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# Identifying psychological predictors of adherence to a community-based lifestyle modification program for weight loss among Chinese overweight and obese adults

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**BACKGROUND/OBJECTIVES:** Existing evidence on lifestyle modification programs for weight loss is limited by the high attrition rate of such programs. Identifying predictors of adherence to a lifestyle modification program could result in program improvement. However, little is known about behavior-specific adherence and its psychological predictors. This study aimed to examine the psychological predictors of adherence after one-month participation in a community-based lifestyle modification program among Chinese overweight and obese adults in Hong Kong.
**SUBJECTS/METHODS:** A total of 205 Chinese overweight and obese adults aged 38.9 ± 10.5 years completed the study. Data were collected at baseline and after one month using self-reported questionnaires, which assessed knowledge (self-developed scale), motivation (Treatment Self-Regulation Questionnaire), stage of change (Stage of Exercise Scale) and self-efficacy (Self-Rated Abilities for Health Practices Scale). At one month, a 4-day dietary recall and the International Physical Activity Questionnaire-Short Form were used to assess dietary and physical activity (PA) adherence. Food and PA diaries were examined to indicate self-monitoring. Program attendance was tracked between baseline and one-month follow-up.
**RESULTS:** After one month, participants reported high dietary adherence, attendance, and adherence to self-monitoring but low PA adherence. Multiple regression analyses suggested that diet self-efficacy (baseline) and nutrition knowledge (one-month change) were independent predictors of dietary adherence score at one month, whereas autonomous PA motivation (baseline) and PA self-efficacy (both baseline and one-month change) were independent predictors of PA adherence score at one month. No significant psychological predictor was identified for attendance or self-monitoring.
**CONCLUSIONS:** The results suggest that the effect of psychological factors on adherence differs between diet and PA adherence outcomes. To promote adherence, practitioners should assess self-efficacy, knowledge, and motivation at the beginning of a weight-loss program and explore behavior-specific strategies to improve knowledge and self-efficacy. The results of this study have direct implications for program improvements.

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## INTRODUCTION

Given the obesity epidemic worldwide, significant public health concern has been raised about both the prevention and management of obesity [1]. Robust community-based randomized controlled trials support the suggestion of adopting a comprehensive lifestyle modification program (LMP) as the first and most cost-effective option to achieve a clinically significant weight loss of 5-10% and to prevent diabetes among overweight and obese adults [2,3]. A typical LMP provides intensive counseling sessions delivered by highly trained health professionals to empower individuals to build healthy eating and regular physical activity (PA) habits by using behavioral techniques [2].

Recognizing the lack of a culturally sensitive and locally appropriate LMP in Hong Kong, one of the researchers (Mandy Man Mei Sea) in our team developed a community-based LMP (CNSLMP) in 2002 in order to enhance local public services [4]. CNSLMP provides individualized weight management plans on a self-financing basis. The theoretical basis and details of the program have been published previously [4,5]. Program length depends on the client's initial weight status, the expected target weight goal set by dietitians/nutritionists, and the weight-loss progress of the client [4]. The first consultation with dietitians/nutritionists is a one-hour long comprehensive health and dietary assessment that includes dietary education. Follow-up sessions mostly occur on a weekly basis for the first

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three months and monthly basis thereafter. Dietary education focuses on a balanced diet, reading of food label, food exchanges, healthy eating-out techniques, healthy cooking methods, and an active lifestyle. For self-monitoring purpose, dietitians/nutritionists instruct the client to complete daily food and PA diaries [4]. Furthermore, clients have to attend at least one PA consultation with a fitness specialist, who assesses their fitness level and designs individualized PA plans according to the American College of Sports Medicine (ACSM)'s Guidelines for Exercise Testing and Prescriptions [6]. Extra PA consultation sessions can be arranged upon client request [4]. The efficacy and cost-effectiveness of the CNSLMP have been previously demonstrated in disease-free overweight and obese Chinese adults [5,7] and in Chinese patients with non-alcoholic fatty liver disease [8,9].

In spite of the promising results of LMPs around the world, the continuing epidemic of obesity suggests that those who are in most need might not be successfully reached or the beneficial effect might not be maintained. On the other hand, the generalizability of lifestyle interventions can be limited by a high program attrition rate [10]. Thus, more research is needed to understand the process of behavioral change and the predictors of such changes. In the context of LMPs, the best indicator of behavioral change is adherence [11]. Currently, there is a huge information gap regarding the factors associated with behavior-specific adherence. A recent review on this topic suggested a broad array of factors, including psychosocial, socio-demographic, behavioral, and physical factors that are associated with behavior-specific adherence, but only a small number of studies were available for review. The review authors also indicated that these factors were mostly measured at baseline, undermining assessment of the temporal influence of lifestyle modification [12]. Among the factors identified, psychosocial factors have been the most commonly studied, and psychological factors including self-efficacy, depression, motivation, stress, body shape concern, quality of life, and stage of change were found to be significantly associated with behavior-specific adherence [12]. Our research team attempted to explore the psychological factors of adherence to CNSLMP in two earlier studies. In one qualitative study, the majority of the participants reported increased health and nutrition knowledge but experienced frustration, negative emotion, and lack of motivation as common psychological factors related to adherence to the CNSLMP [4]. Another observational study suggested that significantly more client weight loss was observed among clients of dietitians/nutritionists who used more patient-centered communication skills and provided stage of change concepts during client consultations [5]. Combining our previous findings with the most frequently cited significant psychological factors, we selected four psychological factors, namely knowledge, self-efficacy, motivation, and stage of change for further investigation in this study.

