

## RESEARCH ARTICLE

# “Follow-the-Leader” domino weight loss effects in low-income Middle Eastern refugee communities: Disentangling macro average peer versus micro leader-driven effects in a randomized trial

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**Data availability statement:** As the trial was conducted in small communities, the dataset contains potentially identifying or sensitive information. Even with anonymization, some risk of identification remains. Therefore, data are available upon reasonable request. All such requests will be reviewed by the data access committee, which can be contacted at [info@microclinics.org](mailto:info@microclinics.org).

## Abstract

Behavioral health and economics rely on understanding underlying mechanisms of action. Drawing from a randomized controlled trial (RCT) conducted among low-income Jordanians and Palestinian refugee communities, this study investigates how individual motivations affect collective actions in a behavioral weight loss program within social networks. Participants were randomly assigned to one of three trial arms: Full Micro-clinic Social Network Intervention (MCP) with curriculum-activated and organic social network interactions; Basic MCP educational sessions with organic social network interactions; or Controls receiving standard care along with active and parallel monitoring. Analysis of the RCT data strongly indicates that behavioral change is repeatedly driven by a “Leader Domino Effect” rather than an average peer pressure. The estimated net leader domino effect for Full and Basic MCP, relative to the control group, is weight loss of 0.207 kg per two weeks (95% CI: 0.103 to 0.311) and 0.123 kg per two weeks (95% CI: 0.006 to 0.241), respectively, on subsequent weight loss. No effects were found for average classroom weight loss on subsequent weight loss. Findings indicate leadership influences exceed average group effects in understanding collective behavioral health and its implications for addressing societal challenges.

## Author summary

Understanding what drives collective behavior is essential for improving health outcomes and informing policy. This study investigates the impact of individual influence on group behavior in a community-based weight loss intervention. Drawing from a

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randomized controlled trial in low-income Jordanian and Palestinian refugee communities, participants were assigned to one of three groups: a Full Microclinic Program (MCP) with structured social network interactions, a Basic MCP with only educational sessions and organic peer engagement, or a Control group receiving standard care. By analyzing weight change over time, we found that behavior change was not driven by average group influence but by a distinct “Leader Domino Effect”—where one influential individual’s progress triggers a cascade of change in others. Participants in both Full and Basic MCP arms lost significantly more weight when exposed to leader-driven influence compared to controls. In contrast, average classroom weight loss had no measurable effect on individual outcomes. These findings suggest that harnessing natural leadership within social networks may be more effective than relying on general peer pressure, offering new directions for behavioral health interventions in resource-constrained settings.

## 1. Introduction

From gentrification to crime and from obesity to smoking, the relationship between micro motives and macro behaviors are fundamental to solving major social dilemmas. As Thomas Schelling [1] argued, such relationships constitute complex systems, involving a multiplicity of causal mechanisms. The Standing Ovation Problem [2] that eventuated from his work is one example that elucidates complex psychological, spatial and temporal dynamics underlying seemingly mundane collective behavior: what causes a room to stand in ovation?

Of vital importance are the following questions: 1) When do agents engage? 2) Where do they engage? 3) Why do they engage? 4) How do they engage? 4) What is the engagement effect and 5) In what sequence does the effect take hold? After the COVID-19 pandemic emerged, the relevance of these questions became all too well-understood both by epidemiologists and the general public. By contrast, they are not at all well understood concerning “non-communicable” disease (NCD) pandemics that are expected to cost \$47 trillion by 2050 [2,3]. In developing countries like Jordan, these trends pose even graver threats than they do in developed countries.

As is suggested by the term “non-communicable,” NCDs are categorized largely according to biological, rather than sociological mechanisms, regardless of epidemic potential. The fact that roughly nine out of ten cases of type-2 diabetes are preventable through dietary and lifestyle modification, demonstrates the need to highlight sociological epidemic mechanisms so that corresponding sociological public health interventions can be deployed.

In 2007, Christakis and Fowler [4] addressed this neglected area of research, arguing that obesity may spread through social ties, extending to three degrees of separation. Unlike their work on cooperative behavior [5], this study was observational, preventing the disentanglement of key phenomena: induction (causation) versus homophily (reverse causation) versus confounding (genetic, temporal). As argued by Lyons [6], the statistical analysis conducted by Christakis and Fowler may be flawed and might not support the claimed conclusion. In particular, the models used in the analysis and the methods for model estimation raise questions. The statistical significance tests conducted on these estimates may not demonstrate the proposed differences. In a related study, Leahey et al. [7] found evidence suggesting that weight-loss motivation can spread among the social networks of overweight and obese young adults attempting to lose weight.

However, a crucial limitation of these studies is that they do not address the reverse question: can social network dynamics be leveraged to promote healthy behaviors? In a study

analyzing the online activity and weight changes of members in an online weight management system [8], individuals with higher social embeddedness within the network were found to experience greater weight loss. The finding was derived from an observational study and is therefore subject to similar limitations as the work by [4].

These questions have recently been addressed by several experiments, quasi-experiments and observational studies performed by this group. Targeting infectious and non-infectious diseases in vastly different geographical, economic, and cultural contexts (Appalachia-Kentucky, Jordan, and Kenya), we have identified key causal pathways activated by the Microclinic Social Network Program that are associated with disease prevention and management. The intervention improved social support, increased disclosure, and reduced stigma for HIV/AIDS [9]. It improved dietary and physical activity behaviors as well as weight loss, HbA1c, and blood pressure for diabetes, obesity, and cardiovascular disease [10–12]. Importantly, these studies controlled for homophily and confounding through randomization.

Questions still remain, however, concerning the temporal dimensions of behavior change: do social networks cause weight improvements to happen in parallel; or do they, like cooperative behaviors [5], cascade through social networks? In this paper, we present, for the first time, evidence from a randomized trial conducted among low income Jordanians and Palestinian refugees to investigate the cascading mechanisms of social network induction on weight loss. We call these the “Follow-the-leader domino effect” and “Average peer effect”.

## 2. Methods

### 2.1. Study design

We conducted this trial (US Clinical Trials Registry Number: NCT01596244) in collaboration with Queen Rania’s Royal Health Awareness Society and the Jordanian Ministry of Health (MoH). A three-arm randomized controlled trial was conducted to test the impact of a 6-month *Microclinic Social Network Intervention* (MCP) on diabetes management behavioral risk factors, and weight and metabolic outcomes in Amman, Jordan. The MCP was designed as a sort of game to activate forces of competition and cooperation through a process we call “Managed Coopetition”. Social clusters dubbed “Microclinics” consisted of 2–6 individuals and participated with other social clusters in broader classroom, physical activity, health education and social activity sessions managed by health-educators. Individual members cooperated with and competed with others as they pursued the ultimate payoff - weight loss.

Participants were recruited through the MoH care centers using a combination of community outreach campaigns and health center patient recruitment between October 2011 and May 2013. Men and women 18 years or older were eligible to participate in the study if they had been previously diagnosed with diabetes, were diagnosed with diabetes or pre-diabetes during recruitment, or were at risk of diabetes. Diabetes and pre-diabetes were confirmed with a fasting plasma glucose (FPG) test at recruitment, using criteria of 100–125 mg/dL for pre-diabetes, and 126 mg/dL or higher for diabetes. Risk of diabetes was defined as having a history of diabetes in close family members AND being overweight/obese, or as having a family history of diabetes AND having either high BP or high serum cholesterol. Pregnant and/or severely ill participants were not eligible.

