

ORIGINAL ARTICLE

Successful weight loss maintainers use health-tracking smartphone applications more than a nationally representative sample: comparison of the National Weight Control Registry to Pew Tracking for Health

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Summary

Objective

The objective of this paper is to evaluate successful weight loss maintainers' use of self-monitoring technology.

Methods

National Weight Control Registry (NWCR) participants, who maintained a ≥ 13.6 kg weight loss for ≥ 1 year, completed an online survey about self-monitoring technology use. The NWCR sample ($n = 794$) was compared with a demographically similar subsample of 833 individuals answering the same questions in the Pew Tracking for Health Survey.

Results

The NWCR had higher rates of tracking weight, diet or exercise using any modality (92.8% vs. 71.3%), on a regular basis (67.4% vs. 41.3%), and frequency of updating records, compared with Pew ($p < .01$). Smartphone ownership was higher in NWCR participants (80.2% vs. 52.8%, $p < .001$), and NWCR smartphone owners had 23.1 times greater odds for using diet, food or calorie counter apps (58.9% vs. 5.9%) and 15.5 times greater odds for using weight monitoring apps (31.7% vs. 3.0%; all $p < .01$). Pew respondents more often changed their behaviour based on their tracking data ($p < .01$).

Conclusion

Use of self-monitoring technology is common in weight loss maintainers: more so than in a nationally representative sample. However, the national sample more often changed their behaviour based on tracking data, perhaps suggesting that weight loss maintainers could derive additional benefit from technology they are already using.

Keywords: Body weight maintenance, health tracking, online trackers, smartphone, weight loss.

Introduction

Most health benefits of weight loss are related to the magnitude of weight change (1,2), and thus it is important to study not only initial weight loss, but also how successful weight loss maintainers keep their weight off over time. Digital health technology represents a set of electronic tools that successful weight loss maintainers may utilize to self-monitor weight, diet and physical

activity, for example, and/or receive feedback about their weight loss maintenance efforts.

While early forms of digital technology tended to be high in cost, such technology has recently become more affordable and thus more accessible (3). Currently, 84% of Americans use the Internet (3), and as of 2015, 68% of Americans own smartphones (defined as cellular phones equipped with additional capabilities including applications and Internet connectivity), an increase from

35% in 2011 (4). Notably, individuals with low household incomes and levels of educational attainment as well as individuals who report being non-White are more likely to rely on smartphones for Internet access because they either do not have broadband Internet at home or they have limited other options for getting online (4,5).

The use of smartphone applications ('apps'), in addition to other online trackers and devices (e.g. wearable physical activity monitors), to monitor, change and maintain health behaviours is now common. A large national survey conducted in the USA in 2015 found that 62% of smartphone owners reported using their smartphone to 'look up' information about a health condition (5). Another large, national survey, the Pew Tracking for Health Survey, examined Americans' health tracking practices including those related to weight loss (6). Use of technology for weight loss is increasing dramatically (7) and numerous commercially available and research-based interventions incorporating online, mobile and other technologies have been tested with individuals attempting to reduce weight (8–17). Given their availability and convenience, these technologies, especially smartphone apps, could serve as an important resource for individuals that want to adopt or refine health behaviours such as increased physical activity or improved dietary selection (18). For individuals who have Internet access or own a smartphone, these apps and trackers are engaging, low-cost options for health behaviour change and maintenance; some programs are even capable of delivering instant machine-generated performance-based feedback (19). These apps and trackers can prompt the user to engage in a wide array of health behaviours. There is a positive relationship between self-monitoring and weight loss, and digital health technologies may facilitate more convenient and frequent self-monitoring (20). For individuals who are currently maintaining a significant weight loss, electronic health and mobile health technologies could play a significant role in continued weight reduction and weight loss maintenance.