The aim of this study was to examine the relationships between these four psychological factors and a one-month adherence to the CNSLMP, a period that corresponds to the early weight-loss phase in the majority of the program participants. We hypothesized that higher baseline knowledge, self-efficacy, motivation, or stage of change of the participants and greater improvement of these psychological factors as a result of CNSLMP at one month could predict a higher CNSLMP adherence level at one month, irrespective of adherence outcomes.

## SUBJECTS AND METHODS

*Design*

The study is a part of a cohort study, in which CNSLMP participants were being followed from the beginning of the weight-loss program until 10 months later. In this study, we report the baseline and one-month follow-up data for the cohort study. The one-month follow-up, representative of the early weight-loss phase for the majority of participants, was set to include those with a body mass index (BMI) $< 24$ kg/m$^2$, based on previous practical experience that the weight-loss phase duration for those with BMI $< 24$ kg/m$^2$ was approximately one month.

*Participants*

The study's convenience sample comprised newly enrolled clients of CNSLMP that were invited to participate in the study. We included Chinese clients who were 18-65 years old and were overweight or obese *i.e.*, BMI $\geq 23$ kg/m$^2$ [13]. Clients with (i) histories of psychiatric disorders; (ii) current use of medication for weight loss; (iii) a medical condition that would limit PA participation; and (iv) a condition that may interfere with participation were excluded from the study.

*Data collection*

This study was undertaken between April 2014 and July 2015. Dietitians/nutritionists referred potential participants to our research staff upon completion of their first consultation. The research staff then briefed the participants on the study details and their rights with the help of an information sheet. Thereafter, informed written consent was sought. Ethical approval was obtained from the Joint Chinese University of Hong Kong - New Territories East Cluster Clinical Research Ethics Committee (Ref. no.: CRE-2013.623) prior to data collection.

At baseline, information on age, sex, marital status, occupation, income, working pattern, education, disease status, smoking habits, drinking habits, and weight-loss history were collected by using a demographic and general health form. Data on diet- and PA-specific knowledge, self-efficacy, motivation, and stage of change were collected by using a structured questionnaire at baseline and at the one-month follow-up. Adherence at one month was assessed by examining attendance, self-monitoring and self-developed diet and PA adherence scores produced from dietary and PA data. Attendance records were provided by dietitians/nutritionists. Food and PA diaries used during the program were collected for assessing self-monitoring. Dietary data was collected in the form of 4-day food records, which included two consecutive weekdays and two consecutive weekend days [14]. PA data were collected in the form of 7-day PA records and using the 7-item International Physical Activity Questionnaire-Short Form (IPAQ-SF) [15,16]. At each recording time, body weight was recorded to the nearest 0.1 kg using a Seca 220 measuring system (Seca 220; Seca, Hamburg, Germany). In addition, a 100 HKD cash incentive was

offered to each participant to acknowledge their time and effort in completing the questionnaires.

*Outcome assessments*

*Adherence outcomes*

Attendance was based on the percentage of sessions attended out of the targeted total number of sessions. The distribution of attendance was skewed to the high end; therefore, the attendance was dichotomized into high (≥ 80%) or low (< 80%) adherence groups for analysis.

Self-monitoring was indicated by the percentage of diaries completed out of the targeted total number. Dietitians/nutritionists assessed the completion of the food and PA diaries. For diet self-monitoring, completion was defined as more than 50% of the food eaten by the clients was recorded in a food diary [17]. For PA self-monitoring, completion was defined according to PA type and PA duration as recorded in the participants' PA diaries. As the distributions of both diet and PA variables were skewed, they were dichotomized into 100% and < 100% completion of self-monitoring for analysis.

Dietary adherence was represented by the dietary adherence score derived from the food records. Initially, the food records were analyzed by using Food Processor software, version 8.0, by ESHA Research (Salem, Oregon, USA) to obtain the nutrient intake for each diet plan, which was then averaged to calculate the mean daily total energy intake, percentages of total energy from carbohydrate, fat and protein, and consumption of fruits and vegetables. A score of one was assigned for meeting each criterion listed in Table 1. The scores were then summed to provide the dietary adherence score, which ranged from 0 to 8 per day with a maximum score of 32 for the four days assessed.