### 2.2. Randomization

Randomization in this study was stratified based on two factors: the study center, with three different centers in total, and the study cohort waves, of which there were up to four. This stratification led to the creation of a total of nine study center-cohorts.

The term "units" refers to two categories of individuals who participated in the study screenings. The first category includes individuals who attended the screenings alone. The second category consists of multiple individuals who attended the screenings together, often comprising family members and friends. The majority of participants fell into the second category. Units in the second category were randomized together, meaning that they were collectively assigned to one of the three arms of the study. This assignment occurred regardless of whether the individuals within these units attended the screenings as singles or as part of a group. All randomized units, regardless of whether they attended screenings alone or as part of a group, met the inclusion criteria for the study.

We employed a randomization process to assign units to different classrooms, each of which received one of three distinct interventions. These classrooms were essentially stable groups of participants who interacted together on a weekly basis throughout the intervention period, based on their assigned randomized arm.

The majority of units randomized into any of the three arms consisted of groups of individuals who initially attended the screenings as friends and family before the randomization process. After randomization, we referred to these social groups as "Microclinics." Some units were initially solo individuals across all three arms. In the Full MCP Intervention Arm (Arm A), solo individuals were actively encouraged to form Microclinics with other units after randomization. These Microclinics, whether composed of pre-existing groups of friends and family or formed after randomization, functioned as friendship circles within the same classroom, fostering interaction and mutual support among participants. In contrast, in the Basic MCP Intervention (Arm B) and the Control (Arm C), initially solo individuals were not encouraged to form Microclinics post randomization.

Furthermore, in the Full MCP program, ancillary support from adjunct non-trial individuals who were not part of the initial randomization process were allowed to support the Full MCP participants. These individuals participated in the educational programs in a supportive role alongside the original participants (nodes) as friends or family members post-randomization. These supporting individuals attended and engaged in Arm A program activities and were referred to as "secondaries", forming part of social circles known as "Expanded Microclinics". To maintain the integrity of the trial's randomization, only the initially recruited nodes were included in our randomized trial analysis, meaning data from secondaries were excluded.

Microclinics, regardless of the arm, typically consisted of 2 to 6 individuals. These Microclinic groups were nested within MCP classrooms, which, in turn, could comprise up to 26 individuals. These classrooms were further organized within 3 community centers, and all of these were part of 4 temporal cohorts. A flow diagram illustrating the randomization process is provided in [S1 Fig](#).

### 2.3. Study intervention

A "Microclinic" refers to a social infrastructure rather than a physical structure. These are groups of friends and family who collectively transform private spaces into health-focused environments. Within Microclinic groups, participants influence each other positively to adopt healthier behaviors, such as maintaining a healthy diet, engaging in regular physical activity, monitoring their health, and adhering to prescribed medications. The educational content of the MCP is encapsulated by the "4 M's": Meals, Movement, Monitoring, and Medication.

The primary MCP interventions were delivered over a period of 6 months (equivalent to 28 weeks), involving 14 program sessions for Arms A and B, or 14 concurrent check-in appointments for Arm C. These sessions or appointments were scheduled in parallel across the different arms, with the first intervention cohort commencing in January 2012. Follow-up data was collected post-intervention, approximately 2 years later, spanning data collected between 21 to 28 months (with a median of 24 months) from the baseline.

- Intervention Arm A: Participants in this arm received the Full MCP educational program. Additionally, they actively engaged in small Microclinic groups, completing behavior change assignments both within and outside classrooms. Before each class, Arm A participants were taught a social network-based theory of change emphasizing the influence of behaviors within communities and the potential for self-improvement as well as community-level change.
- Intervention Arm B: This arm consisted of the Basic MCP intervention, with participants receiving the same educational content as Arm A. While many participants in this arm knew each other socially or were connected through their wider neighborhood, formal Microclinic group activities were not assigned. Classroom discussions were also not initiated by facilitators but were self-initiated by participants. The key distinction here was that social interaction occurred more organically.
- Intervention Arm C (Control Group): Participants in this arm did not attend any classes. However, they had individual appointments scheduled on weekdays, coinciding with the matching week of concurrently run Arm A and B classroom programs. During these appointments, participants collected their biometric data and underwent lab measurements without any additional interactions or programming.

A detailed curriculum for Intervention Arms A and B is provided in the [S1 Text](#). Specifically, the curriculum covers topics such as Diabetes Overview, Monitoring Hypo/Hyperglycemia, Nutrition for Diabetic Individuals, a Nutritionist-led Vegetable Variety Cooking Class, Diabetes Complications, Physical Activity, and more. A key distinction between Arms A and B is that social interactions among participants were structured and directed in Arm A, whereas they occurred organically in Arm B.

As part of the program, food was provided to participants, who also received instruction on preparing nutritious, cost-effective meals. They were encouraged to engage in collaborative cooking outside the program setting. Fortunately, the local cuisine represents a variation of the healthy Mediterranean diet, which is heavy on beans (hummus, fava), olive oil, fresh fruit and vegetables. This dietary pattern remains relatively affordable compared to red meat and fast food options.

A unique aspect of the intervention, which distinguishes it from other social network interventions, involved the sharing of clinical outcomes among participants during each of the 14 sessions in Arm A and B [13]. During these sessions, participants within the same MCP classrooms were encouraged to share their weight change progress between sessions. Special recognition was awarded to the individual who achieved the greatest weight loss in each session. Participants who achieved the greatest weight loss were publicly recognized during class sessions, with the amount of weight loss explicitly announced, thereby making their accomplishments highly visible to the entire class. This unique aspect enables a formal statistical examination of whether and to what extent the magnitude of a leader's weight loss affects the other individuals within the same MCP classroom.

Additionally, it is reasonable to expect that an individual's weight loss may be influenced by the overall weight loss within their class. Although the average weight loss per class between

sessions was not formally disclosed, participants were encouraged to share their progress with one another, suggesting they had some awareness of the group’s average weight loss. Combined with the fact that special recognition was awarded to the individual with the greatest weight loss, this allows for a statistical examination of both the impact of the leader’s weight loss and the class’s average weight loss on individual outcomes.

We illustrate the Leader domino effect and the peer average effect through visualizations. Fig 1 demonstrates the Leader domino effect, while Fig 2 depicts the peer average effect. Fig 3 and Fig 4 present both effects for Intervention Arm A and its corresponding control, respectively. Similarly, Fig 5 and Fig 6 illustrate both effects for Intervention Arm B and its control.

### 2.4. Sample size

Randomization of individuals was allocated with the ratio of 3:1:1, with resulting group sizes of n=540, 186, and 188 in arms A, B, and C, respectively.

### 2.5. Data collection

Clinical data was collected by trained nurses/study personnel at MoH centers. We collected data on clinical measures (height, weight, waist circumference, BP, HbA1c, and FBG), health knowledge, behavior, and demographic data (including survey questions on diabetes/obesity knowledge, healthcare access, exercise/dietary habits, and education status). Survey and social network data were collected via paper-based surveys, administered by nurses/coordinators.