In 1993, the National Weight Control Registry (NWCR) was created to examine the characteristics and behavioural patterns of successful weight loss maintainers. It is the largest registry of successful weight loss maintainers, with approximately 10,000 participants to date. To be eligible, individuals are required to have maintained a weight loss of ≥ 13.6 kg (30 lb) for ≥ 1 year. The NWCR is characterized by high levels of physical activity, limiting television watching, eating a consistent, low-calorie low-fat diet, regularly eating breakfast, measuring high on dietary restraint and low on disinhibition, and high levels of self-monitoring (21–25). NWCR participants weigh themselves daily (38%) or at least weekly (75%), and many continue to track calories (35.5%) or fat

grammes (30%) during weight maintenance (25). Upon 10-year follow-up, decreases in dietary restraint, leisure-time physical activity and frequency of self-weighing, as well as increases in disinhibition and percentage of calories from fat in overall diet, were associated with weight regain (26). Additionally, at 5- and 10-year follow-ups, over 87% of participants were estimated to be maintaining weight loss of at least 10% of their lifetime maximum body weight (26).

Since the creation of the NWCR in the early 1990s, the availability of digital health technology has increased dramatically. However, no study has yet evaluated technology use for weight maintenance and overall health in the NWCR. If NWCR participants are using digital health technology more or less than a national sample, it could indicate that these tools are especially useful (or less useful) for individuals maintaining significant weight losses compared with individuals not known to be successful with weight management. The findings could also inform technology-based interventions for weight loss maintenance.

The purpose of the current study is therefore to describe the use of self-monitoring technology, specifically smartphone apps and online trackers, amongst a group of successful weight loss maintainers, and to compare those usage patterns to those observed in the Pew Tracking for Health Survey. This study focused on app use because smartphone apps are some of the most widely used tools in the general population; there are numerous freely available apps that target weight, diet and/or physical activity. These apps are also likely to be some of the most relevant for weight loss maintainers. In addition, the Pew Tracking for Health Survey, which includes questions about use of tracking apps, provides a convenient group for comparison with successful weight loss maintainers. We hypothesized that NWCR participants would report higher rates of using self-monitoring technology than individuals in the Pew sample. We also hypothesized that NWCR participants would be more likely to change their behaviour as a result of using self-monitoring technology.

Materials and methods

Subjects

National Weight Control Registry

Members of the NWCR are self-selected individuals who have maintained a weight loss of ≥ 13.6 kg or more (representing a minimum weight loss of $\geq 10\%$ of maximum lifetime body weight for most participants) for ≥ 1 year. At the start of their participation, participants

consent to receive invitations to annual online surveys and can opt in or out of receiving invitations to supplemental surveys on special topics. These annual and supplemental online surveys are administered to each participant for 10 years, and they focus on weight maintenance behaviours, overall health, and other psychosocial and behavioural factors. Participants are not compensated for their participation in this longitudinal study. NWCR participants are recruited through national and local television, print and radio advertisements on an ongoing basis. A subset of 1,000 individuals who completed their annual survey within the last year were randomly selected to participate in the present study.

Pew

Participants in the Pew Tracking for Health Survey were part of a national telephone survey conducted by the Pew Research Center's Internet and American Life Project. Participants were adults in the USA with access to a landline or cellular phone. The objective was to capture responses regarding personal technology use for health from a representative sample of the population using procedures described subsequently. The raw, de-identified Pew Tracking for Health Survey data are available for public download on the Pew Research website after completing an online dataset use agreement; Pew Research is the sole, exclusive owner of all right, title and interest in the data.

Procedures

A random 1,000-person subset of individuals who had completed an annual survey for the NWCR in the last 12 months was approached via email through SurveyMonkey (Palo Alto, CA, USA) requesting their participation in a web-based survey about technology use, weight loss and weight loss maintenance. Of those, 794 (79.4%) completed the online survey. Data were collected in September and October, 2014. All procedures were Institutional Review Board-approved by The Miriam Hospital.

The Pew Tracking for Health Survey involved telephone interviews conducted with 3,014 adults residing in the USA. Princeton Survey Research Associates International (Princeton, NJ, USA) conducted the interviews in August and September, 2012 (5,6). Interviews were conducted by landline and cellular phone (5,6). Phone numbers were selected via landline and cellular random digit dial and were called up to seven times to reach a respondent at different times throughout the day (5,6). Statistical results of the interviews were weighted to correct for known demographic discrepancies (including whether each

participant had access to landlines, cellular phones, or both) in the published and available Pew dataset (5,6). The California HealthCare Foundation provided financial support for the study. Participants provided oral consent to participate, and they were not compensated for their participation. The principles outlined in the Declaration of Helsinki were followed to ensure ethical treatment of human participants.

