



OPEN ACCESS

EDITED BY

Paolo Vineis,
Imperial College London, United Kingdom

REVIEWED BY

Melissa M. Reznar,
Oakland University, United States

*CORRESPONDENCE

Terry T. -K. Huang
✉ terry.huang@sph.cuny.edu

RECEIVED 08 April 2023

ACCEPTED 04 July 2023

PUBLISHED 25 July 2023

CITATION

Finn EB, Whang C, Hong PH, Costa SA,
Callahan EA and Huang TT-K (2023) Strategies
to improve the implementation of intensive
lifestyle interventions for obesity.
Front. Public Health 11:1202545.
doi: 10.3389/fpubh.2023.1202545

COPYRIGHT

© 2023 Finn, Whang, Hong, Costa, Callahan
and Huang. This is an open-access article
distributed under the terms of the [Creative Commons Attribution License \(CC BY\)](https://creativecommons.org/licenses/by/4.0/). The use,
distribution or reproduction in other forums is
permitted, provided the original author(s) and
the copyright owner(s) are credited and that
the original publication in this journal is cited, in
accordance with accepted academic practice.
No use, distribution or reproduction is
permitted which does not comply with these
terms.

Strategies to improve the implementation of intensive lifestyle interventions for obesity

Emily Benjamin Finn¹, Christine Whang¹, Peter Houlin Hong¹, Sergio A. Costa¹, Emily A. Callahan² and Terry T. -K. Huang^{1*}

¹Center for Systems and Community Design and NYU-CUNY Prevention Research Center, Graduate School of Public Health and Health Policy, City University of New York, New York, NY, United States, ²EAC Health and Nutrition, LLC, Leesburg, VA, United States

KEYWORDS

obesity, lifestyle intervention, behavior change, human-centered design, implementation science

1. Introduction

Obesity is one of the most consequential diseases in the United States given its prevalence, long-term consequences, and high costs. More than 40% of U.S. adults and more than one-fifth (21.5%) of children aged 2–19 years have obesity, with worsening trends of inequities by race, ethnicity, socio-economic status, and geography (e.g., rural vs. urban) (1–3). People with obesity are at higher risks of multiple comorbidities, including cardiovascular disease, Type 2 diabetes, fatty liver disease, some forms of cancer, and depression (4, 5). The social consequences of obesity include discrimination, stigma and adverse impacts on education and employment (6, 7). The U.S. annual economic burden of obesity, including direct (health-related) and indirect (lost productivity) costs, has been estimated to be as high as \$1.72 trillion (8).

First-line clinical management of obesity typically consists of multi-component, intensive lifestyle interventions (ILIs) that combine nutrition, physical activity, and behavior change support (9). Based on recommendations from authoritative bodies such as the U.S. Community Preventive Services Task Force and the American Academy of Pediatrics, these interventions are often based on social cognitive models, including health education, goal setting, and social support (e.g., coaching) and can include motivational incentives such as rewards and behavioral feedback mechanisms (10, 11). Although several ILIs have demonstrated efficacy in clinical trials, their real-world impact, especially over the long-term, has been more limited; post-ILI weight regain is not uncommon. One systematic review demonstrated that some patients begin to experience weight regain around 36 weeks post-intervention, and that many participants regain all lost weight by 48 weeks (12–17). The persistent increase in rates of obesity suggests that we need to critically examine and directly address challenges in ILI design and delivery.

The goal of this opinion paper is to identify shortcomings in current ILIs, or “pain points,” experienced by patients—particularly those in underserved or minoritized communities—affected by obesity in the context of ILI implementation, that have not been adequately addressed to date. This paper is not meant to be an exhaustive discussion but reflects insights from the authors’ research and reflections on the literature. The limitations are organized into three domains: (1) implementation context, (2) intervention components, targets, and sequencing, and (3) delivery strategies.

2. Implementation context

2.1. Mismatch between intervention and community readiness

Community readiness is defined by a community's preparedness to undertake change, which is influenced by its perceived importance of the health issue in question as well as its capacities, resources, and political climate (18). Low community readiness diminishes an intervention's impact potential. The Community Readiness Model (CRM), developed to guide the creation of community-level behavior change interventions, has been applied to a wide range of public health topics, including alcohol abuse, cardiovascular disease, and children's social-emotional development (19–22). A community's readiness varies by issue; for obesity, community readiness is often low or middling, in part because people may discount negative consequences of obesity that will accrue in the distant future (23–25). In this context, ILIs that target weight-related behaviors (e.g., diet or physical activity) may fail if they are not aligned with the community's highest priorities. Moving a community through stages of readiness can itself be an intervention outcome (18, 26). For example, baseline CRM findings were used to tailor a youth advocacy intervention to increase the community readiness for obesity prevention (27, 28).