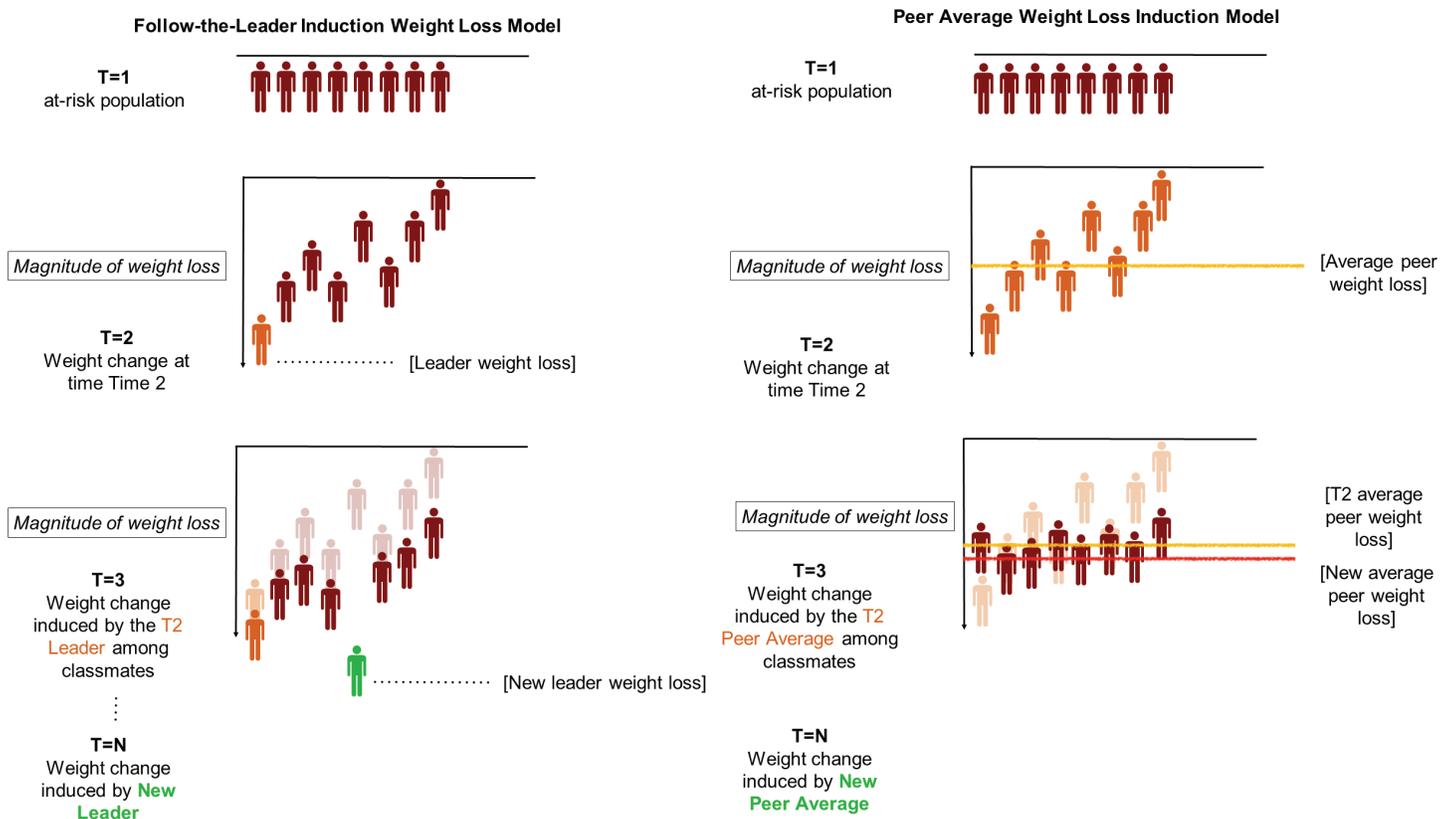


Fig 1. Illustrates the Leader domino effect.

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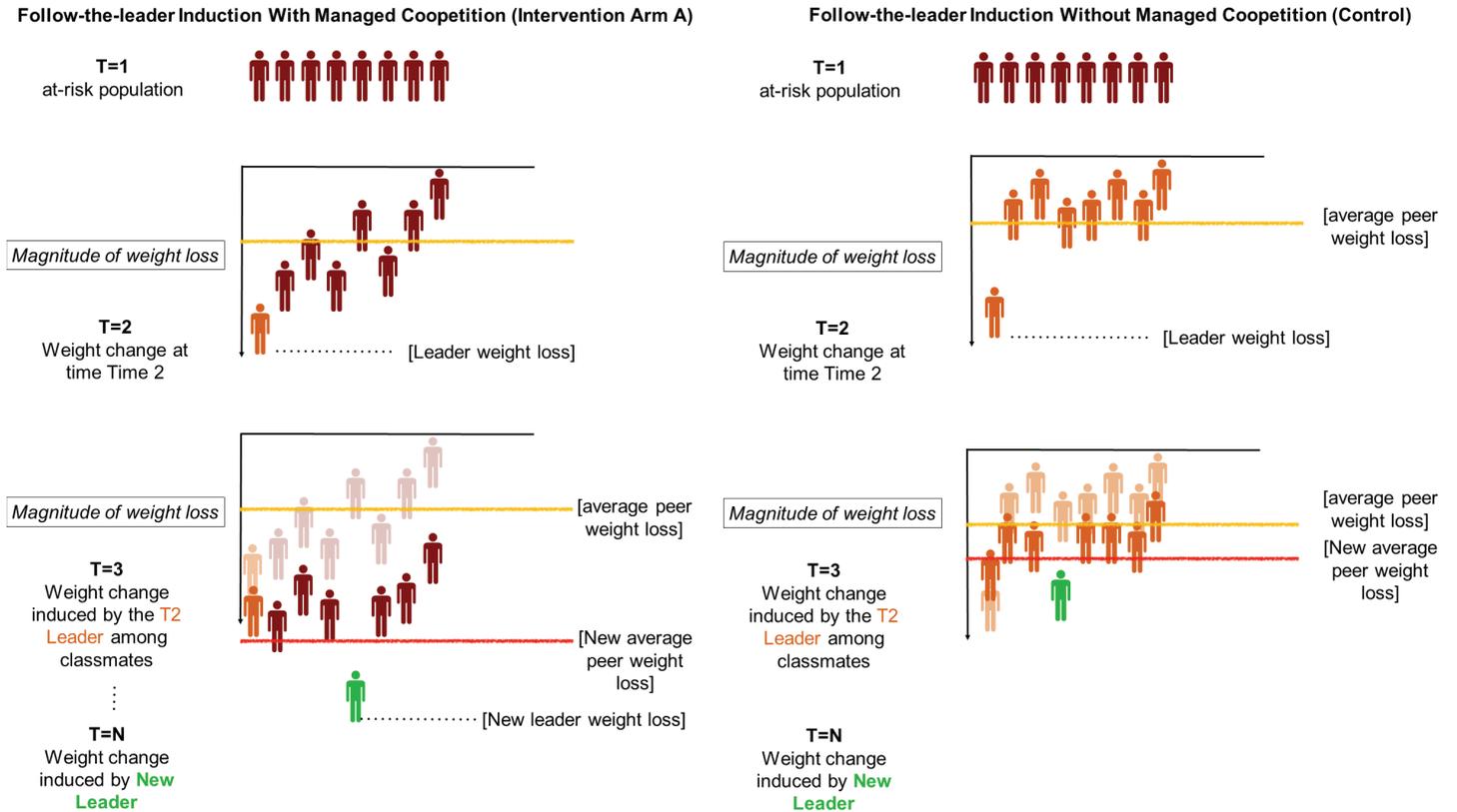


Fig 2. Depicts the peer average effect.