Because of demographic differences between the NWCR and Pew samples, subjects from each sample were matched on demographic factors and cellular phone ownership (any kind of cellular phone) to yield a total sample of 1,627 (833 from Pew, 794 from NWCR). Participants in the Pew sample were selected using a random sampling procedure designed to approximate the NWCR distribution across demographic variables. Given that participants in the NWCR tend to be better-educated, more affluent and more often non-Hispanic White than the national population, particular attention was paid to matching participants on the basis of income, race and educational attainment. Matching participants based on a more specific criterion (e.g. smartphone ownership only, high levels of educational attainment only) was not feasible and would have reduced generalizability of findings. In their analysis, Pew weighted individual responses to correct for known discrepancies between their sample and the national population. For the purposes of the present study that aimed to compare two distinct samples (Pew versus NWCR), and because the samples were matched to create a subsample of cellular phone owners, those weights were discarded and participants' raw data were used in all analyses.

Measures

Participants in both samples provided demographic information. In order to facilitate comparisons between the samples, NWCR participants were asked the same questions (with same item response options) as Pew participants (5,6) on the topics of cellular phone and smartphone ownership, tracking measures of health, tracking methods and sharing records. All participants were asked whether they owned a smartphone (a phone that may have apps or Internet connectivity), a non-smartphone cellular phone (a cellular phone with calling features but without advanced capabilities and Internet) or no cellular phone. To assess utilization of health tracking apps, Pew participants were asked questions such as 'On your cell phone, do you happen to have any software applications or "apps" that help you track or manage your health, or not?' and 'Do you use apps to monitor your weight?' Although the majority of the questions do not specifically target weight management, the questions

from the Pew dataset were asked verbatim in the NWCR sample to allow for direct comparisons between groups. To assess the impact of tracking on health behaviour, participants were specifically asked if using health

tracking tools had affected a decision about how to treat an illness or condition, made it more likely that they would change their approach to maintaining their own health or the health of someone they help care for, and whether

Table 1 Participant characteristics

	Overall (n = 1627)		NWCR (n = 794)		Pew (n = 833)		<i>p</i> -value
	Mean	SD	Mean	SD	Mean	SD	
Age	55.0	12.9	54.2	11.3	55.7	14.3	.02
	Number	%	Number	%	Number	%	
Sex							<.001
Female	1158	71.3	612	77.1	546	65.5	
Male	459	28.2	172	21.7	287	34.5	
Race							<.001
White	1423	87.6	742	93.5	681	81.8	
Black or African American	149	9.2	22	2.8	127	15.2	
Asian or Pacific Islander	30	1.8	9	1.1	21	2.5	
Mixed Race	3	0.2	3	0.4	0	0.0	
Native American/American Indian	12	0.7	8	1.0	4	0.5	
Prefer not to answer	8	0.5	10	1.3	0	0.0	
Ethnicity							.05
Not Hispanic or Latino	1583	97.3	779	98.1	804	96.5	
Hispanic or Latino	44	2.7	15	1.9	29	3.5	
Education							<.001
Junior high school or less	1	0.1	1	0.1	0	0.0	
Attended or graduated from high school or earned GED	114	7.0	19	2.4	95	11.4	
Some college but no degree, community college, vocational school or associate's degree	302	18.6	102	12.8	200	24.0	
College or university degree	535	32.9	259	32.6	276	33.1	
Graduate or professional education	675	41.5	413	52.0	262	31.5	
(e.g. MBA, MS, MA, PhD, MD, JD)							
Marital status							<.001
Married	1111	68.3	556	70.0	555	66.6	
Separated	13	0.8	6	0.8	7	0.8	
Divorced	155	9.5	75	9.4	80	9.6	
Widowed	107	6.6	24	3.0	83	10.0	
Never married	180	11.1	105	13.2	75	9.0	
Living with a partner (not married)	57	3.5	28	3.5	29	3.5	
Other	4	0.2	0	0.0	4	0.5	
Income							<.001
Under \$50,000	292	17.9	100	12.6	192	23.0	
\$50,000–99,999	533	32.8	238	30.0	295	35.4	
\$100,000 or higher	571	35.1	345	43.5	226	27.1	
Prefer not to answer	202	12.4	108	13.6	94	11.3	
Do not know	29	1.8	3	0.4	26	3.1	
Employment status							<.001
Employed full-time	815	50.1	428	53.9	387	46.5	
Employed part-time	146	9.0	67	8.4	79	9.5	
Self-employed	96	5.9	75	9.4	21	2.5	
Not currently employed or not employed for pay	119	7.3	38	4.8	81	9.7	
Retired	421	25.9	173	21.8	248	29.8	
Disabled	17	1.0	7	0.90	10	1.20	
Student	7	0.4	6	0.80	1	0.10	
Other or declined to provide an answer	6	0.4	0	0.00	6	0.70	