2.2. Overlooking the built and social environment in a community

One premise of community readiness is that some communities may be unable to focus on obesity and its longer-term consequences until more immediate threats to safety and health (e.g., housing insecurity, crime, etc.) are addressed. Research has shown the importance of the role of built (e.g., distribution of food outlets) and social (e.g., perceived safety) environments in obesity. Few interventions, however, have incorporated environmental change as a critical component of ILIs (29–31). Dietz (32) cites “social conditions”, including safety, participant trauma, and housing insecurity, as a reason that seemingly promising ILIs have failed to improve body mass index (BMI) in low-income communities. For example, programs that focus on physical activity but do not account for neighborhood safety, park accessibility, quality of sidewalks or other environmental factors are unlikely to succeed (33). Environmental change often necessitates local policy intervention and cross-sectoral partnerships, which should be incorporated to a greater extent in the next generation of ILIs (34). The use of community health workers (CHWs) or patient navigators may also help patients address social determinants of health by linking patients to clinical and social services (35).

2.3. Lack of attention to cultural nuance

Evidence-based ILIs are often assumed to be equally effective across different populations. In reality, systems, cultural phenomena, and lived experiences shape unique pathways to

obesity, which warrants culturally responsive design for evidence-based interventions (36). For example, among Chinese-American residents in Manhattan's Chinatown, grandparents are key caretakers and strongly influence young children's dietary intake. Many Chinese grandparents believe that chubby babies are healthy babies, partly due to historical experiences of food insecurity; this perception can lead to over-feeding. It is also common for newly immigrated parents, who often work multiple jobs, to send their newborns back to China to be raised by grandparents until children reach school age. Given these cultural nuances, ILIs developed in predominantly white populations may not be as effective with newly immigrant Chinese American families if interventions fail to engage grandparents in the U.S. or China (37). The use of culturally and linguistically concordant CHWs may help to bridge this cultural divide (35). In addition, the need for ILI adaptations is increasingly recognized in implementation science; however, how to optimally effect these adaptations is the next frontier of research (38).

3. Intervention components, targets, and sequencing

3.1. Discounting different individual stages of change for different behaviors

As with community readiness, many interventions fail to account for differences in participants' stages of change for various behaviors. The Transtheoretical Model, which maps individual behavior change progressing through six stages of change (SOC) (39), has been widely applied to obesity prevention and weight management efforts (40–43). However, individual SOC is behavior-specific: one may eat fruits and vegetables daily (action or maintenance stage) but not exercise (pre-contemplation or contemplation stage). As such, ILIs, which are designed to simultaneously address multiple aspects of obesity (e.g., physical activity, nutrition, sleep, etc.), must consider participant SOC relative to each behavior. Training for interventionists should include how to recognize participant SOC for each behavior and to tailor the intervention to each SOC.

3.2. Overlooking participants' mental health, cognitive load, and executive functioning

Mental health influences individual engagement with and response to ILIs. Weight stigma, low self-esteem, and mental health disorders (e.g., depression, anxiety) can all impede motivation, which is critical to individual movement through the SOC (44–46). Chronic stress interferes with self-regulation by decreasing physical activity, impairing sleep, and facilitating unhealthy eating (47, 48). Compared to other factors, poor mental health is a stronger predictor of attrition in obesity interventions, and mental health and weight loss have been strongly correlated, in some cases up to 12 months—and likely longer—after beginning ILIs (49, 50).

Cognitive load refers to the amount of information the brain can simultaneously process. It is not only negatively associated with mental health, but also limits ILI reach and uptake as people face competing demands that can become barriers to participation in obesity interventions (51, 52). Cognitive overload can result in decreased cognitive functioning. As such, participants who are cognitively overloaded before an ILI is introduced may be less likely to process the intervention effectively (53, 54). Teaching strategies developed specifically to avoid contributing to cognitive overload can be applied during the intervention design phase (55).

ILIs will be most effective when they address mental health and minimize cognitive load; more research is needed on this topic. The few pilot studies that have assessed the extent to which supporting participant stress management affected weight loss had small samples, short durations, and low generalizability (56–58). Studies with more robust statistical power as well as repeated longer-term measures of stress and mental health, cognitive functioning, health behaviors, and body composition would inform more effective ILI development. Qualitative studies are also needed to better contextualize the life experiences of intervention participants, so that desired behaviors such as healthy eating and physical activity can be considered as part of other life demands and stresses rather than be treated in isolation.

3.3. Knowledge gaps around the optimal sequencing of intervention components

Despite significant research around prevention and management of obesity, the optimal ways to combine ILI components remain under-explored (59). Most weight interventions target only one or two of the many factors associated with obesity; diet and physical activity are the most common but the importance of other behaviors, such as sleep, is increasingly recognized (60). The complexity of obesity demands broad-based interventions, but more research is needed on how to optimize the combination and sequencing of multiple intervention components, taking into account that such optimization may vary across populations. Several methodologies are available to explore optimal sequencing. Multiphase optimization strategy trials enable rigorous exploration of sequencing intervention components for obesity (61–64). The Fogg Behavior Model (FBM), which suggests that a behavior happens when motivation, ability, and prompt occur simultaneously, has been effectively applied to interventions for multiple health challenges. The FBM may enable obesity interventionists to more effectively support desired behavior changes, including by considering the specific sequencing of small behavioral steps before or after a current habit, leading to greater uptake of the target behavior (65–69). Adaptive interventions can be tailored to individual participant preferences and needs, and can be used to address early non-responders by modifying intervention intensity or form (70–72). Lastly, the use of simulation models in systems science has been applied to support optimization of intervention sequencing across several public health areas and could be similarly applied to obesity (73–75).