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Participants were required to fast before their appointment. Height was measured using a hospital and home scale with height meter; weight was measured using Health Scale SVR160. Fasting Plasma glucose was measured via finger prick using AccuCheck-Performa. Digital readings on this device converted blood glucose concentrations to plasma glucose concentrations, conforming to international reporting standards. Omron and A&D blood pressure cuffs were used to measure blood pressure; both types measured systolic blood pressure (SBP) and diastolic blood pressure (DBP) three consecutive times; mean arterial pressure was calculated using the clinical formula  $MAP = (SBP + (2 \times DBP))/3$ . HbA1c levels were tested at MoH Lab Centers via High Performance Liquid Chromatography (HPLC). Laboratory analysis for HbA1c was masked, meaning technicians were not aware which treatment group the samples came from. No masking took place for other outcome measurements. Information on interpersonal relationships among participants was also collected, covering various types such as spouses, family members, relatives, friends, and acquaintances.

### 2.6. Statistical analysis

We investigate the presence of a cascading mechanism of social network influence on weight loss using a multilevel mixed effects modelling framework. A fundamental premise in our model is that the weight loss of individuals is influenced by the weight loss of other individuals within the same class. Specifically, our hypothesis posits that the weight change of individuals could be influenced by the class leader, referring to the person who achieves the

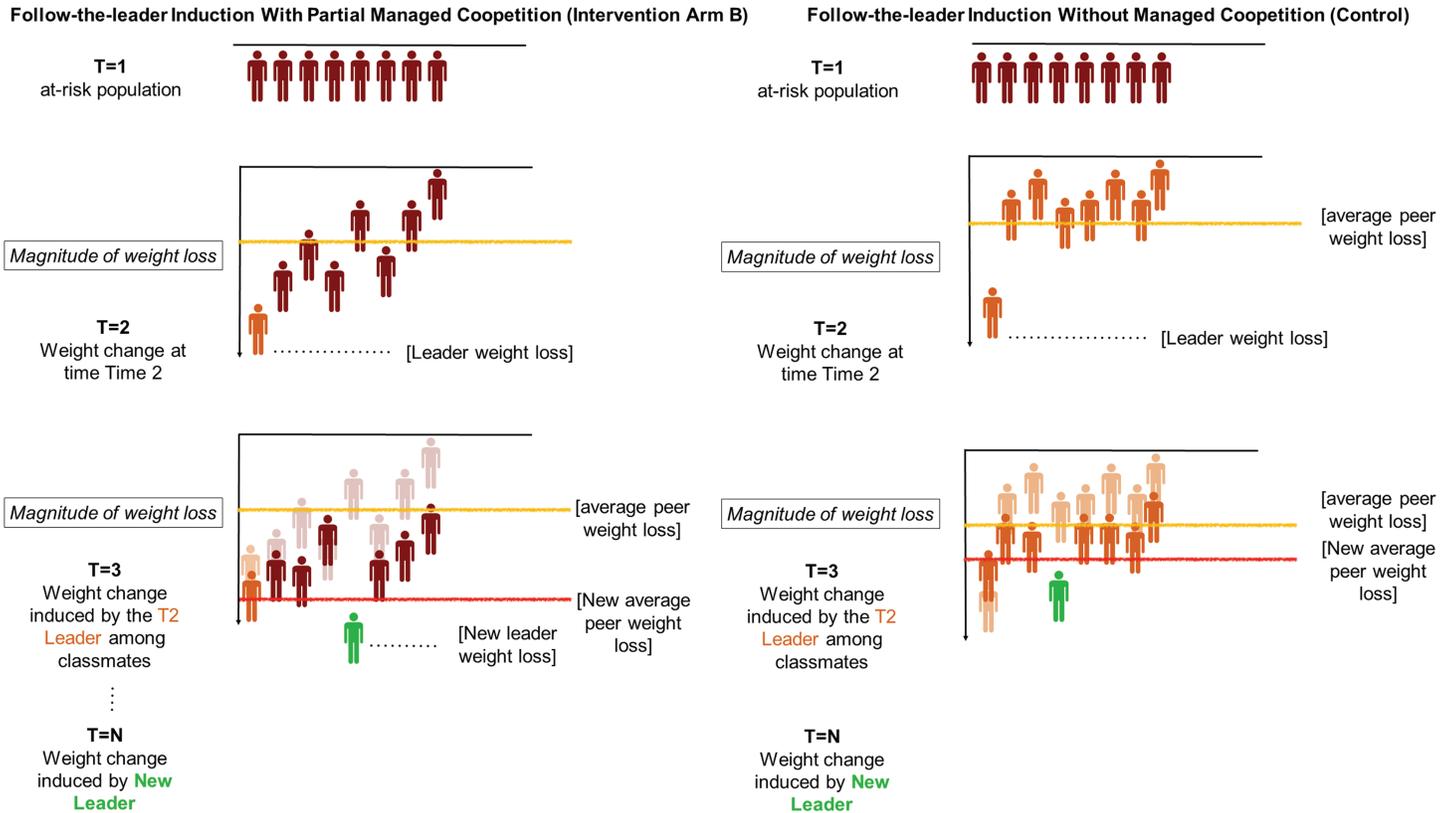


Fig 3. Presents both Leader domino effect and peer average effect for Intervention Arm A.

<https://doi.org/10.1371/journal.pcsy.0000052.g003>

most significant weight loss, or the collective average weight loss of the class, or possibly a combination of both factors.

Our randomized trial offers a distinctive chance to evaluate the existence and importance of these effects. This evaluation involves comparing the estimated effects in the Full and Basic social network groups with those in the control group. For a comprehensive understanding of the proposed models, essential terminologies are outlined in Table 1.

Before delving into the details of the multilevel models used in the analysis, we will introduce some notation. Let  $y_{i,t}$  denote the weight change of an individual  $i$  during the time period  $t$ , where  $i = 1, \dots, N$  and  $t = 1, \dots, T$ . Here,  $N$  is the total number of participants and  $T$  is the number of time periods. We let  $a_i$  denote the trial arm to which individual  $i$  was allocated ( $a_i = 2$  for Full MCP,  $a_i = 1$  Basic MCP, and  $a_i = 0$  Control), and let  $c_i$  denote the class to which individual  $i$  was assigned. Let  $\mathbf{z}_i$  and  $\mathbf{x}_{i,t}$  denote the time invariant and time variant covariates for individual  $i$ , respectively. The time invariant and time variant covariates include age, gender, weight at baseline, diet, physical activity, medications, blood relationship between the leader and the follower, and Ramadan and political events. In particular, Ramadan has a significant impact on eating and fasting practices in Muslim societies, with with a previous study in Jordan reporting related effects on body weight [14,15].