PA adherence was represented by the PA adherence score, which ranged from 0 to 10 and comprised the "Program PA score" and the "IPAQ PA score". The "Program PA score" was used to assess adherence to the PA goal established by a fitness specialist using PA diaries. Based on the assumption that any increase in PA is better than no increase in PA, the "IPAQ PA Score" was added to include those who did increase the amount of PA but did not meet the goal, or those who had not yet consulted a fitness specialist. The scoring criteria are presented in Table 1.

*Psychological outcomes*

Nutrition and PA knowledge were assessed by using a self-developed questionnaire based on the content of CNSLMP. The knowledge questionnaire included two sections: nutrition and PA knowledge. The nutrition section consisted of 22 questions in six domains: balanced diet (2 questions), weight-loss diet (5 questions), healthy eating-out techniques (4 questions), healthy cooking methods (3 questions), and food exchanges (8 questions). The PA section consisted of 11 questions on PA knowledge, of which 6 were adapted from the Chinese Physical Activity Questionnaire [16]. One score was assigned for each correct answer. Scores were summed to give total scores of 22 and 11 for nutrition and PA knowledge, respectively. Higher scores indicate better knowledge.

Self-efficacy was assessed by the Exercise and Nutrition subscale of Self-Rated Abilities for Health Practices Scale (SRAHP), a 28-item questionnaire on the self-perceived ability to implement health-promoting behaviors within a scale from 0 (not at all) to 4 (completely). The diet and PA subscale scores, each made up of 7 items, were used for the analysis. The scores were summed to give a total subscale score of 28. Higher scores indicate higher self-efficacy. The Chinese version of the SRAHP scale has demonstrated high internal consistency and test-retest reliability [18].

Motivation was assessed by the 15-item Treatment Self-Regulation Questionnaire (TSRQ) and rated on a 7-point scale, ranging from 1 (not at all true) to 7 (very true). The autonomous and controlled motivation subscale scores, each made up of 6 items, were used for the analysis. The scores were summed to give a total subscale score of 42. Higher scores indicate higher motivation. The TSRQ has been validated among weight-loss program participants [19] and individuals engaged in various health-related behaviors including diet and exercise

**Table 1.** Scoring criteria for dietary and physical activity adherence scores

Scoring criteria for dietary adherence score:
A score of one was assigned for meeting each criterion below. The scores were summed to give a dietary adherence score, ranging from 0 to 8 per day and a maximum of 32 for four days.
- (i) Total energy not exceeding 10% of the diet plan
- (ii) % energy from fat 20-30% [46-48]
- (iii) % energy from protein within the range of 15-20% [47]
- (iv) % energy from carbohydrate 50-65%
- (v) Consumption of fruits > 160 g [49]
- (vi) Consumption of vegetables > 240 g [49]
- (vii) Regular meal consumption as prescribed by dietitians/nutritionists
- (viii) Not consuming the "Avoid food" specified in the program handbook

Scoring criteria for physical activity (PA) adherence score:
The PA adherence score is composed of Program PA score and IPAQ PA score. The two scores were added to obtain a maximum of 10.
- (a) Program PA score: For each of the four components below, a score of two was assigned if 80% of the recommended volume of exercise (frequency x duration) had been met during the week of follow-up while a score of one was assigned if 50% of the recommended volume of exercise had been met. The scores were summed to provide a range from 0 to 8.
  - (i) Walking
  - (ii) Aerobic exercises
  - (iii) Stretching exercises
  - (iv) Muscle strengthening or balance exercises
- (b) IPAQ PA Score: a score of one was assigned for meeting each criterion below. The two scores were added up to give IPAQ score, ranging from 0-2
  - (i) The total MET score increased compared to baseline
  - (ii) Moderate or vigorous intensity PA increased compared to baseline

[20]. The Chinese version of the TSRQ has shown high internal consistency in athletes [21]. The wording within the TSRQ can be slightly modified to accommodate different behaviors. Diet and PA motivation were assessed using two sets of TSRQs - healthy diet or regular PA. In addition, self-developed items " I want to do regular physical activity / maintain a healthy diet because I want to improve my body image" were used to examine motivation to improve body image.

Stage of change was assessed by diet and PA stage of change scales modified from the 5-item, ordered categorical stage of exercise scale developed by Cardinal [22]. The Chinese version of the stage of exercise scale has shown good test-retest reliability [23]. In order to examine diet- and PA-specific stages of change, "physical activity" and "healthy diet" were used, where appropriate, to replace 'exercise' in the original exercise scale.

*Data analysis*

Data are presented using appropriate statistics: mean (standard deviation), median (interquartile range), and frequency (percentage) for normal-like, skewed, and categorical variables, respectively. Listwise deletion, which refers to the elimination of cases with missing data, was used in this study. Univariate comparison between completers and non-completers was performed by performing independent sample t-tests or chi-squared tests, whenever appropriate. The Pearson correlation was used to explore the relationship between weight loss and adherence scores. Changes in psychological variables between baseline and the one-month follow-up were compared using paired t-tests or Wilcoxon signed-rank tests as appropriate.