4. Delivery strategies

Interventionists must consider several aspects of ILI delivery. One is whether intervention materials are actively distributed (“pushed”) or must be actively sought by the participant (“pulled”). While comparisons of “push” vs. “pull” modalities have been studied, further research is needed to better understand when and where to use each type (76). For instance, one study found that patients and clinicians had opposite preferences, with patients preferring “pulling” information on resources, and clinicians preferring “pushing” (77). However, pull and push strategies may also be used together, for example, using an opt-out approach for intervention enrollment to maximize reach while allowing patients to customize some of the content or its presentation in the intervention.

Another aspect is whether interventions are delivered virtually or in-person. The pivot of in-person ILIs to virtual delivery at the onset of the COVID-19 pandemic provided a natural experiment to compare these modes, and early evidence suggests this virtual transition may work for some programs but perhaps not others if staff and/or participants lack the technological self-efficacy to engage digitally, or if staff do not have the bandwidth to gain the required technological know-how (78). Currently, the U.S. Community Preventive Services Task Force recommends digital health interventions to improve diet and physical activity in workplace, higher education and community settings (10). However, with the exception of adolescents for whom this recommendation is made specifically to reduce overweight or obesity, the other companion recommendations are made to improve lifestyle behaviors only.

The field of lifestyle medicine has put forth successful practices related to the delivery of ILIs for obesity in clinical settings, such as shared medical appointments (79). In addition, the American College of Lifestyle Medicine released a statement in April 2023 stating that lifestyle interventions to treat obesity are often inadequately dosed for success (as it relates to the six pillars of lifestyle medicine used to treat chronic conditions, including obesity), indicating that delivery strategies must carefully consider dose (80).

Last but not least, interventionists must consider new and creative ways to meet intended participants where they are, physically, emotionally, and socially. Manga comics, exergaming (i.e., video games with interactive physical activity), and weight management podcasts have been used to engage various groups with promising results (81–83). Similar creativity for in-person interventions could facilitate embedding interventions into participants’ day-to-day life. For instance, nutrition components of ILIs could be offered through parent and child engagement during grocery trips. Exercise components for adults could rely on brief “exercise snacks” instead of longer bouts of physical activity (84). The current evidence base for such strategies is limited.

5. Discussion

This opinion paper is focused on critical considerations for improving implementation and impact of obesity-related ILIs. The

points raised have been understudied in the obesity field and warrant further research and development.

As the field moves toward the next generation of ILIs, further attention to the metrics used to gauge ILI success is important (85, 86). For example, given intra-individual variations in SOC in the context of multi-component interventions, a participant could become more physically active without making dietary changes while another could experience the reverse—but both individuals may experience only minor changes in BMI, although the intervention has improved their health to some degree. The selection of intervention success metric(s) can be influenced by the target population, goal(s) of the intervention recipients, intervention type, and intervention duration, among other factors.

As obesity interventions scale, the expected magnitude of behavior or health changes needs to be considered in line with the reach of ILIs. For instance, many digital interventions (e.g., web- or app-based) have had low or no statistically significant effect on participant weight despite high acceptability and feasibility (82, 87–90). Considering near-universal cell phone ownership, these types of interventions may offer wider benefit on a population level than the literature acknowledges, especially when offered in addition to standard clinical care rather than a stand-alone intervention (82, 87, 91–93).

The rise of implementation science (IS) has informed early efforts to improve the adoption, implementation, and sustainment of evidence-based interventions (94). IS offers a variety of frameworks and theories that can help design better interventions, improve outcomes or guide evaluations (95). Most IS frameworks are top-down and deterministic rather than bottom-up and human-centered. Although some recent advances have been made to address patient or community engagement in intervention implementation (96, 97), “how to” solve for patient pain points is still a major inquiry. Note that patient pain points may be affected by other concomitant chronic diseases or competing life priorities, which may influence the motivation to engage in obesity interventions. Human-centered design (HCD) can help bridge this gap in establishing program-context fit. HCD is a process for innovation by which design of a product or system incorporates end-user needs, preferences, and usage to develop a product that solves the user’s “pain point” (98). HCD has slowly entered public health practice as a way to solve implementation challenges identified by IS frameworks. For example, Haines

et al. (99) employed a three-step process of “usability testing,” “ethnographic contextual inquiry,” and “iterative prototyping” to ensure that their intervention, including its delivery methods, was best designed to fit the implementation context. Though more research is needed, HCD may allow for more innovative, strategic, and contextually tailored intervention designs, which may increase participant adoption and maintenance of health behaviors.

For obesity interventions to be successful in producing long-term changes in greater numbers of people, more effective, customized, and engaging interventions are needed. We hope this opinion will help move the field toward this end.

Author contributions

TH conceived of this work, which was drafted by EF, PH, and CW, and substantially revised by TH, PH, CW, SC, and EC. All authors read and approved the submitted version of the manuscript.

Funding

The paper has been supported, in part, by funding from the National Institutes of Health (R01MD018209) and the Centers for Disease Control and Prevention (U48DP006396).