**2.6.1. Leader domino effect.** We propose that the person in a class who achieves the most significant weight loss within a specific time frame  $t - 1$  (referred to as the leader) will impact the weight loss of individuals within the same class during the subsequent time period  $t$ . The multilevel linear mixed effects model used in the analysis is described as follows (**Model 1**):

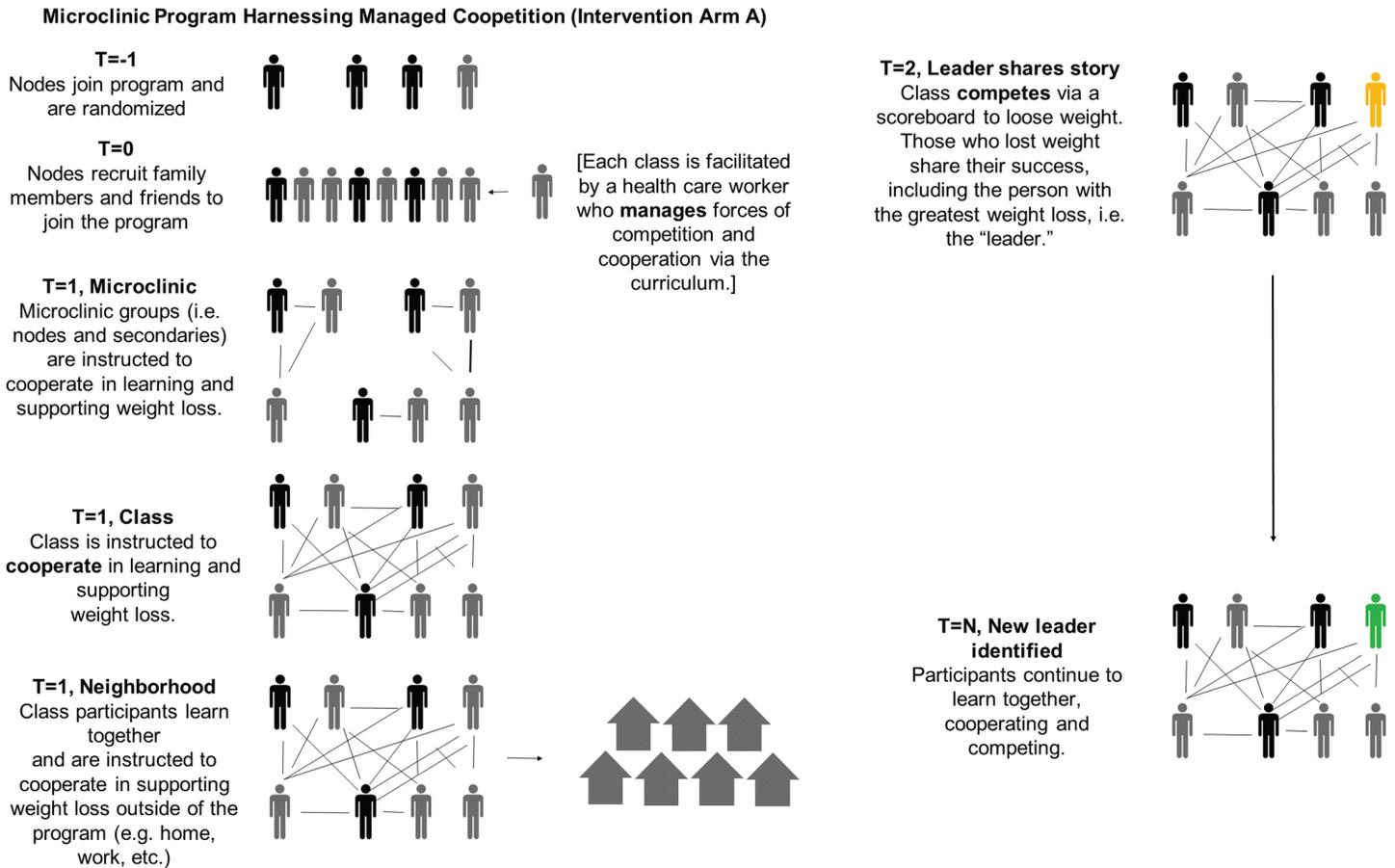


Fig 4. Presents both Leader domino effect and peer average effect for the corresponding control.

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Leader domino effect):

$$y_{i,t} = \beta_{0i} + \beta_1 y_{i,t-1} + \tau_{a_i}^{(1)} \max_{j:c_j=c_i} y_{j,t-1} + \gamma^T \mathbf{z}_i + \eta^T \mathbf{x}_{i,t} + \epsilon_{i,t}. \tag{1}$$

Here  $\beta_{0i}$  is a random intercept parameter which depends on the individual  $i$ , and the parameter  $\beta_1$  captures the effect of an individual’s weight change in the previous time period on the weight change over the subsequent time period. The term  $\max_{j:c_j=c_i} y_{j,t-1}$  denotes the weight change of the leader in the same class as individual  $i$  for time period  $t - 1$ , and  $(\tau_1^{(1)}, \tau_2^{(1)})$  are the main parameters of interest that represents the *net leader domino effect*. The associated vectors of parameters for time invariant and time variant covariates are denoted by  $\gamma$  and  $\eta$ , respectively, and  $\epsilon_{i,t}$  is the random error term.

We further extend the random intercept component of the model by incorporating hierarchical nesting of individuals (individuals within MCP classrooms, within class days, within community centres, and within temporal cohort waves), with random intercepts at each hierarchical level.

A natural question arises is whether leaders’ weight change has longer term impact on the followers beyond the immediate effect captured by  $\tau_{a_i}^{(1)}$ . To address this question, we extend the model in (1) by incorporating the weight change of the former leader (**Model 2: Leader**

