetics.

Theoretical Framework

The theory of planned behaviour (TPB) is commonly employed to explain and predict human health behaviour. [18,19] Its central principle addresses the intention of a person to engage in a particular behaviour and suggests that several salient beliefs be treated as determinants of this intention. Attitude, subjective feelings regarding social norms, and perceived behavioural control (PBC) are the three immediate beliefs that facilitate or hinder the attainment of behaviour. The TPB has provided extensive explanations of beliefs in behavioural outcome evaluations and other behaviour-influencing beliefs. In addition,

understanding the normative beliefs and motivation to comply of people who experience the perceived social pressure to perform a target behaviour is valuable. Finally, control beliefs and perceived barriers can be attributed to the extent to which people perceive themselves as being able to perform a behaviour easily.

Although the TPB has been applied extensively to health behaviour topics such as human immunodeficiency virus protection, human papillomavirus vaccination, smoking cessation, and fruit and vegetable consumption,[20-24] its use in explaining weight loss and weight loss maintenance has been limited.[25-28] To assess the applicability of the TPB in measuring the intention to lose weight, this study evaluated whether the aforementioned three salient beliefs (attitude, subjective norms, and PBC) explain weight loss behaviour. In addition, this study examined the role of PBC in relation to weight loss and weight loss maintenance. In response to the rising trend of electronic self-monitoring applications, instant-learning objects such as online reports could be built in such applications. Gradually, this learning process enabled the participants to change their eating habits. The feedback from previous reports initiated reflective learning among the participants that they then applied every time they decided what and how much to eat.[29] The study here proposes that behavioural feedback is integral to the electronic platform compared with conventional paper and pen recording processes and can provide users with higher intention to engage in and maintain weight loss.

Method

This study was part of a quasi-experiment conducted between January 2013 and February 2014. Another study describing cost-effectiveness and weight loss effect was published previously.[17] The focus of this study was to examine how behavioural feedback explained the variance in weight loss and weight loss maintenance.

Sampling

Adults aged 20–50 years with a body mass index greater than 23 kg/m^2 were recruited using a convenience sampling method through a community health centre and a community dietetics clinic in Hong Kong. The participants were required to live in Hong Kong, be literate in Chinese, and be able to use the Internet. Participants with mental illnesses that might hinder their dietary input or the comprehensibility of their reports were excluded. Fifty adults meeting the inclusion criteria were recruited. The 25 participants recruited through the community health centre were assigned to the experimental group (EG) and used electronic dietary records to self-monitor their progress. The 25 participants recruited through the dietetic clinic were assigned to the control group (CG) and employed paper-format dietary records to self-monitor their progress.

Intervention

The participants in both groups engaged in a 12-week weight-reduction programme that included dietary counselling, nutritional education, and dietary recording. The participants were asked to review the dieticians' advice and then modify their food choices or portion sizes to meet the energy requirements according with the principles of a balanced diet. This self-monitoring was crucial for the participants' ability to work towards their weight-reduction goals. The participants in the EG input their daily dietary records using a web-based system that generated calorie and nutrient reports tailored to each participant. The reports were considered "tailored" because the participants' physical parameters were input into the system. Furthermore, the participants input their daily activity level each time they recorded their diet in the system. The energy reports indicated the daily energy requirements and the actual intake of energy from food. The participants received daily nutrient reports, listing the energy and nutrient details of each food item; these reports helped educate the participants about high-energy and low-nutrient food items.

The participants in the CG recorded their diet on paper on a log sheet and then emailed the log sheet to a research assistant who was directed to seek comments from dieticians. Dieticians reviewed the participants' dietary records and provided written feedback on the log sheet; then, they emailed their comments to the research assistant, who then sent back the comments to the participants by e-mail on a weekly basis. The participants adjusted their food choices or portion sizes based on the professional feedback. The difference between the EG and CG was that the EG received behavioural feedback generated by the electronic dietary recording system, whereas the CG did not (Figure 1).