Linear regression analyses were performed for continuous outcomes such as dietary or PA adherence scores, whereas logistic regression analyses were performed for binary outcomes (*i.e.*, attendance or self-monitoring). Multivariable regression models were created to identify independent predictors of adherence. Independent variables were changes in psychological variables from baseline to one month and baseline psychological variables. Baseline socio-demographic characteristics, BMI, weight-loss history, number of consultations, and location of the center were entered as covariates. Covariates with a *P*-value $< 0.2$ in univariate analysis were selected as candidate variables for multivariable regression analyses.

All statistical analyses were performed in STATA 13.0 software using two-sided significance tests with statistical significance set at 0.05.

## RESULTS

*Participants*

A total of 284 potential participants were approached, and 19 of them refused to join the study. Of the remaining 265 participants who agreed to join the study, 60 (22.6%) did not complete the one-month follow-up. Descriptive data for the completers and non-completers of the one-month follow-up are shown in Table 2. There were almost no significant differences between completers and non-completers except that non-completers were more likely to have tertiary or above education ($P < 0.001$) and a full-time job ($P = 0.027$).

Among the 205 completers of the one-month follow-up, the mean age was $38.9 \pm 10.5$ and the mean BMI was $28.4 \pm 1.2$. The majority of the completers were female (78.0%) and did not have smoking (88.3%) or drinking (68.8%) habits. Around half of the completers were married (45.4%), with one or more chronic diseases (43.9%) and had tertiary education or above (59.0%). Approximately two-thirds of the completers had a monthly family income more than 30,000 HKD, which was higher than the median household income in Hong Kong in 2016 [24]. Around one-third of them were professionals or associate professionals (31.5%). Regarding weight-loss history, the majority of the completers had gradually increased their weight during the past 10 years (64.2%) and only 18.5% did not have any weight-loss attempt before joining CNSLMP.

*Adherence outcomes*

There were high levels of dietary adherence, attendance, and self-monitoring but not of PA adherence. On average, participants attended 80.1% of the targeted total sessions in the one-month period. Slightly more than half of them (53.7%) were in the high attendance group. For self-monitoring, participants completed, on average, 88.3% of their food records and 76.0% of their PA diaries. More than half of them (53.2% and 56.2%) were in the 100% diet or PA self-monitoring groups, respectively. The mean dietary adherence score at one month was $22.2 \pm 5.9$, indicating a high level of dietary adherence. On the other hand, the mean PA adherence score at one month was only $3.5 \pm 2.1$, indicating a low level of PA adherence.

*Relationship between adherence and weight loss*

The mean weight loss at one month was $2.8 \pm 1.6$ kg, corresponding to a $3.8 \pm 2.0\%$ mean loss of baseline body weight. Weight loss at one month was positively correlated with the dietary ($r = 0.157$, $P = 0.025$) and PA ($r = 0.264$, $P < 0.001$) adherence scores but no significant relationship was detected between weight loss and attendance or between weight loss and self-monitoring.

*Psychological outcomes*

The changes in psychological outcomes between baseline and one month were compared and the results are presented in Table 3. At one month, participants had significantly higher nutrition knowledge, diet and PA self-efficacies, autonomous motivation for a healthy diet, PA motivation to improve body image, and lower diet and PA stages of change than at baseline. More profound increases were observed in nutrition knowledge and PA self-efficacy ($P < 0.05$).

*Psychological predictors of dietary adherence*

Table 4 summarizes the results of the univariate and multivariable regression analyses for dietary adherence score at the one-month follow-up. Change in nutrition knowledge and baseline diet self-efficacy were significant predictors in both univariate and multivariable models ($P < 0.05$), whereas the change in diet self-efficacy was marginally associated with dietary adherence score in the multivariable model ($P = 0.05$). With regard to non-psychological factors, being female ($P < 0.001$) and having a higher total number of consultations ($P = 0.011$) were significant predictors in both models.

**Table 2.** Comparison of socio-demographic characteristics, BMI, and general health factors between completers and non-completers of the study