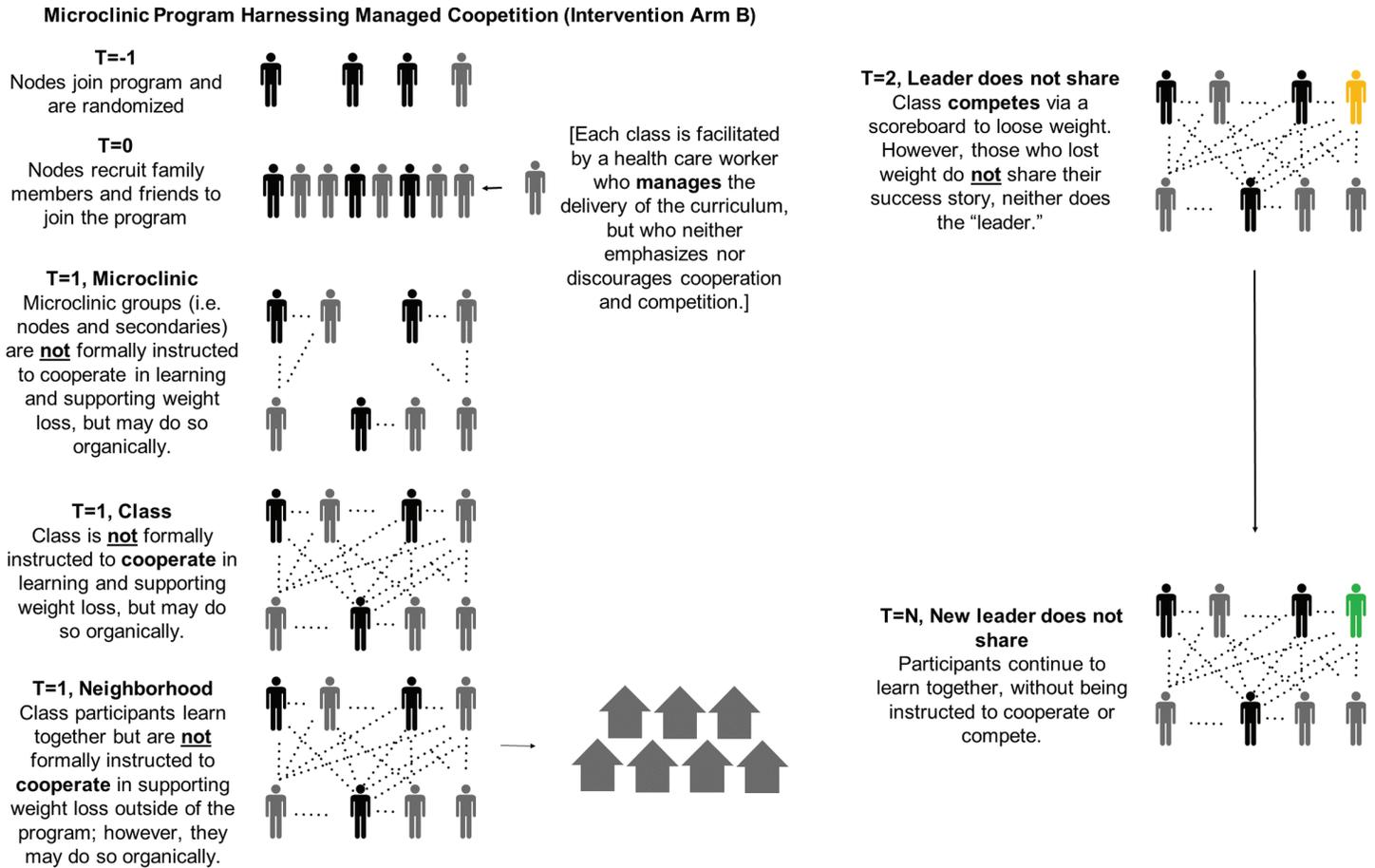


Fig 5. Shows both Leader domino effect and peer average effect for Intervention Arm B.

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and former leader domino effects):

$$y_{i,t} = \beta_{0i} + \beta_1 y_{i,t-1} + \tau_{a_i}^{(0)} \max_{j:c_j=c_i} y_{j,t-2} + \tau_{a_i}^{(1)} \max_{j:c_j=c_i} y_{j,t-1} + \gamma^T \mathbf{z}_i + \eta^T \mathbf{x}_{i,t} + \epsilon_{i,t} \tag{2}$$

where  $\max_{j:c_j=c_i} y_{j,t-2}$  is the weight change of the leader at time period  $t-2$  (the former leader) and  $(\tau_1^{(0)}, \tau_2^{(0)})$  capture the net former leader domino effects.

**2.6.2. Average peer effect.** We also investigate the effect of average weight change in a class on an individual’s weight change, in contrast to the hypothesis on the leader domino effect. The multilevel model is expressed as follows (**Model 3: Average peer effect**):

$$y_{i,t} = \beta_{0i} + \beta_1 y_{i,t-1} + \tau_{a_i}^{(2)} \frac{1}{n_i} \sum_{j:c_j=c_i} y_{j,t-1} + \gamma^T \mathbf{z}_i + \eta^T \mathbf{x}_{i,t} + \epsilon_{i,t}, \tag{3}$$

where  $\frac{1}{n_i} \sum_{j:c_j=c_i} y_{j,t-1}$  is the average weight change for individuals in the same class as individual  $i$  at time period  $t-1$ , where  $n_i$  is the number of individuals in this class. The parameter  $(\tau_1^{(2)}, \tau_2^{(2)})$  capture the average peer effect for the Basic and Full MCP relative to control.

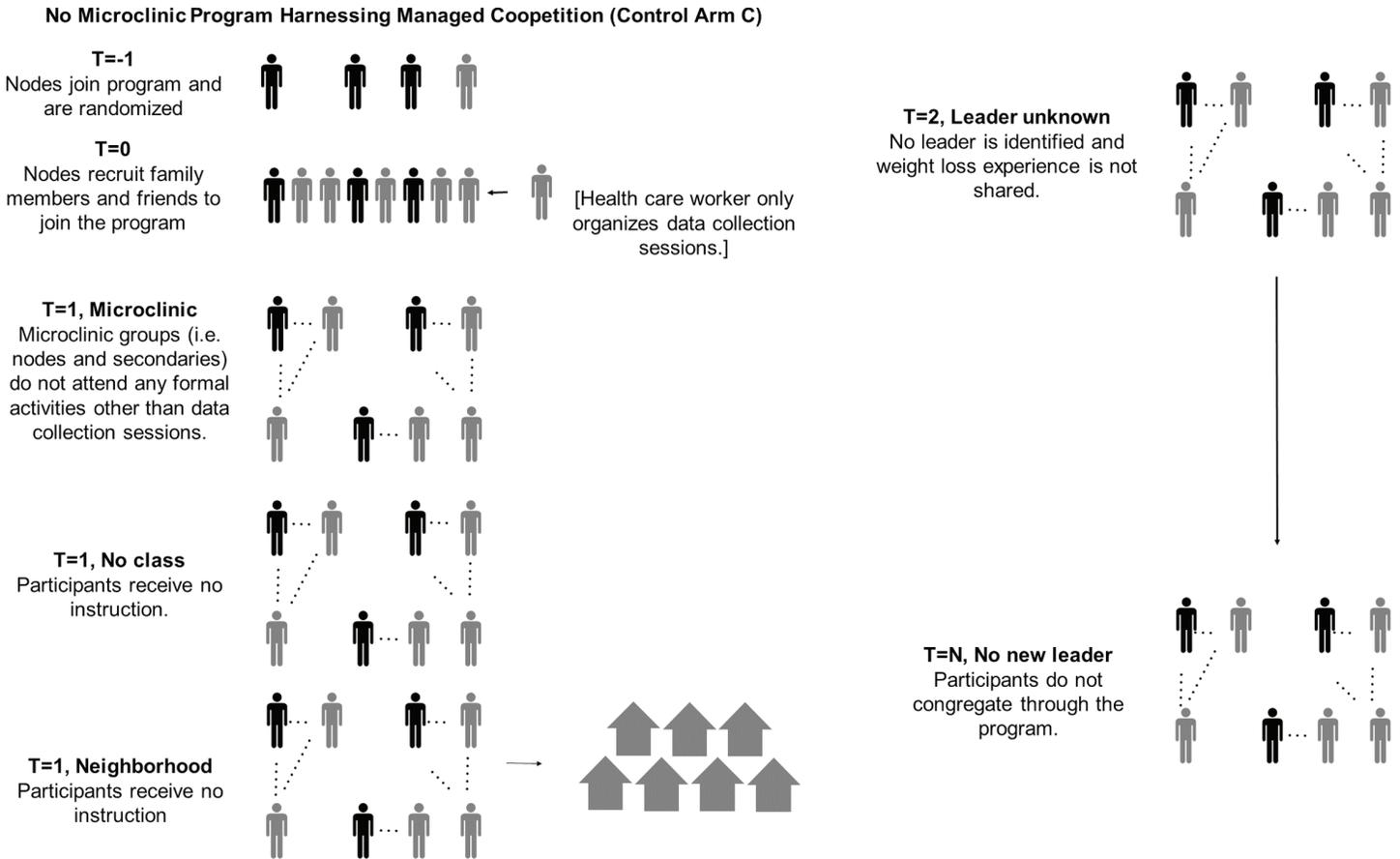


Fig 6. Presents both Leader domino effect and peer average effect for the corresponding control.

<https://doi.org/10.1371/journal.pcsy.0000052.g006>

**2.6.3. Joint effect.** Finally, we investigate the joint leader domino effect and the average peer effect (**Model 4: Joint Model**):

$$y_{i,t} = \beta_{0i} + \beta_1 y_{i,t-1} + \tau_{a_i}^{(1)} \max_{j:c_j=c_i} y_{j,t-1} + \tau_{a_i}^{(2)} \frac{1}{n_i} \sum_{j:c_j=c_i} y_{j,t-1} + \gamma^T \mathbf{z}_i + \eta^T \mathbf{x}_{i,t} + \epsilon_{i,t}. \tag{4}$$

Statistical analyses were performed using R software (version 4.1.2).