Conflict of interest

EC was employed by EAC Health and Nutrition.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher’s note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

- Centers for Disease Control and Prevention. *Overweight and Obesity/Data and Statistics*. (2022). Available online at: <https://www.cdc.gov/obesity/data/index.html> (accessed September 9, 2022).
- Fryar CD, Carroll MD, Afful J. *Prevalence of Overweight, Obesity, and Severe Obesity Among Children and Adolescents Aged 2–19 Years: United States, 1963–1965 Through 2017–2018*. Hyattsville, MD: National Center for Health Statistics (2020). Available online at: <https://www.cdc.gov/nchs/data/hestat/obesity-child-17-18/obesity-child.htm>
- Hu K, Staiano AE. Trends in obesity prevalence among children and adolescents aged 2 to 19 years in the US from 2011 to 2020. *JAMA Pediatr*. (2022) 176:1037–9. doi: 10.1001/jamapediatrics.2022.2052
- Andolfi C, Fisichella PM. Epidemiology of obesity and associated comorbidities. *J Laparoendoscopic Adv Surg Techniq A*. (2018) 28:919–24. doi: 10.1089/lap.2018.0380
- Apovian CM. Obesity: definition, comorbidities, causes, and burden. *Am J Manag Care*. (2016) 22:s176–85. Available online at: <https://www.ajmc.com/view/obesity-definition-comorbidities-causes-burden>
- Centers for Disease Control and Prevention. *Obesity Basics / Consequences of Obesity*. (2022). Available online at: <https://www.cdc.gov/obesity/basics/consequences.html> (accessed September 9, 2022).
- Puhl RM, Heuer CA, Brownell KD. Stigma and social consequences of obesity. In: Kopelman PG, Caterson ID, Dietz WH, editors. *Clinical Obesity in Adults and Children*. Hoboken, NJ: Wiley Blackwell (2010). p. 25–40.
- Waters H, Graf M. *America’s Obesity Crisis: The Health and Economic Costs of Excess Weight*. Washington, DC: Milken Institute (2018). Available online at: https://milkeninstitute.org/sites/default/files/reports-pdf/Mi-Americas-Obesity-Crisis-WEB_2.pdf