| | Completers (n = 205) | Non-completers (n = 60) | *t* or $\chi^2$ |
|---|---|---|---|
| | Mean+SD / n (%) | Mean+SD / n (%) | |
| Age (yrs) | 38.9 ± 10.5 | 38.8 ± 9.3 | 0.06 |
| BMI (kg/m$^2$) | 28.4 ± 1.2 | 28.1 ± 4.0 | 0.11 |
| Gender | | | |
| Female | 160 (78.0) | 43 (71.7) | 1.06 |
| Male | 45 (22.0) | 17 (28.3) | |
| Marital status[1)] | | | |
| Married | 93 (45.4) | 16 (41.3) | 0.25 |
| Never married/ Divorced/ Widow | 112 (54.6) | 23 (59.0) | |
| Level of education[1)] | | | |
| Below tertiary | 84 (41.0) | 3 (8.1) | 14.71*** |
| Tertiary or above | 121 (59.0) | 34 (91.9) | |
| Occupation[1)] | | | |
| Managers and administrators | 43 (21.2) | 11 (19.0) | 1.39 |
| Professionals or associate professionals | 64 (31.5) | 16 (27.6) | |
| Clerical or services workers | 54 (26.6) | 20 (34.5) | |
| Others[2)] | 42 (20.7) | 11 (19.0) | |
| Working pattern[1)] | | | |
| Full time | 166 (81.0) | 54 (93.1) | 4.86* |
| Not Full Time | 39 (19.0) | 4 (6.9) | |
| Monthly family income (HKD)[1)] | | | |
| ≤ 30,000 | 68 (34.0) | 9 (28.1) | 0.94 |
| 30,001-60,000 | 79 (39.5) | 12 (37.5) | |
| > 60,000 | 53 (26.5) | 11 (34.4) | |
| Number of chronic diseases | | | |
| None | 115 (56.1) | 31 (51.7) | 0.37 |
| ≥ 1 | 90 (43.9) | 29 (48.3) | |
| Current drinking habit | | | |
| No | 141 (68.8) | 42 (70.0) | 0.03 |
| Yes | 64 (31.2) | 18 (30.0) | |
| Current smoking habit | | | |
| No | 181 (88.3) | 56 (93.3) | 1.25 |
| Yes | 24 (11.7) | 4 (6.7) | |
| Weight change during the past 10 years[1)] | | | |
| Gradually increased | 131 (64.2) | 43 (71.7) | 1.15 |
| Ups and downs / No big changes | 73 (35.8) | 17 (26.7) | |
| Number of previous weight-loss attempts | | | |
| None | 38 (18.5) | 14 (23.3) | 1.83 |
| 1 | 59 (28.8) | 13 (21.7) | |
| 2 | 49 (23.9) | 13 (21.7) | |
| ≥ 3 | 59 (28.8) | 20 (33.3) | |
| Center location | | | |
| Business district | 45 (22.0) | 10 (16.7) | 0.79 |
| Residential area | 160 (78.0) | 50 (83.3) | |
| Joined CNSLMP before | | | |
| No | 176 (85.9) | 57 (95.0) | 3.66 |
| Yes | 29 (14.1) | 3 (5.0) | |

SD, standard deviation; BMI, body mass index.
* $P < 0.05$, *** $P < 0.001$
[1)] Different sample sizes due to missing data
[2)] Others included unemployed (n = 2), housewife (n = 7), student (n = 9), retired (n = 9), elementary occupations (n = 1), skilled agricultural and fishery worker (n = 1), self-employed (n = 10) and church workers (n = 3).

**Table 3.** Comparison of psychological outcomes at baseline and one-month follow-up

| Outcomes [Range] | Baseline | One-month | t/z |
|---|---|---|---|
| | Mean ± SD / Median (IQR) | Mean ± SD / Median (IQR) | |
| Nutrition knowledge score [0-22] | 10.72 ± 3.11 | 14.29 ± 2.65 | -15.16*** |
| PA knowledge score [0-11] | 7.25 ± 1.39 | 7.49 ± 1.48 | -1.62 |
| Diet self-efficacy [0-28] (SRAHP-Nutrition subscale) | 21.35 ± 3.47 | 22.83 ± 3.07 | -5.98*** |
| PA self-efficacy [0-28] (SRAHP-PA subscale) | 16.91 ± 5.07 | 19.09 ± 4.60 | -6.93*** |
| Autonomous motivation for healthy diet [1-42] (TSRQ-autonomous subscale) | 34.72 ± 5.11 | 35.70 ± 4.48 | -2.82** |
| Autonomous motivation for PA [1-42] (TSRQ-autonomous subscale) | 33.29 ± 5.82 | 33.16 ± 5.60 | 0.72 |
| Controlled motivation for healthy diet [1-42] (TSRQ-controlled subscale) | 24.15 ± 6.19 | 24.77 ± 6.98 | -1.96 |
| Controlled motivation for PA [1-42] (TSRQ-controlled subscale) | 22.42 ± 6.35 | 22.60 ± 7.19 | -0.66 |
| Diet motivation to improve body image [1-7][1)] | 6 (5 to 7) | 6 (5 to 7) | 1.52 |
| PA motivation to improve body image [1-7] | 6 (5 to 7) | 6 (4 to 6) | 2.15* |
| Stage of change for healthy diet [1-5][2)] | 3 (3 to 4) | 2 (2 to 2) | 10.95*** |
| Stage of change for PA [1-5][2)] | 3 (2 to 4) | 2 (2 to 3) | 5.03*** |

n = 205, SD, standard deviation; IQR, interquartile range; PA, physical activity; SRAHP, self-rated abilities for health practices scale; TSRQ, treatment self-regulation questionnaire
* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$
[1)] n = 202, different sample sizes due to missing data
[2)] stage of change: 1, maintenance; 2, action; 3, determination; 4, contemplation; 5, pre-contemplation.