Measurements

Demographic data and TPB components were measured using self-administered questionnaires. All participants in both groups completed the same paper questionnaire before the study. The TPB components were the intention to lose weight, attitude, PBC, subjective norms, and behaviour. The statements measuring the participants' intention, attitude, PBC, and subjective norms were adopted from Povey, Conner, Sparks, et al. [30], whose evaluation of the application of the TPB to healthy eating exhibits similarities to the use of the TPB in this study. The TPB measure is composed of different subscales, so internal consistency of the items in each subscale was evaluated separately. This ensured that all items in the subscales reflected the same attributes or homogeneity.

Behaviour

Body height and weight were measured using a standing scale. Body height was measured to the nearest 1 cm. Body weight was measured to the nearest 0.1 kg. Each participant's body weight was measured at baseline (Week 0), after the weight loss programme (Week 12), and after the 12-week observation period (Week 24). During the observation period, no dietary record was conducted by any participant and thus no feedback

was given to them. The observation period would be a follow-up to investigate whether the participants continued their dietary control with their reflective learning gained from previous 12 weeks' feedback. The participants' weight loss percentages were calculated at Weeks 12 and 24, and the baseline measurements were used as a reference. Two measures of behaviour were obtained. They were 10% weight loss and maintained 10% weight loss. The participants who achieved 10% weight loss by Week 12 were coded "1", and those who did not were coded "0"; code "1" represented success. The same coding and interpretation were applied at Week 24. In the context of this study, 10% weight loss in relation to the initial body weight may not be sufficient to regard a patient as having re-established a normal body size. However, 10% weight loss has been evidenced to produce substantial improvements in health, such as reductions in the risk of cardiovascular diseases and diabetes.[2,31]

Attitude

The participants' attitudes towards reducing their body weight were measured using a 5-point semantic differential scale that measured the response to the prompt "attitude towards weight reduction." The scales were anchored with the statements "extremely harmful" to "extremely beneficial," "extremely foolish" to "extremely wise," "extremely bad" to extremely good," "extremely unenjoyable" to "extremely enjoyable," and "extremely unpleasant" to "extremely pleasant," each ranging from a score of -2 to a score of +2, respectively. The overall measure of attitude was calculated by computing the mean of the responses to the five statements. Cronbach's alpha for the five statements was 0.880.

Subjective Norms

Subjective norms were measured using four statements ranked on 5-point scales. The four statements were "People who are important to me think I should lose weight," "People who are important to me would approve/disapprove of me losing weight," "People who are

important to me want me to lose weight," and "I feel social pressure to lose weight." The responses were provided on a fully labelled scale, scored from "strongly agree" (+2) to "strongly disagree" (-2). An overall measure of subjective norms was calculated for each participant by computing the mean of the four responses. Cronbach's alpha for these four statements was 0.755.

Perceived Behavioural Control

PBC was measured using three items and applying 5-point response formats that were fully labelled. The first items was "How easy or difficult would it be for you to lose weight in the next 6 months?," and it was scored from "very difficult" (+1) to "very easy" (+5). The second item was "Whether I lose weight in the next 6 months is entirely up to me," and it was scored from "not at all" (+1) to "to an extremely great extent" (+5). The third item was "How much control do you feel you have over losing weight over the next 6 months?," and it was scored from "no control" (+1) to "complete control" (+5). Cronbach's alpha for the three items was 0.718, and the overall measure of PBC was calculated by computing the mean of the three responses of each participant.

Intention

The participants' intention to reduce their body weight was measured using two statements: "I intend to lose weight in the next 6 months" and "I plan to lose weight in the next 6 months." The first statement described the participants' desires to lose weight in the next 6 months, and the second statement determined whether the participants had any action plan for losing weight in the next 6 months. Explanation of the operational definitions was made in footnotes to the questionnaire. The responses were measured on 5-point scales ranging from "definitely agree" (+2) to "definitely do not agree" (-2). An overall measure of intention was calculated by computing the mean of the two responses. Cronbach's alpha for

the two statements was 0.928.