GED, General Educational Development; NWCR, National Weight Control Registry.

or not using these tools led the participant to ask a doctor new questions or to get a second opinion from another doctor. Again, these items were taken verbatim from the Pew survey.

Statistics

The analyses were completed using IBM SPSS Statistics for Windows, Version 20.0. (IBM Corp. Released 2011. Armonk, NY: IBM Corp.). Descriptive statistics were calculated using the mean and standard deviation or counts and percentages, as appropriate, to characterize sample characteristics and patterns of digital health technology use. Chi-square tests were used to compare the NWCR and Pew samples on categorical variables. Independent samples *t*-tests were used to compare the two samples on continuous variables. Comparisons of the NWCR and Pew samples were conducted twice; once via an approach with demographic covariates (sex, age, income, marital status, employment status, race and ethnicity) included in the analysis, and once without. The pattern of results did not differ. Therefore, unadjusted results of analyses not including the demographic covariates are reported.

Results

Characteristics of subjects

The NWCR sample was predominantly female (77.1%, $n = 562$), college-educated (84.6%, $n = 672$), non-Hispanic (98.6%, $n = 728$), White (702, $n = 96.7\%$) and had attained at least some graduate or professional

education (52.0%, $n = 413$). Most of the NWCR sample had excess weight (36.4%) or was normal weight (35.1%) according to their self-reported height and weight, and 23.4% remained in the obese range despite a substantial weight loss. The matched Pew sample of 833 individuals was also mostly female (65.5%, $n = 546$), non-Hispanic (96.5%, $n = 804$), White (81.8%, $n = 681$) and college-educated (33.1%, $n = 276$). Pew participants did not self-report their height or weight. Despite best efforts to match the two samples, it was not possible to perfectly match the samples, so statistically significant differences remained. See Table 1 for demographic characteristics of the two samples. As described previously, controlling for these differences did not affect results obtained in this study.

Smartphone ownership was higher in the NWCR (80.2% of the sample; see Table 2 for descriptive statistics related to technology ownership and use) than Pew (52.8%; $\chi^2 (2) = 138.5$, $p < .001$), and non-smartphone ownership was higher in the Pew sample (44.7%) than the NWCR (18.0%; $\chi^2 (2) = 132.7$, $p < .001$). Relatively few individuals in either sample did not own any type of cellular phone (1.5% in NWCR, 2.5% in Pew), although this was one of the matching criteria. The odds of NWCR participants accessing the Internet on a mobile handheld device at least occasionally were 6.3 times greater than for members of the Pew sample $\chi^2 (1) = 211.4$, $p < .001$.

Health tracking

National Weight Control Registry participants had 5.2 times greater odds for using any method of tracking and

Table 2 Differences between samples on device ownership, health tracking and how health tracking affects behaviour

Item	NWCR ($n = 794$)	Pew ($n = 833$)
	Count (%)	Count
Owns a smartphone	637 (80.2%)	440 (52.8%)
Owns a non-smartphone cellular phone	143 (18.0%)	372 (44.7%)
Does not own any type of cellular phone	12 (1.5%)	21 (2.5%)
Accesses the Internet on a cellular phone, tablet or other mobile device at least occasionally	712 (89.7%)	482 (57.9%)
Currently tracks one's own weight, diet or exercise	737 (92.8%)	594 (71.3%)
Currently tracks one's own health indicators on a regular basis	535 (67.4%)	344 (41.3%)
Has apps for health tracking or health management*	451 (70.8%)	83 (18.9%)
Uses diet, food or calorie counter apps*	375 (58.9%)	26 (5.9%)
Uses an app to monitor weight*	202 (31.7%)	13 (3.0%)
Uses apps to monitor exercise, fitness, step count or heart rate*	324 (50.9%)	32 (7.3%)
Health tracking has affected a decision about how to treat an illness or condition	71 (8.9%)	242 (29.0%)
Health tracking has influenced someone to change one's overall approach to maintaining one's own health or the health of someone they help care for	226 (28.5%)	323 (38.8%)
Health tracking has lead the respondent to ask a doctor new questions or to get a second opinion from another doctor	101 (12.7%)	284 (34.1%)