**Table 4.** Results of univariate and multivariable regression analyses for dietary adherence score

| | Univariate model | | Multivariable regression model[2)] | |
|---|---|---|---|---|
| | β | 95% CI | β | 95% CI |
| Changes in psychological variables (T1-T0) | | | | |
| Nutrition knowledge score | 0.30* | (0.05, 0.55) | 0.38* | (0.06, 0.69) |
| Diet self-efficacy (SRAHP-Nutrition subscale) | 0.01 | (-0.26, 0.28) | 0.33 | (0.00, 0.65) |
| Autonomous motivation for healthy diet (TSRQ-autonomous subscale) | -0.07 | (-0.11, 0.24) | -0.01 | (-0.24, 0.21) |
| Controlled motivation for healthy diet (TSRQ-controlled subscale) | -0.13 | (-0.27, 0.01) | -0.07 | (-0.22, 0.09) |
| Diet motivation to improve body image (Ref: No change/decreased)[1)2)] | | | | |
| Low to high | 0.05 | (-2.61, 2.72) | -0.84 | (-3.82, 2.14) |
| Stage of change for a healthy diet (Ref: No change/decreased) | | | | |
| Increased | -0.20 | (-2.05, 1.64) | -0.71 | (-3.23, 1.82) |
| Baseline psychological variables | | | | |
| Nutrition knowledge score | 0.05 | (-0.22, 0.32) | 0.14 | (-0.21, 0.48) |
| Diet self-efficacy (SRAHP-Nutrition subscale) | 0.33** | (0.09, 0.56) | 0.49** | (0.19, 0.79) |
| Autonomous motivation for healthy diet (TSRQ-autonomous subscale) | 0.05 | (-0.11, 0.21) | 0.01 | (-0.20, 0.22) |
| Controlled motivation for healthy diet (TSRQ-controlled subscale) | 0.07 | (-0.06, 0.19) | 0.04 | (-0.10, 0.18) |
| Diet motivation to improve body image (Ref: low)[1)2)] | | | | |
| High | 0.13 | (-1.58, 1.84) | -1.68 | (-3.77, 0.42) |
| Stage of change for healthy diet (Ref: Contemplation/ Pre-contemplation) | | | | |
| Determination | -0.75 | (-2.53, 1.02) | -0.94 | (-2.72, 0.84) |
| Action/ Maintenance | 0.27 | (-2.05, 2.58) | -0.84 | (-3.95, 2.26) |
| Other covariates | | | | |
| Female gender (Ref: Male) | 2.61** | (0.69, 4.53) | 3.15** | (0.90, 5.39) |
| Married (Ref: Not married) | 1.44 | (-0.17, 3.06) | 0.49 | (-1.22, 2.19) |
| Number of previous weight-loss attempts (Ref: None) | | | | |
| 1 | 3.08* | (0.69, 5.46) | 2.16 | (-0.19, 4.52) |
| 2 | 1.81 | (-0.67, 4.28) | 1.56 | (-0.91, 4.03) |
| ≥ 3 | 2.30 | (-0.08, 4.68) | 1.36 | (-1.11, 3.84) |
| Number of consultations at T1 | 1.04** | (0.41, 2.26) | 1.21* | (0.29, 2.14) |
| $R^2$ | | | 0.21 | |
| $F$ | | | 2.58*** | |

n = 205. CI, confidence interval; T1, one month, T0: baseline; SRAHP, self-rated abilities for health practices scale; TSRQ, treatment self-regulation questionnaire
[1)] Diet motivation to improve body image score: Low < 6, High ≥ 6
[2)] n = 202, different sample sizes due to missing data
* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