Procedure

The protocol used was approved by the human ethics committee at the Hong Kong Institute of Education before the study commenced. The participants were provided with a document describing the study's objectives, details on the weight management program, and an overview of the required tasks. People who expressed interest in joining the study were provided with a consent form and the TPB questionnaires. Mann-Whitney U-tests of TPB components were used to determine significant differences between the groups. Hierarchical regression analyses of TPB components were conducted for each power to predict the participants' intention to lose 10% of their body weight. Finally, a logistic regression analysis was performed to investigate the odds ratios of intention, the PBC, and the group effect (CG vs. EG) for predicting 10% weight loss and maintained 10% weight loss.

Results

Fifty adults who were overweight participated in this study. The overweight cut-off was based on the definition from the World Health Organization for Asian populations.[32] One participant in the CG withdrew before completing the weight reduction programme due to pregnancy. Twenty-four and 25 of the participants in the CG and EG, respectively, completed the 12-week programme and returned for weight measurements at Week 24.

The median scores for the attitude and subjective norms of the participants in the EG were higher than those of the participants in the CG, whereas the median score for PBC of the participants in the CG were higher than that of the participants in the EG. The median scores of intention, however, were the same in the two groups. However, at the beginning of the study, no significant difference in attitude, subjective norms, PBC, or intention was observed between the two groups (Table 1).

Theory of Planned Behaviour as an Indicator of Intention to Lose Body Weight

A hierarchical multiple regression analysis was conducted to determine the influence of the TPB variables on the intention to reduce body weight. Step 1 assessed the contribution of attitude, subjective norms, and PBC to intention. The overall model explained 43.7% of the variance in intention (R^2 = 0.400, $F_{3, 45}$ = 11.660, p < .001) and was significant. When subjective norms were removed in Step 2 of the regression analysis, the overall model was not significant and explained 41.2% of the variance in intention (R^2 = 0.412, $F_{1, 45}$ = 0.061, p = .806). When subjective norms and attitude were removed in Step 3, the variation in intention to lose body weight decreased by 1.4% (R^2 = 0.398, $F_{1, 45}$ = 2.140, p = .150); this reduction did not constitute a significant R^2 change. In the three models, PBC was the only unique significant predictor of intention to reduce body weight.

Ten Percent Weight Loss Between Groups

Immediately after the intervention (Week 12), similar percentages of the participants in the CG (n = 4, 18.2%) and EG (n = 4, 16.0%) achieved a 10% reduction in their initial body weight (p = .573). Twelve weeks after the intervention (Week 24), the percentage of participants who had achieved or maintained a 10% reduction of their initial body weight was significantly higher in the EG (n = 22, 88.0%) than in the CG (n = 6, 25.0%) (p < .001).

Predictors of Ten Percent Weight Loss

Logistic regression analysis was conducted to determine whether the TPB variables could be employed as predictors for the differences in 10% weight loss between the two groups. Because PBC provided unique contributions to the intention to reduce weight in the hierarchical regression analysis, the predictive values of PBC, intention, and the group effect were investigated further.

At Week 12, the first logistic regression analysis was conducted to determine the relationship between intention and immediate 10% weight loss (as behaviour; $\chi^2 = 0.058$; $p = .809$). The statistical model contributed to 0.1% of the variation in immediate 10% weight loss and correctly classified 83% of the cases. Intention was determined to be an insignificant predictor of immediate 10% weight loss. The second analysis was conducted to determine the influence of PBC when controlling for intention. This statistical model contributed to 3.6% of the variation in the desired behaviour and correctly classified 83% of the cases ($\chi^2 = 1.680$; $p = .195$). Neither intention nor PBC were significant predictors of immediate 10% weight loss. Finally, the group effect was added to investigate its contribution to the desired behaviour. Intention, PBC, and the group effect jointly accounted for 4.2% of the variation in behaviour, and the percentage of cases correctly classified the remaining 83% ($\chi^2 = 0.263$; $p = .608$). Again, neither variable was a unique significant predictor of immediate 10% weight loss. The odds ratio of the group effect in this step was lower than that of intention (Table 2).