9. Kahan S. Overweight and obesity management strategies. *Am J Manag Care*. (2016) 22:s186–96. Available online at: <https://www.ajmc.com/view/overweight-and-obesity-management-strategies>
10. *Obesity: The Community Guide*. Available online at: <https://www.thecommunityguide.org/topics/obesity.html#cc-widget-45ec> (accessed June 28, 2023).
11. Hampl SE, Hassink SG, Skinner AC, Armstrong SC, Barlow SE, Bolling CF, et al. Clinical practice guideline for the evaluation and treatment of children and adolescents with obesity. *Pediatrics*. (2023) 151:e2022060640. doi: 10.1542/peds.2022-060640
12. Savoye M, Shaw M, Dziura J, Tamborlane WV, Rose P, Guandalini C, et al. Effects of a weight management program on body composition and metabolic parameters in overweight children: a randomized controlled trial. *Jama*. (2007) 297:2697–704. doi: 10.1001/jama.297.24.2697
13. Sacher PM, Kolotourou M, Chadwick PM, Cole TJ, Lawson MS, Lucas A, et al. Randomized controlled trial of the MEND program: a family-based community intervention for childhood obesity. *Obesity*. (2010) 18 (Suppl. 1):S62–8. doi: 10.1038/oby.2009.433
14. Curioni CC, Lourenço PM. Long-term weight loss after diet and exercise: a systematic review. *Int J Obes*. (2005) 29:1168–74. doi: 10.1038/sj.ijo.0803015
15. Barte JC, ter Bogt NC, Bogers RP, Teixeira PJ, Blissmer B, Mori TA, et al. Maintenance of weight loss after lifestyle interventions for overweight and obesity: a systematic review. *Obes Rev*. (2010) 11:899–906. doi: 10.1111/j.1467-789X.2010.00740.x
16. Machado AM, Guimarães NS, Bocardí VB, da Silva TPR, Carmo ASD, Menezes MC, et al. Understanding weight regain after a nutritional weight loss intervention: Systematic review and meta-analysis. *Clin Nutr ESPEN*. (2022) 49:138–53. doi: 10.1016/j.clnesp.2022.03.020
17. Hall KD, Kahan S. Maintenance of lost weight and long-term management of obesity. *Med Clin North Am*. (2018) 102:183–97. doi: 10.1016/j.mcna.2017.08.012
18. Plested BA, Thurman P, Edwards R, Oetting E, Jumper-Thurman P. Community readiness: a tool for effective community-based prevention. *Prev Res*. (1998) 5:5–7.
19. Paltzer J, Black P, Moberg DP. Evaluating community readiness to implement environmental and policy-based alcohol abuse prevention strategies in Wisconsin. *J Alcohol Drug Educ*. (2013) 57:27–50. Available online at: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4204645/pdf/nihms521333.pdf>
20. Peercy M, Gray J, Thurman PJ, Plested B. Community readiness: an effective model for tribal engagement in prevention of cardiovascular disease. *Fam Community Health*. (2010) 33:238–47. doi: 10.1097/FCH.0b013e3181e4bca9
21. Borraro EA. Using a community readiness model to help overcome breast health disparities among U.S. Latinas. *Subst Use Misuse*. (2007) 42:603–19. doi: 10.1080/10826080701202205
22. Islam S, Small N, Bryant M, Bridges S, Hancock N, Dickerson J. Assessing community readiness for early intervention programmes to promote social and emotional health in children. *Health Expect*. (2019) 22:575–84. doi: 10.1111/hex.12887
23. Pradeilles R, Rousham EK, Norris SA, Kesten JM, Griffiths PL. Community readiness for adolescents' overweight and obesity prevention is low in urban South Africa: a case study. *BMC Public Health*. (2016) 16:763. doi: 10.1186/s12889-016-3451-9
24. Findholt N. Application of the community readiness model for childhood obesity prevention. *Public Health Nurs*. (2007) 24:565–70. doi: 10.1111/j.1525-1446.2007.00669.x
25. Schröder M, Schnabel M, Hassel H, Babitsch B. Application of the community readiness model for childhood obesity prevention: a scoping review. *Health Promot Int*. (2022) 37:1–10. doi: 10.1093/heapro/daac120
26. Edwards RW, Jumper-Thurman P, Plested BA, Oetting ER, Swanson L. Community readiness: research to practice. *J Commun Psychol*. (2000) 28:291–307. doi: 10.1002/(SICI)1520-6629(200005)28:3<291::AID-JCOP5>3.0.CO;2-9
27. Frerichs L, Brittin J, Robbins R, Steenson S, Stewart C, Fisher C, et al. SaludABLEOmaha: improving readiness to address obesity through healthy lifestyle in a Midwestern Latino community, 2011–2013. *Prevent Chronic Dis*. (2015) 12:E20. doi: 10.5888/pcd12.140328
28. Frerichs L, Brittin J, Stewart C, Robbins R, Riggs C, Mayberger S, et al. SaludABLEOmaha: development of a youth advocacy initiative to increase community readiness for obesity prevention, 2011–2012. *Prevent Chron Dis*. (2012) 9:E173. doi: 10.5888/pcd9.120095
29. Committee on Accelerating Progress in Obesity Prevention; Food and Nutrition Board; Institute of Medicine. *Accelerating Progress in Obesity Prevention: Solving the Weight of the Nation*. In: Glickman D, Parker L, Sim LJ, Del Valle Cook H, Miller EA, editors. Washington, DC: National Academies Press (2012). p. 1–462.
30. Bleich SN, Segal J, Wu Y, Wilson R, Wang Y. Systematic review of community-based childhood obesity prevention studies. *Pediatrics*. (2013) 132:e201–10. doi: 10.1542/peds.2013-0886
31. Kumanyika S, Grier S. Targeting interventions for ethnic minority and low-income populations. *Fut Child*. (2006) 16:187–207. doi: 10.1353/foc.2006.0005