### 3. Results

Study participants’ baseline characteristics across all three treatment arms were generally similar (**Table 2**), with mean age in Arm A being a minor exception (mean age 54.2 years versus Arm B 56.6 years, versus Arm C 56.2 years). Mean BMI was similar across the three arms (Arm A 33.6 kg/m<sup>2</sup> versus Arm B 33.5 kg/m<sup>2</sup> versus 33.4 kg/m<sup>2</sup>).

Furthermore, 19% of participants had a highest education level of primary school, 29% had completed secondary or high school, and 12% held a bachelor’s degree or higher. Additionally, 83% of participants were married, and 56% lived in households with five or more members. Notably, 97% had not received any diabetes education before the trial.

**Table 1. Key terminologies.**

| Terminology                     | Definition  |
|---------------------------------|---|
| Session                         | A meeting in which participants come together   |
| Class                           | A collection of microclinics allocated to the same classroom  |
| Microclinic                     | A pre-existing social cluster consisting of 2-6 individuals   |
| Leader                          | An individual who had achieved the highest weight loss in the previous session among all participants within the same class   |
| Former Leader                   | An individual who had achieved the highest weight loss in the session immediately preceding the previous session among all participants within the same class. Note: the leader and the former leader can be the same person.   |
| Follower                        | The definition of a follower can vary depending on the specific model being used. If the statistical model considers only the leader, then a follower is defined as any individual who is not the leader. However, if the statistical model includes both the leader and the former leader, the definition of a follower expands to include any individual who is neither the leader nor the former leader. |
| Leader Domino Effect            | The percentage of leader's weight loss that a follower is expected to achieve in the subsequent session.  |
| Net Leader Domino Effect        | Leader domino effect for the intervention group minus leader domino effect for the control group.   |
| Former Leader Domino Effect     | The percentage of former leader's weight loss that a follower is expected to achieve in the subsequent session.   |
| Net Former Leader Domino Effect | Former leader domino effect for the intervention group minus former leader domino effect for the control group.   |
| Average Peer Effect             | The percentage of average weight change of a class that an individual is expected to achieve in the subsequent session.   |
| Net Average Peer Effect         | Average peer effect for the intervention group minus average peer effect for the control group.   |

<https://doi.org/10.1371/journal.pcsy.0000052.t001>

**Table 2. Baseline characteristics of study participants.**

| Characteristic, mean (SD) or %  | Full MCP (n = 537) | Basic MCP (n = 186) | Control Group (n = 187) |
|---------------------------------|--------------------|---------------------|-------------------------|
| Age, years                      | 54.2               | 56.6                | 56.2                    |
| Women, (%)                      | 66.5               | 67.0                | 65.0                    |
| Weight, kg                      | 85.9               | 85.0                | 86.0                    |
| Height, m                       | 160.3              | 159.6               | 160.3                   |
| BMI, kg/m <sup>2</sup>          | 33.6               | 33.5                | 33.4                    |
| Systolic blood pressure, mm Hg  | 129.1              | 131.7               | 132.2                   |
| Diastolic blood pressure, mm Hg | 81.3               | 81.0                | 81.3                    |
| Mean arterial pressure, mm Hg   | 97.2               | 97.9                | 98.3                    |
| HbA1c (%) (SD)                  | 6.91               | 6.90                | 6.91                    |
| Fasting plasma glucose*, mg/dL  | 147.8              | 142.8               | 145.7                   |

\* Baseline fasting glucose average of first and second weeks.

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The results obtained from fitting the four models are presented in Table 3. In the leader domino effect model (Model 1), we found that the net leader domino effect was strongly statistically significant for both Full and Basic MCP ( $p < 0.001$  for the joint Wald test of Full and Basic MCP versus control). The estimated net leader domino effects were 0.207 (95% CI: 0.105 to 0.309) and 0.119 (95% CI: 0.004 to 0.235) for Full and Basic MCP, respectively. This suggests that, relative to the control group, a 1 kg weight loss of the leader in Full (Basic) MCP resulted in a weight loss of 0.207 (0.119) kg for the followers over the subsequent session.

In the leader and former leader domino effects model (Model 2), we observed a significant positive net leader domino effect for both Full and Basic MCP relative to the control group, with an estimated effect of 0.207 (95% CI: 0.103 to 0.311) and 0.123 (95% CI: 0.006 to 0.241),

**Table 3. Multilevel mixed effect models results (Model 1–4).**

| Parameters                         | Model 1<br>Estimate<br>(95% CI) | Model 2<br>Estimate<br>(95% CI) | Model 3<br>Estimate<br>(95% CI) | Model 4<br>Estimate<br>(95% CI) |
|------------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Current leader domino effect (net) |                                 |                                 |                                 |                                 |
| Full MCP                           | 0.207<br>(0.105, 0.309)         | 0.207<br>(0.103, 0.311)         |                                 | 0.222<br>(0.111, 0.333)         |
| Basic MCP                          | 0.119<br>(0.004, 0.235)         | 0.123<br>(0.006, 0.241)         |                                 | 0.135<br>(0.011, 0.259)         |
| Control                            | ref                             | ref                             |                                 | ref                             |
| Joint Wald test                    | $p < 0.001$                     | $p < 0.001$                     |                                 | $p < 0.001$                     |
| Former leader domino effect (net)  |                                 |                                 |                                 |                                 |
| Full MCP                           |                                 | 0.024<br>(-0.088, 0.136)        |                                 |                                 |
| Basic MCP                          |                                 | -0.023 (-0.151, 0.104)          |                                 |                                 |
| Control                            | ref                             | ref                             |                                 | ref                             |
| Joint Wald test                    |                                 | $p = 0.55$                      |                                 |                                 |
| Average peer domino effect (net)   |                                 |                                 |                                 |                                 |
| Full MCP                           |                                 |                                 | 0.268<br>(0.017, 0.520)         | -0.163<br>(-0.459, 0.133)       |
| Basic MCP                          |                                 |                                 | 0.194<br>(-0.080, 0.468)        | -0.098<br>(-0.418, 0.222)       |
| Control                            | ref                             | ref                             | ref                             | ref                             |
| Joint Wald test                    |                                 |                                 | $p = 0.11$                      | $p = 0.5$                       |

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respectively. On the contrary, former leader-to-followers effect was not found to be significant for either Full or Basic MCP, indicating that the weight change of individuals was not associated with the weight change of the former leader.

In the average peer effect model (Model 3), we observed a statistically significant average peer effect for Full MCP relative to control, with an estimated effect of 0.268 (95% CI: 0.017 to 0.520). A smaller positive average peer effect of 0.194 (95% CI: -0.080, 0.468) was observed for the Basic MCP relative to control.

In the joint model (Model 4), we found that the leader domino effect significantly outweighs the average peer effect. The estimated net leader domino effects were 0.222 (95% CI: 0.111 to 0.333) for the Full MCP and 0.135 (95% CI: 0.011, 0.259) for the Basic MCP relative to control. These estimates are consistent with those obtained in Model 1 and 2. In comparison, the average peer effect for both Full and Basic MCP were not found to be significantly different from 0.

To evaluate the sensitivity and robustness of the findings, [S2 Text](#) presents the results of the sensitivity analyses and alternative model specifications.