At Week 24, the first logistic regression analysis was conducted to determine the relationship between intention and maintained 10% weight loss (as behaviour; $\chi^2 = 0.023$; $p = .879$). The statistical model accounted for less than 0.1% of the variation in the desired behaviour and correctly classified 57.1% of the cases. Here, intention was not shown to be a significant predictor of behaviour. The second analysis was conducted to determine the influence of PBC when controlling for intention, and this statistical model contributed to 3.8% of the variation in the desired behaviour and correctly classified 59.2% of the cases. Again, neither variable was a unique significant predictor of maintained 10% weight loss. Finally, the group effect was added to investigate the contribution of behavioural feedback to maintained 10% weight loss. Intention, PBC, and the group effect jointly accounted for 37.7% of the variation in behaviour and could be used to correctly classify 81.6% of the cases. Here, the group effect was determined to be a significant predictor of the desired behaviour ($p < .001$). The odds ratio of the group effect in this step was higher than those of intention and

PBC (Table 2).

Discussion

Insignificant differences in the scores between groups at the baseline confirmed that all of the participants reported similar attitude, subjective norms, PBC, and intention towards successful weight loss. Hierarchical regression analyses of intention revealed that attitude and subjective norms only slightly improved predictions of the participants' weight loss behaviour, indicating that PBC was the major significant predictor in the TPB framework for weight reduction. Our findings support those of previous studies conducted by Schifter and Ajzen[25] and Povey et al.[30], who measured weight loss behaviour by employing self-reported questionnaires. The objective measurement uniquely adopted in this study confirmed that PBC significantly contributes to the intention to reduce body weight. The results indicated that PBC strongly determined either the intention to lose weight or weight loss behaviour, as proposed in the TPB framework.

Although behavioural feedback is not a new concept and has been applied to behavioural change in many studies, those focusing on how prior behaviour guides future actions cannot draw a framework with a similar concept.[33] Cognitive activity has been determined to influence participants' decisions based on the consequences of behaviour. In this study, feedback regarding past behaviour directly affected the participants' attitudes and their final behavioural decisions. In the EG, participants reflected on their previous eating decisions from online reports. Although dieticians produced energy profiles and nutrient profiles for analysis, they did not provide face-to-face feedback. The participants in the EG had more autonomy in the review process and reflected on their own eating problems to try to determine a balanced diet that fit the diet approach. It was hypothesized that this user-centred reflective process would strengthen the modification of the participants' eating habits and be established as long-term eating behaviour after the observation period. For the participants in

the CG, dietary feedback was also provided by dieticians; however, the participants may have taken less ownership in reflecting on their own eating problems, which were identified by the dieticians. The participants in the CG were less involved in thinking of how to modify their food choices, and it took longer for them to achieve balanced eating habits than the participants in the EG. Therefore, our results agree with those obtained using the Albarracin and Wyer model[33] and indicate that positive and negative feedback influence participants' actions and can lead to desired behavioural consequences.

Behavioural feedback was the main factor that revealed the difference between the two groups. Thus, the behavioural feedback, as demonstrated in the group effect, was proposed to elicit a difference in cognitive activity during self-monitoring. After Week 12, the results indicated that intention was the strongest predictor of immediate weight loss; however, the odds ratios of intention in Steps 2 and 3 were greater than 2, which suggests that the participants with greater intention to lose weight were twice as likely to be successful. Regarding immediate successful weight loss, although behavioural feedback did not appear to exert an effect, it significantly indicated a difference in weight loss maintenance at Week 24. The odds ratios of intention increased in Steps 1, 2, and 3, suggesting that the intention to reduce weight increased when PBC and the group effect were added. This observation can be explained based on the findings in previous studies that indicate that PBC is highly correlated with intention or based on the inclusion of behavioural feedback in the electronic dietary records applied in the EG. The participants in the EG learned how to modify their food choices and portion sizes during the 24 week period, and this reflective learning during self-monitoring reinforced their newly acquired healthy eating habits. In addition, the participants in the EG received suggestions in their reports stating that if they exercised more, then they could increase their energy intake from food. This reflects the various alterations in energy intake and output that the participants could experience through the electronic dietary recording system. The same effect was not shown in 12-week weight loss. This outcome