32. Dietz WH. We need a new approach to prevent obesity in low-income minority populations. *Pediatrics*. (2019) 143:e20190839. doi: 10.1542/peds.2019-0839
33. Roberto CA, Swinburn B, Hawkes C, Huang TT, Costa SA, Ashe M, et al. Patchy progress on obesity prevention: emerging examples, entrenched barriers, and new thinking. *Lancet*. (2015) 385:2400–9. doi: 10.1016/S0140-6736(14)61744-X
34. Huang TT, Cawley JH, Ashe M, Costa SA, Frerichs LM, Zwicker L, et al. Mobilisation of public support for policy actions to prevent obesity. *Lancet*. (2015) 385:2422–31. doi: 10.1016/S0140-6736(14)61743-8
35. Islam NS, Wyatt LC, Ali SH, Zanowski JM, Mohaimin S, Goldfeld K, et al. Integrating community health workers into community-based primary care practice settings to improve blood pressure control among South Asian immigrants in New York City: results from a randomized control trial. *Circ Cardiovasc Qual Outcomes*. (2023) 16:e009321. doi: 10.1161/CIRCOUTCOMES.122.009321
36. Kumar V, Kumar A, Ghosh AK, Samphel R, Yadav R, Yeung D, et al. Enculturating science: Community-centric design of behavior change interactions for accelerating health impact. *Semin Perinatol*. (2015) 39:393–415. doi: 10.1053/j.semperi.2015.06.010
37. Swierad E, Huang TT, Ballard E, Flórez K, Li S. Developing a socioculturally nuanced systems model of childhood obesity in Manhattan's Chinese American community via group model building. *J Obes*. (2020) 2020:4819143. doi: 10.1155/2020/4819143
38. Chambers DA. Advancing adaptation of evidence-based interventions through implementation science: progress and opportunities. *Front Health Serv*. (2023) 3:1204138. doi: 10.3389/frhs.2023.1204138
39. Prochaska JO, Velicer WF. The transtheoretical model of health behavior change. *Am J Health Promot*. (1997) 12:38–48. doi: 10.4278/0890-1171-12.1.38
40. de Freitas PP, de Menezes MC, Dos Santos LC, Pimenta AM, Ferreira AVM, Lopes ACS. The transtheoretical model is an effective weight management intervention: a randomized controlled trial. *BMC Public Health*. (2020) 20:652. doi: 10.1186/s12889-020-08796-1
41. Mastellos N, Gunn LH, Felix LM, Car J, Majeed A. Transtheoretical model stages of change for dietary and physical exercise modification in weight loss management for overweight and obese adults. *Cochrane Database Syst Rev*. (2014) 2014:CD008066. doi: 10.1002/14651858.CD008066.pub3
42. Hayotte M, Nègre V, Gray L, Sadoul JL, d'Arripe-Longueville F. The transtheoretical model (TTM) to gain insight into young women's long-term physical activity after bariatric surgery: a qualitative study. *Obesity surgery*. (2020) 30:595–602. doi: 10.1007/s11695-019-04220-9
43. Crabtree VM, Moore JB, Jacks DE, Cerrito P, Topp RV, A. transtheoretical, case management approach to the treatment of pediatric obesity. *J Prim Care Community Health*. (2010) 1:4–7. doi: 10.1177/2150131909357069
44. Karasu SR. Psychotherapy-lite: obesity and the role of the mental health practitioner. *Am J Psychother*. (2013) 67:3–22. doi: 10.1176/appi.psychotherapy.2013.67.1.3
45. Livia B, Elisa R, Claudia R, Roberto P, Cristina A, Emilia ST, et al. Stage of change and motivation to a healthier lifestyle before and after an intensive lifestyle intervention. *J Obes*. (2016) 2016:6421265. doi: 10.1155/2016/6421265
46. Puhl RM, Lessard LM. Weight stigma in youth: prevalence, consequences, and considerations for clinical practice. *Curr Obes Rep*. (2020) 9:402–11. doi: 10.1007/s13679-020-00408-8
47. Tomiyama AJ. Stress and obesity. *Annu Rev Psychol*. (2019) 70:703–18. doi: 10.1146/annurev-psych-010418-102936
48. Adam TC, Epel ES. Stress, eating and the reward system. *Physiol Behav*. (2007) 91:449–58. doi: 10.1016/j.physbeh.2007.04.011
49. Alhalel N, Schueller SM, O'Brien MJ. Association of changes in mental health with weight loss during intensive lifestyle intervention: does the timing matter? *Obes Sci Pract*. (2018) 4:153–8. doi: 10.1002/osp4.157
50. Moroshko I, Brennan L, O'Brien P. Predictors of dropout in weight loss interventions: a systematic review of the literature. *Obes Rev*. (2011) 12:912–34. doi: 10.1111/j.1467-789X.2011.00915.x
51. Grootens-Wiegers P, van den Eynde E, Halberstadt J, Seidell JC, Dedding C. The “Stages Towards Completion Model”: what helps and hinders children with overweight or obesity and their parents to be guided towards, adhere to and complete a group lifestyle intervention. *Int J Qual Stud Health Well-being*. (2020) 15:1735093. doi: 10.1080/17482631.2020.1735093
52. Byrd-Bredbenner C, Eck KM. Relationships among executive function, cognitive load, and weight-related behaviors in university students. *Am J Health Behav*. (2020) 44:691–703. doi: 10.5993/AJHB.44.5.12
53. Sisakhti M, Sachdev PS, Batouli SAH. The effect of cognitive load on the retrieval of long-term memory: an fMRI study. *Front Hum Neurosci*. (2021) 15:700146. doi: 10.3389/fnhum.2021.700146
54. Howard ZL, Evans NJ, Innes RJ, Brown SD, Eidels A. How is multi-tasking different from increased difficulty? *Psychon Bull Rev*. (2020) 27:937–51. doi: 10.3758/s13423-020-01741-8
55. Siregar NR. Explicit instruction and executive functioning capacity: a new direction in cognitive load theory. *J Educ*. (2023) 203:451–8. doi: 10.1177/00220574211033256