*Only out of individuals who own a smartphone ($n = 637$ in the National Weight Control Registry [NWCR] and $n = 440$ in Pew). All differences between samples are statistically significant at $p < .05$.

recording their own weight, diet and/or exercise, including paper diaries or booklets to record data $\chi^2 (1) = 129.6, p < .001$. NWCR participants had 2.5 times greater odds for tracking on a regular basis than individuals from the Pew sample $\chi^2 (1) = 62.7, p < .001$. Of participants who track a health indicator, the majority of NWCR participants update their health records about once daily (27.3%), and 18.1% update several times daily. The majority of the Pew sample updates 1–2 days each week (26.6%), 20.1% update about once daily and 12.7% update several times daily.

Health tracking using apps in smartphone owners

The odds of NWCR participants having apps to track or manage health were 10.0 times greater than individuals from the Pew sample $\chi^2 (1) = 278.3, p < .001$. Of the individuals that owned smartphones in each sample, 58.9% of NWCR participants reported using a diet, food or calorie counter apps compared with 5.9% of the Pew sample, a 22.8-fold difference in odds $\chi^2 (1) = 312.3, p < .001$. NWCR participants had 15.5 times greater odds for using an app to monitor weight than the Pew sample $\chi^2 (1) = 134.7, p < .001$. Nearly one-third (31.7%) of NWCR participants that own smartphones used apps to monitor weight compared with only 3.0% of the Pew sample. NWCR smartphone owners had 13.3 times greater odds for using apps to monitor exercise, fitness, step count or heart rate than members of the Pew sample that owned smartphones (50.9% versus 7.3%; $\chi^2 (1) = 233.5, p < .001$).

Utilization of health tracking data

Although NWCR participants track health indicators more frequently than the Pew respondents included in these analyses, the Pew sample was far more likely to change their behaviour in response to their health tracking data than NWCR. Almost a third (29.0%) of the Pew sample reported that health tracking has affected a decision about how to treat an illness or condition compared with only 8.9% of NWCR participants $\chi^2 (1) = 131.0, p < .001$. The Pew sample was more likely to change their approach to maintaining their own health or the health of someone they help care for based on health tracking data (38.8%) than NWCR participants (28.5%; $\chi^2 (1) = 33.7, p < .001$). Finally, over a third (34.1%) of the Pew sample reported that health tracking led the participant to ask a doctor new questions or to get a second opinion from another doctor compared to only 12.7% of the NWCR participants $\chi^2 (1) = 130.0, p < .001$.

Discussion

National Weight Control Registry respondents consistently reported higher rates of tracking health indicators via technology or any other means. Nearly all of the individuals included in the study owned cellular phones of some kind, although smartphone ownership was higher in the NWCR. Previous research conducted by Pew has illustrated that individuals with higher incomes and education levels are more likely to own smartphones; (5) given the demographic profile of the NWCR, it is unsurprising that this sample contains more smartphone owners than Pew. NWCR participants had 22.8 times greater odds for using diet, food or calorie counter apps and 15.5 times greater odds for using an app to monitor weight than the Pew sample. In contrast, the Pew sample was more likely to report that they changed their overall approach to managing health conditions for themselves or someone they care for, to request a second opinion from a doctor and to ask a doctor new questions based on their health tracking data.

Structured behavioural programs for weight loss and maintenance typically strongly encourage participants to self-monitor their eating behaviour, physical activity and body weight on a daily basis (27), as individuals who self-monitor more tend to be more successful (20,28). One rationale for self-monitoring is that it can be used for self-regulation (i.e. to promote changes in behaviour to improve weight control). For example, a period of weight gain may prompt an individual to increase their physical activity or limit their dietary intake. The STOP Regain study demonstrated that recent weight losers who received a program focused on self-monitoring and self-regulation maintained their weight loss better than those who received minimal intervention (29).