indicated that reflection on eating advice and healthy food choice required time to be internalized. In this finding, users with higher PBC demonstrated higher capability for achieving weight loss maintenance supported by behavioural feedback. This dietary recording system is a suitable knowledge transfer system for educating people with obesity in how to modify their eating behaviour and exercise patterns to achieve weight loss goals. The odds ratio of the group effect strongly indicated that the behavioural feedback of the electronic dietary recording system was 24 times more likely to lead to maintenance of weight loss in 24 weeks than paper self-monitoring.

Limitation and Implications

This is the first study to establish theoretical support for weight loss by applying teledietetics. The TPB framework was applied to explore the effect of behavioural feedback on weight loss and weight loss maintenance, providing valuable findings regarding the application of this framework of self-monitoring with the features of behavioural feedback. However, two limitations in the research design may warrant caution. One limitation is the difference in the dietician feedback given to the participants. The feedback given to the EG occurred on a daily basis, whereas the feedback given to the CG occurred on a weekly basis. This difference in the present study was due to the consideration of efficient email communication between the participants and the research assistant. If the feedback in the CG was made daily, the participants may feel too busy to send and receive email messages daily. Therefore, the observed variance in the group difference could be a result from the behavioural feedback plus a more frequent dietician feedback in the EG group. Another limitation is the statistical analysis in this study. Logistic regression is commonly adopted for the TPB framework but cannot make causal determinations. Statistical models such as path analysis and computational simulations such as artificial neural networks merit further

investigation as they may facilitate recognizing patterns in how behavioural feedback influences PBC, intention, weight loss, and weight loss maintenance.

Conclusion

As demonstrated by the electronic dietary recording and self-monitoring system examined in this study, behavioural feedback improved weight loss maintenance over a 24-week period. However, no significant improvement in weight loss success was observed over a 12-week period.

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Figure 1: Schematic representation of the current and proposed predictors in the theory of planned behaviour

Figure 1: Schematic representation of the current and proposed predictor in the Theory of Planned Behavior.