56. Geiker NRW, Astrup A, Hjorth MF, Sjödin A, Pijs L, Markus CR. Does stress influence sleep patterns, food intake, weight gain, abdominal obesity and weight loss interventions and vice versa? *Obes Rev.* (2018) 19:81–97. doi: 10.1111/obr.12603
57. Cox TL, Krukowski R, Love SJ, Eddings K, DiCarlo M, Chang JY, et al. Stress management-augmented behavioral weight loss intervention for African American women: a pilot, randomized controlled trial. *Health Educ Behav.* (2013) 40:78–87. doi: 10.1177/1090198112439411
58. Christaki E, Kokkinos A, Costarelli V, Alexopoulos EC, Chrousos GP, Darviri C. Stress management can facilitate weight loss in Greek overweight and obese women: a pilot study. *J Hum Nutr Diet.* (2013) 26 (Suppl. 1):132–9. doi: 10.1111/jhn.12086
59. Huang TT, Drewnoski A, Kumanyika S, Glass TA. A systems-oriented multilevel framework for addressing obesity in the 21st century. *Prevent. Chron. Dis.* (2009) 6:A82. Available online at: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2722412/pdf/PCD63A82.pdf>
60. Ash T, Agaronov A, Young T, Aftosmes-Tobio A, Davison KK. Family-based childhood obesity prevention interventions: a systematic review and quantitative content analysis. *Int J Behav Nutr Phys Act.* (2017) 14:113. doi: 10.1186/s12966-017-0571-2
61. Collins LM, Murphy SA, Strehler V. The multiphase optimization strategy (MOST) and the sequential multiple assignment randomized trial (SMART): new methods for more potent eHealth interventions. *Am J Prev Med.* (2007) 32:S112–8. doi: 10.1016/j.amepre.2007.01.022
62. Ventura AK, Birch LL. Does parenting affect children's eating and weight status? *Int J Behav Nutr Phys Act.* (2008) 5:15. doi: 10.1186/1479-5868-5-15
63. Kuhl ES, Clifford LM, Stark LJ. Obesity in preschoolers: behavioral correlates and directions for treatment. *Obesity.* (2012) 20:3–29. doi: 10.1038/oby.2011.201
64. Kugler KC, Balantekin KN, Birch LL, Savage JS. Application of the multiphase optimization strategy to a pilot study: an empirical example targeting obesity among children of low-income mothers. *BMC Public Health.* (2016) 16:1181. doi: 10.1186/s12889-016-3850-y
65. Alrige M, Bitar H, Meccawy M. Promoting precautionary behavior during the COVID-19 pandemic: development and validation of a behavior-change messaging campaign. *J Infect Public Health.* (2021) 14:1727–32. doi: 10.1016/j.jiph.2021.09.026
66. Sittig S, Wang J, Iyengar S, Myrnes S, Franklin A. Incorporating behavioral trigger messages into a mobile health app for chronic disease management: randomized clinical feasibility trial in diabetes. *JMIR mHealth and uHealth.* (2020) 8:e15927. doi: 10.2196/15927
67. Sporrer K, Wang S, Ettema DDE, Nibbeling N, Krose BJA, Deutekom M, et al. Just-in-time prompts for running, walking, and performing strength exercises in the built environment: 4-week randomized feasibility study. *JMIR formative research.* (2022) 6:e35268. doi: 10.2196/35268
68. Agha S, Tollefson D, Paul S, Green D, Babigumira JB. Use of the Fogg Behavior Model to Assess the Impact of a Social Marketing Campaign on Condom Use in Pakistan. *J Health Commun.* (2019) 24:284–92. doi: 10.1080/10810730.2019.1597952
69. Fogg B. A behavior model for persuasive design. In: *Persuasive '09: Proceedings of the 4th International Conference on Persuasive Technology.* (2009). p. 1–7. doi: 10.1145/1541948.1541999
70. Winett RA, Davy BM, Savla J, Marinik EL, Winett SG, Baugh ME, et al. Using response variation to develop more effective, personalized behavioral medicine?: evidence from the Resist Diabetes study. *Transl Behav Med.* (2014) 4:333–8. doi: 10.1007/s13142-014-0263-2
71. Sherwood NE, Butryn ML, Forman EM, Almirall D, Seburg EM, Lauren Crain A, et al. The BestFIT trial: A SMART approach to developing individualized weight loss treatments. *Contemp Clin Trials.* (2016) 47:209–16. doi: 10.1016/j.cct.2016.01.011
72. Unick JL, Pellegrini CA, Demos KE, Dorfman L. Initial weight loss response as an indicator for providing early rescue efforts to improve long-term treatment outcomes. *Curr Diab Rep.* (2017) 17:69. doi: 10.1007/s11892-017-0904-1
73. Hovmand PS, Ford DN. Sequence and timing of three community interventions to domestic violence. *Am J Community Psychol.* (2009) 44:261–72. doi: 10.1007/s10464-009-9264-6
74. Guynn J, Simon J, Anderson S, Klamann SL, Mullenix A, Cilenti D, et al. Tools for supporting the MCH workforce in addressing complex challenges: a scoping review of system dynamics modeling in maternal and child health. *Matern Child Health J.* (2022) 26:176–203. doi: 10.1007/s10995-022-03376-8
75. Naumann RB, Austin AE, Sheble L, Lich KH. System dynamics applications to injury and violence prevention: a systematic review. *Curr Epidemiol Rep.* (2019) 6:248–62. doi: 10.1007/s40471-019-00200-w
76. MacDermid JC, Law M, Buckley N, Haynes RB. "Push" versus "Pull" for mobilizing pain evidence into practice across different health professions: a protocol for a randomized trial. *Implement Sci.* (2012) 7:115. doi: 10.1186/1748-5908-7-115