## 4. Discussion

Do group norms shape individual behaviors or do individuals shape group norms? Our analysis demonstrates that "current leaders," showing the greatest magnitude of change, shape group norms, ultimately creating a domino cascade. Importantly, this peacocking behavior corresponds to underlying aspirations of the group. Those who enrolled in our program likely did so to improve their metabolic health; therefore they were receptive to dramatic displays of weight loss by "current leaders".

Yet we find that weight loss "leadership" is transitory as the torch is passed from a current leader to a new leader. Our analysis of current versus former leaders reinforces this finding; the weight loss domino cascade is driven by "current" but not former leaders. At least

with respect to weight change, leaders are not simply “born” as such; they switch to being followers, and vice versa, at various points in time.

In addition to temporal considerations, we discovered that weight change leadership is an individual leader-driven characteristic at each time point. Given the widely accepted wisdom that group peer-pressure shapes individual norms, we wanted to disaggregate the leader from the average peer effect. We rather surprisingly discovered that the average peer effect was not significant on the individual in the presence of leader domino effect. Thus, the peer-pressure phenomenon, which extends well beyond weight change, may in fact also be a follow-the-leader domino effect and should be investigated.

From our analyses, we infer that follow-the-leader domino effects are indeed causal, as we disentangled induction versus homophily versus confounding. Our results show, for the first time, that weight loss not only socially propagates; it can also be engineered by health systems to do so. Hence, we see a more profound effect in Arm A, where a win-win “Managed Cooperation” game is underway. Part of this process of balancing these cooperative and competitive forces involves inspiring collective weight loss by recognizing individual achievement.

Finally, our results address some basic questions about behavioral cascades: when, where, why, how, what, and when [16]. In brief, non-placebo class participants engage in defined and undefined spaces at defined and undefined times with varying degrees of social network dosing. They likely do so for a multiplicity of reasons yet to be further studied. Depending on their intervention Arm randomized assignment, they combined varying degrees of competition and cooperation. Ultimately, weight loss cascaded.

Given the alarming economic and humanitarian costs of obesity to the global economy, preventing and managing the disease via self-propagating social norms could be a more effective and cost efficient strategy for public health, by orders of magnitude.

## 5. Limitations

The study is not without its limitations; it was conducted in low-income refugee communities and a conflict adjacent setting. Although other studies have supported the efficacy of the Microclinic Program in Lebanon, West Bank, Gaza, Appalachia-Kentucky, and Kenya for preventing and managing HIV/AIDS, obesity, and diabetes in low income settings, the specific models used in this paper were not replicated due to a lack of data [9–12]. Therefore, while we believe this study’s results have the potential to be generalized to these other geographical contexts due to similarly positive responses to the Microclinic Program, further studies are needed to validate this. We explored potential mechanisms for the propagation of weight loss in social networks. Although these mechanisms are intuitive, it’s essential to note that alternative weight propagation mechanisms cannot be entirely ruled out. Finally, the authors were also unable to determine whether the impact of the social propagation extended to people outside the trial.

## Supporting information

### **S1 Fig. Flow diagram of randomization.**

(EPS)

### **S1 Text. Detailed curriculum of intervention.**

(PDF)

### **S2 Text. Results of sensitivity analyses and alternative model specifications used to assess the robustness of the findings.**

(PDF)

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## References

1. Schelling T. Micromotives and macrobehavior. New York: W. W. Norton & Company. 1978.
2. Miller J, Page S. The standing ovation problem. *Complexity*. 2004;9(5):8–16.
3. Bloom D, Cafiero E, Jané-Llopis E, Abrahams-Gessel S, Bloom L, Fathima S. The Global Economic Burden of Noncommunicable Diseases. 8712. Program on the Global Demography of Aging. 2012.
4. Christakis NA, Fowler JH. The spread of obesity in a large social network over 32 years. *N Engl J Med*. 2007;357(4):370–9. <https://doi.org/10.1056/NEJMsa066082> PMID: 17652652
5. Fowler JH, Christakis NA. Cooperative behavior cascades in human social networks. *Proc Natl Acad Sci U S A*. 2010;107(12):5334–8. <https://doi.org/10.1073/pnas.0913149107> PMID: 20212120
6. Lyons R. The spread of evidence-poor medicine via flawed social-network analysis. *Statist Politics Policy*. 2011;2(1). <https://doi.org/10.2202/2151-7509.1024>
7. Leahey TM, Gokee LaRose J, Fava JL, Wing RR. Social influences are associated with BMI and weight loss intentions in young adults. *Obesity (Silver Spring)*. 2011;19(6):1157–62. <https://doi.org/10.1038/oby.2010.301> PMID: 21164501
8. Poncela-Casasnovas J, Spring B, McClary D, Moller AC, Mukogo R, Pellegrini CA, et al. Social embeddedness in an online weight management programme is linked to greater weight loss. *J R Soc Interface*. 2015;12(104):20140686. <https://doi.org/10.1098/rsif.2014.0686> PMID: 25631561
9. Hickey MD, Ouma GB, Mattah B, Pederson B, DesLauriers NR, Mohamed P, et al. The Kanyakla study: randomized controlled trial of a microclinic social network intervention for promoting engagement and retention in HIV care in rural western Kenya. *PLoS One*. 2021;16(9):e0255945. <https://doi.org/10.1371/journal.pone.0255945> PMID: 34516557
10. Zoughbie DE, Rushakoff JA, Watson KT, Bui N, Ireifij A, Farraj RS, et al. A social-network behavioral health program on sustained long-term body weight and glycemic outcomes: 2-year follow-up of a 4-month Microclinic Health Program in Jordan. *Prev Med Rep*. 2018;13:160–5. <https://doi.org/10.1016/j.pmedr.2018.12.002> PMID: 30596007
11. Ding E, Prescott M, Watson K, Bui N, Makarechi L, Zoughbie D. Microclinic social network lifestyle intervention for weight loss and obesity management: a 10-month randomized controlled trial. *Circulation*. 2013;127(suppl\_12):A009–A009.
12. Ding E, Watson K, Bui N, Makarechi L, Lang L, Prescott M, et al. Randomized trial of social network lifestyle intervention for obesity: microclinic intervention results and 16-month follow-up. *Circulation*. 2013;128:2706.

13. Zoughbie DE, Huddleston D, Ding EL. Game theory and weight loss: harmonic evidence from randomized controlled trials in Appalachia, KY and Jordan. *PLOS Glob Public Health*. 2025;5(2):e0004100. <https://doi.org/10.1371/journal.pgph.0004100> PMID: 39919098
14. Zoughbie DE, Ng TLJ, Thompson JY, Watson KT, Farraj R, Ding EL. Ramadan fasting and weight change trajectories: time-varying association of weight during and after Ramadan in low-income and refugee populations. *PLOS Glob Public Health*. 2022;2(10):e0000371. <https://doi.org/10.1371/journal.pgph.0000371> PMID: 36962504
15. Zoughbie DE, Ng TLJ, Thompson JY, Watson KT, Farraj R, Ding EL. Correction: Ramadan fasting and weight change trajectories: time-varying association of weight during and after Ramadan in low-income and refugee populations. *PLOS Glob Public Health*. 2023;3(6):e0002126. <https://doi.org/10.1371/journal.pgph.0002126> PMID: 37363895
16. Ding EL, Feigl AB, Watson KT, Ng TLJ, Makerechi L, Bui N, et al. Social network enhanced behavioral interventions for diabetes and obesity: a 3 arm randomized trial with 2 years follow-up in Jordan. *PLOS Glob Public Health*. 2024;4(3):e0001514. <https://doi.org/10.1371/journal.pgph.0001514> PMID: 38507441