**Table 5.** Results of univariate and multivariable regression analyses for PA adherence score

| | Univariate model | | Multivariable regression model | |
|---|---|---|---|---|
| | β | 95% CI | β | 95% CI |
| Changes in psychological variables (T1-T0) | | | | |
| PA knowledge score | -0.12 | (-0.31, 0.07) | -0.05 | (-0.25, 0.14) |
| PA self-efficacy (SRAHP-PA subscale) | 0.11** | (0.04, 0.18) | 0.13** | (0.06, 0.22) |
| Autonomous motivation for PA (TSRQ-autonomous subscale) | 0.03 | (-0.03, 0.09) | 0.06 | (-0.01, 0.13) |
| Controlled motivation for PA (TSRQ-controlled subscale) | -0.02 | (-0.07, 0.03) | -0.02 | (-0.07, 0.03) |
| PA motivation to improve body image (Ref: No change/decreased)[1)] | | | | |
| Low to high | 0.33 | (-0.61, 1.28) | -0.24 | (-1.22, 0.75) |
| Stage of change for PA (Ref: No change/decreased) | | | | |
| Increased | 0.41 | (-0.17, 0.99) | 0.49 | (-0.18, 1.16) |
| Baseline psychological variables | | | | |
| PA knowledge score | 0.09 | (-0.11, 0.30) | 0.07 | (-0.15, 0.29) |
| PA self-efficacy (SRAHP-PA subscale) | 0.05 | (-0.00, 0.11) | 0.08* | (0.01, 0.15) |
| Autonomous motivation for PA (TSRQ-autonomous subscale) | 0.08** | (0.03, 0.13) | 0.08* | (0.02, 0.14) |
| Controlled motivation for PA (TSRQ-controlled subscale) | 0.05* | (0.00, 0.09) | 0.03 | (-0.02, 0.07) |
| PA motivation to improve body image (Ref: low)[1)] | | | | |
| High | -0.30 | (-0.89, 0.30) | -0.57 | (-1.20, 0.07) |
| Stage of change for PA (Ref: Contemplation/ Pre-contemplation) | | | | |
| Determination | 0.56 | (-0.12, 1.23) | 0.29 | (-0.37, 0.95) |
| Action/ Maintenance | 0.62 | (-0.12, 1.35) | 0.32 | (-0.56, 1.21) |
| Other covariates | | | | |
| Married (Ref: Not married) | 0.42 | (-0.15, 0.99) | 0.30 | (-0.27, 0.87) |
| Full time work (Ref: Not full time) | -0.54 | (-1.27, 0.19) | -0.23 | (-0.92, 0.45) |
| Current smoking habit (Ref: No) | -0.63 | (-1.52, 0.26) | -0.60 | (-1.42, 0.22) |
| Center location: Business district (Ref: Residential area) | 0.68 | (-0.01, 1.37) | 0.31 | (-0.34, 0.96) |
| Had PA consultation (Ref: No) | 1.25*** | (0.69, 1.82) | 0.95*** | (0.40, 1.49) |
| $R^2$ | | | 0.29 | |
| $F$ | | | 4.18*** | |

n = 205. CI, confidence interval; T1, one month; T0, baseline; SRAHP, self-rated abilities for health practices scale; TSRQ, treatment self-regulation questionnaire
[1)] PA motivation to improve body image score: Low < 6, High ≥ 6
* $P$< 0.05, ** $P$< 0.01, *** $P$< 0.001

*Psychological predictors of PA adherence*

Table 5 summarizes the results of univariate and multivariable regression analyses for PA adherence score at the one-month follow-up. Change in PA self-efficacy, baseline PA autonomous motivation, and having a PA consultation were significant predictors in both models ($P < 0.05$). Furthermore, baseline PA self-efficacy was a significant predictor in the multivariable model ($P < 0.05$).

*Psychological predictors of attendance and self-monitoring*

Univariate regression analyses revealed no significant relationship when using attendance or diet self-monitoring as dependent variables (result not shown). For PA self-monitoring, the only significant univariate predictor of 100% completion of a PA diary was change in PA knowledge (OR = 1.30, $P = 0.028$).

## DISCUSSION

To our knowledge, this is the first study that has explored the longitudinal relationship between psychological factors and diet and PA adherence in a Chinese setting. Similar to results in other weight-loss studies [25], females (78%) were over-represented in our study. As we purposively recruited all eligible participants who were enrolled in the CNSLMP, the small number of male participants in our study reflects the reality that the CNSLMP was predominantly comprised of women.

Due to the lack of studies examining behavior-specific adherence, we developed a scoring system for dietary and PA adherence based on the program content. Our results suggested there was a high level of dietary adherence during the weight-loss phase. The mean dietary adherence score was 22.2 out of a possible total of 32, implying that on average, 70% of the dietary recommendations were met. When compared to other studies that measured adherence to dietary goals, dietary adherence in the present study was quite high despite different measurement tools being used [26]. On the other hand, the level of PA adherence was low, with less than 50% of the PA recommendations being met. A few weight-loss studies have reported a wide range of adherence to PA goals, with higher adherence to step goals (80.9% to 99%) than to aerobic exercise goals (31% to 36%) [26]. It is inappropriate to compare our PA adherence results with the results in those studies due to the variation in definition and measurement tools; nevertheless, the low PA adherence observed in our study concurs with the

reported low PA participation of the adult population in Hong Kong [27]. The discrepancy between the dietary and PA adherence levels observed in our study further implies that the program had more influence on dietary behaviors than on PA behaviors.

Attendance and self-monitoring were commonly used adherence indicators in previous studies. The observed attendance and adherence to self-monitoring results in our study were higher than those reported in other weight management programs [12]. The overall high levels of attendance and self-monitoring might be attributed to the self-financing nature of the CNSLMP.

Of the four indicators of adherence, only dietary and PA adherence were positively associated with weight loss at the one-month follow-up. Similar results have been consistently reported in previous studies [28-30]. Regardless, the absence of significant relationships of attendance and self-monitoring with weight loss at one month in our study was contradictory to those in previous studies [17,28,30]. The high levels of attendance and self-monitoring in the present study might have limited the power to achieve statistical significance.