77. Wallace AS, Wang CY, Flake N, Bristol AA, Altizer R. Feasibility and usefulness of the going home toolkit, an mhealth app, during hospital discharge: patient and clinician perspectives. *Inform Health Soc Care.* (2023) 48:1–12. doi: 10.1080/17538157.2022.2043330
78. Al-Badri M, Kilroy CL, Shahar JI, Tomah S, Gardner H, Sin M, et al. In-person and virtual multidisciplinary intensive lifestyle interventions are equally effective in patients with type 2 diabetes and obesity. *Ther Adv Endocrinol Metab.* (2022) 13:20420188221093220. doi: 10.1177/20420188221093220
79. Lacagnina S, Tips J, Pauly K, Cara K, Karlsen M. Lifestyle medicine shared medical appointments. *Am J Lifestyle Med.* (2021) 15:23–7. doi: 10.1177/1559827620943819
80. Branch A. *American College of Lifestyle Medicine Releases Statement Calling for Compassionate, Evidence-Based Lifestyle Intervention as First Treatment for Overweight and Obesity.* Chesterfield, MO: American College of Lifestyle Medicine (2023).
81. Leung MM, Tripicchio G, Agaronov A, Hou N. Manga comic influences snack selection in Black and Hispanic New York City youth. *J Nutr Educ Behav.* (2014) 46:142–7. doi: 10.1016/j.jneb.2013.11.004
82. Okorodudu DE, Bosworth HB, Corsino L. Innovative interventions to promote behavioral change in overweight or obese individuals: a review of the literature. *Ann Med.* (2015) 47:179–85. doi: 10.3109/07853890.2014.931102
83. Turner-McGrievy GM, Campbell MK, Tate DF, Truesdale KP, Bowling JM, Crosby L. Pounds off digitally study: a randomized podcasting weight-loss intervention. *Am J Prev Med.* (2009) 37:263–9. doi: 10.1016/j.amepre.2009.06.010
84. Islam H, Gibala MJ, Little JP. Exercise snacks: a novel strategy to improve cardiometabolic health. *Exerc Sport Sci Rev.* (2022) 50:31–7. doi: 10.1249/JES.0000000000000275
85. Carey L. Taking BMI off the table. *N Z Med J.* (2019) 132:77–80.
86. Burkhauser RV, Cawley J. Beyond BMI: the value of more accurate measures of fitness and obesity in social science research. *J Health Econ.* (2008) 27:519–29. doi: 10.1016/j.jhealeco.2007.05.005
87. Sandborg J, Söderström E, Henriksson P, Bendtsen M, Henström M, Leppänen MH, et al. Effectiveness of a smartphone app to promote healthy weight gain, diet, and physical activity during pregnancy (HealthyMoms): randomized controlled trial. *JMIR mHealth and uHealth.* (2021) 9:e26091. doi: 10.2196/26091
88. Nollen NL, Mayo MS, Carlson SE, Rapoff MA, Goggin KJ, Ellerbeck EF. Mobile technology for obesity prevention: a randomized pilot study in racial- and ethnic-minority girls. *Am J Prev Med.* (2014) 46:404–8. doi: 10.1016/j.amepre.2013.12.011
89. Bonvicini L, Pingani I, Venturelli F, Patrignani N, Bassi MC, Broccoli S, et al. Effectiveness of mobile health interventions targeting parents to prevent and treat childhood obesity: systematic review. *Prevent Med Rep.* (2022) 29:101940. doi: 10.1016/j.pmedr.2022.101940
90. Ang SM, Chen J, Liew JH, Johal J, Dan YY, Allman-Farinelli M, et al. Efficacy of interventions that incorporate mobile apps in facilitating weight loss and health behavior change in the Asian population: systematic review and meta-analysis. *J Med Internet Res.* (2021) 23:e28185. doi: 10.2196/28185
91. Eisenhauer CM, Brito F, Kupzyk K, Yoder A, Almeida F, Beller RJ, et al. Mobile health assisted self-monitoring is acceptable for supporting weight loss in rural men: a pragmatic randomized controlled feasibility trial. *BMC Public Health.* (2021) 21:1568. doi: 10.1186/s12889-021-11618-7
92. Ogden J, Maxwell H, Wong A. Development and feasibility study of an app (Ladle) for weight loss and behaviour change. *PeerJ.* (2019) 7:e6907. doi: 10.7717/peerj.6907
93. Nikolauou CK, Tay Z, Leu J, Rebello SA, Te Morenga L, Van Dam RM, et al. Young people's attitudes and motivations toward social media and mobile apps for weight control: mixed methods study. *JMIR mHealth and uHealth.* (2019) 7:e11205. doi: 10.2196/11205
94. University of Washington. *What is Implementation Science?* Washington, DC: University of Washington. Available online at: <https://impsciuw.org/implementation-science/learn/implementation-science-overview/> (accessed October 25, 2022).
95. University of Washington. *Theories, Models, and Frameworks.* Available online at: <https://impsciuw.org/implementation-science/research/frameworks/> (accessed January 4, 2023).
96. Pinto RM, Park S, Miles R, Ong PN. Community engagement in dissemination and implementation models: a narrative review. *Implement Res Pract.* (2021) 2:2633489520985305. doi: 10.1177/2633489520985305
97. Peek ST, Wouters EJ, Luijckx KG, Vrijhoef HJ. What it takes to successfully implement technology for aging in place: focus groups with stakeholders. *J Med Internet Res.* (2016) 18:e98. doi: 10.2196/jmir.5253
98. Norman DA, Draper SW. *User Centered System Design; New Perspectives on Human-Computer Interaction.* Mahwah, NJ: L Erlbaum Associates Inc. (1986).
99. Haines ER, Dopp A, Lyon AR, Wittman HO, Bender M, Vaisson G, et al. Harmonizing evidence-based practice, implementation context, and implementation strategies with user-centered design: a case example in young adult cancer care. *Implement Sci Commun.* (2021) 2:45. doi: 10.1186/s43058-021-00147-4