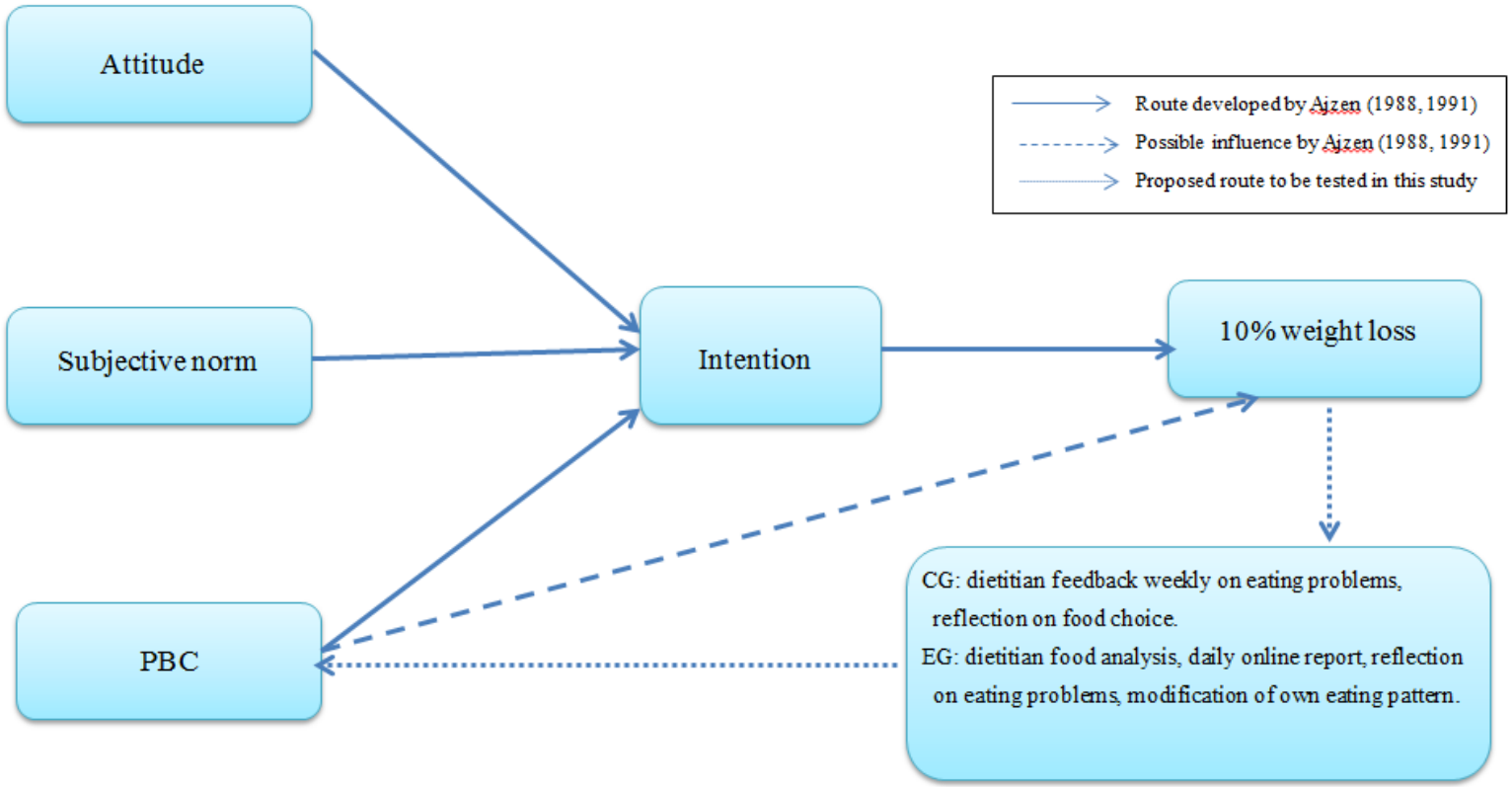

Table 1:Mann—Whitney U-test on group differences in TPB variables

	CG participants N = 24 Median (IQR)	**EG participants N = 25 Median (IQR)**	***U value***	***p value***
Attitude	1.00 (1.00)	1.30 (1.20)	269.0	0.395
Subjective norm	0.25 (1.38)	0.88 (1.19)[†]	232.0	0.171
PBC	3.67 (0.67)	3.50 (1.00)	257.0	0.275
Intention	5.00 (1.00)	5.00 (1.00)	271.0	0.363

[†] One participant in the teledietetic group did not respond to the subjective norm; IQR:interquartile Range

Table 2: Logistic regression analyses: predicting ≥ 10% weight loss at 12 and 24 weeks

		B	S.E.	*p* value	Odds Ratio	95% Confidence Interval	
12 weeks						**(lower)**	**(upper)**
Step 1	Intention	-0.171	0.703	0.808	0.843	0.213	3.344
	Constant	-0.812	3.193	0.799	0.444		
Step 2	Intention	0.732	1.016	0.471	2.080	0.284	15.225
	PBC	-1.009	0.790	0.202	0.364	0.077	1.716
	Constant	-1.508	3.292	0.647	0.221		
Step 3	Intention	0.767	1.017	0.451	2.154	0.293	15.814
	PBC	-1.109	0.824	0.178	0.330	0.066	1.659
	Group	-0.425	0.832	0.610	0.654	0.128	3.340
	Constant	-1.114	3.380	0.742	0.328		
24 weeks							
Step 1	Intention	0.081	0.533	0.879	1.085	0.381	3.085
	Constant						
Step 2	Intention	0.760	0.746	0.308	2.139	0.496	9.227
	PBC	-0.814	0.611	0.183	0.443	0.134	1.467
	Constant						
Step 3	Intention	1.180	0.971	0.224	3.255	0.485	21.830
	PBC	-0.695	0.807	0.389	0.499	0.103	2.425
	Group	3.202	0.828	<0.001	24.592	4.857	124.531
	Constant						