The findings in this study partially supported the study hypotheses. We hypothesized that an increase in knowledge, self-efficacy, motivation, or stage of change could predict higher adherence to the program, irrespective of adherence outcomes. However, our results revealed independent predictors for dietary and PA adherence only. Again, with the high levels of attendance and self-monitoring in this study, there may be a limitation to the statistical power needed to detect the influences of psychological factors.

With regard to knowledge, increases in nutrition knowledge, but not baseline nutrition knowledge, independently predicted a higher level of dietary adherence. This implies that the increase in nutrition knowledge was more important than the level of pre-treatment nutrition knowledge for better dietary adherence in this program. To our best knowledge, this is the first report of a positive relationship between an increase in nutrition knowledge and dietary adherence in an LMP. No other studies investigating a longitudinal relationship between nutrition knowledge and dietary adherence or dietary change were identified. Nevertheless, there is substantial evidence supporting the presence of correlational associations between nutrition knowledge and dietary intake among general adult populations [31,32].

Regarding self-efficacy, both diet and PA self-efficacies were found to be independent predictors of dietary and PA adherence, respectively. The increase in diet self-efficacy was only a marginally significant predictor, whereas baseline diet self-efficacy remained significant in the multivariable model. Therefore, pre-treatment diet self-efficacy appears to be more important for predicting better dietary adherence than that from an increase in diet self-efficacy. Similarly, although limited, other evidence available to date has consistently indicated that diet self-efficacy is a predictor of dietary change [33-35] and weight loss [36,37]. For PA self-efficacy, both baseline and an increase in PA self-efficacy were independent predictors in the multivariable model, implying that both pre-treatment and increased PA self-efficacy were important for predicting a higher level of PA adherence. Similar relationships were reported in previous weight-loss studies, in which PA self-efficacy was identified as a predictor of change in PA [33-35,38] and weight-loss [39]

With regard to motivation, only baseline autonomous motivation for PA independently predicted PA adherence. No other significant relationships were detected. Previous research results consistently support the presence of a positive association between weight-loss-specific motivation and weight loss, but the association between motivation and program attrition was inconclusive [40]. Our study results did not indicate a longitudinal relationship between motivation and adherence. One possible explanation of that absence was that the small and insignificant change in motivation from baseline to the one-month follow-up might have limited the capacity to detect statistical significance. Nevertheless, a prospective positive association between exercise autonomous motivation and changes in PA level has been established [41,42]. Moreover, one internet-based behavioral weight-loss trial reported that higher autonomous motivation at week 4 could predict a higher number of weeks of completion of food and exercise diaries at 16 weeks [19]. These recent findings suggest that behavior-specific autonomous motivation for diet or PA behavior changes is a highly promising area for research.

In contrast to our hypothesis, no significant relationship was observed for stage of change in both diet-related and PA-related models. The absence of a significant relationship might be due to an insufficient time period to allow for the stage of change to proceed and statistical significance to be detected. To our knowledge, despite the stage of change concept being widely adopted in weight-loss or lifestyle studies, there are no reports on investigations into the longitudinal relationship between stage of change and dietary or PA behavior changes [43,44]. However, Logue *et al.* [45] reported on an investigation into the longitudinal relationship between elapsed time in the "action" stage of change and weight loss and found a significant positive relationship between elapsed time in "action" or "maintenance" for each score and for a composite score of the five diet and PA behaviors and weight loss [45].

The findings of this study highlight several important implications for improving CNSLMP. First, it is important to assess self-efficacy, knowledge, and motivation at the beginning of a program to identify those who are less likely to adhere to the program so that more focused efforts could be applied to improve adherence. Second, dietitians/nutritionists should explore tailored strategies aimed at improving participants' nutrition knowledge and their diet and PA self-efficacies. Third, given the low PA adherence, the PA component should be strengthened throughout the program.

The major strength of this study lies in the operationalization of dietary and PA adherence, which are the immediate outcomes of LMPs. The study results can help to fill the existing knowledge gaps in previous research that had limited practical implications for program improvement as the study authors mainly focused on factors associated with program attendance, self-monitoring, and weight-loss outcomes. Another strength is that the present study was conducted in a real-world setting with minimal experimental control. Therefore, the findings may

be readily translated into practice. However, the generalizability of the study findings is limited due to the short follow-up period (one month), high dropout rate, adoption of convenience sampling, and self-reporting of measures. Further research with a longer follow-up duration is warranted to investigate the long-term effect of psychological factors on adherence.

In conclusion, this study identified psychological predictors of adherence to an LMP during the weight-loss phase in a convenience sample of Chinese overweight and obese adults. The results of this study can help elucidate the modifiable psychological factors associated with adherence, provide evidence to develop service improvements, and allow better allocation of resources when designing and implementing more effective LMPs.

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## CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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