While tracking rates and ownership of tracking tools (e.g. smartphones with weight-related apps) were remarkably high in the NWCR, they were not used by NWCR participants in the same way as in the Pew sample: the Pew sample consistently reported that their tracking data motivated them to change their behaviour in various ways, whereas only approximately one-tenth to one-third of NWCR participants changed their behaviours based on their tracking data. There are at least two potential explanations for this pattern of results. NWCR participants may be so successfully persisting in their weight maintenance behaviours that they do not need to enact further behaviour change, whereas the Pew sample may have a greater need to improve their health behaviours across a variety of domains. In that case, it is encouraging to see that individuals using self-monitoring technology in the Pew sample are using their data to better manage their health. An alternative explanation is that NWCR participants are

not deriving complete benefit from their frequent tracking, as it does not appear to be influencing their behaviour. While weight loss maintenance is generally very good in the NWCR, gradual regain is common (26). Thus weight loss maintenance in the NWCR sample might be improved with intervention aimed at utilizing tracking data to determine when a change in behaviour is necessary to prevent or reverse weight regain.

It may be advantageous for researchers and commercial app developers to create digital health tools specifically for weight maintenance. The majority of currently available smartphone apps are geared towards weight loss rather than maintenance. Previous studies (30–33), including in the NWCR (21,34), have demonstrated that high levels of physical activity are particularly important for weight loss maintenance. Consequently, physical activity monitors, in particular, may be a technology tool to consider when targeting successful weight maintainers given their widespread popularity and adoption (26.63% of the present NWCR participants reported using wearable monitors, but similar data were not collected in the Pew sample). Clinically, this study suggests that many successful weight loss maintainers are using digital tools in the service of their continued success. Thus, individuals struggling to maintain a weight loss may benefit from instruction on how to use these convenient, widely available resources to their benefit. More consideration of how specific features of digital health technologies (e.g. planning tools, tracking tools, prompting and machine learning-based feedback) can bolster technology-based treatments are needed before implementing and broadly disseminating weight interventions. Ideally, future clinical interventions will be delivered ‘just-in-time’ (10) and adapted to the user’s needs over time. These considerations are particularly critical for users who transition from weight loss to weight maintenance and need different kinds of support along the way. A similar framework could also be used to identify lapses and prevent weight regain; other investigations in this area continue and will have important clinical implications for patients and providers.

The quickly evolving field of digital health technology raises additional important questions related to but not directly investigated within the present project. Presently available technologies and applications can support specific diet and exercise plans beyond merely self-monitoring (e.g. some offer feedback on adherence to a specific dietary restriction, others allow for participation in commercial weight loss programs); however, these were not expressly studied in the present project. Adjunctive technologies that interface with smartphones, including chest straps with physiological sensing capabilities, wristbands and Bluetooth-connected scales, were also not studied in the present comparison. Researchers may

wish to examine whether there are any potential negative consequences of technology use or over-reliance on technology for self-regulation, although previous examinations of individuals participating in behavioural weight control programs have demonstrated that frequent self-monitoring of weight does not appear to be associated with an increase in eating disorder symptomatology (35).

This study has notable strengths. It is the first to examine how successful weight loss maintainers use technology to track health indicators that may influence their continued weight maintenance success. This study also highlights a potential intervention target, namely, the use of popular electronic self-monitoring tools to drive behavioural self-regulation in weight loss maintainers. Another asset is the use of a nationally representative sample, the Pew Tracking for Health Survey, to serve as a reference group for the NWCR, both of which had large sample sizes adding to the robustness of the findings.

There were some limitations to the present study. Perhaps most importantly, there was a gap between the data collections; the Pew Tracking for Health Survey was conducted in 2012 (which is the most recently available survey), whereas the NWCR sample was surveyed in 2014. Smartphone ownership rose 16% in that time (4), which may partially account for the 27% difference between groups in rates of smartphone ownership in this study. In addition to smartphone ownership, existence and use of health behaviour apps may have increased during that time. Regrettably, there is a reliable method to control for this statistically in the present study given the data currently available, so readers are cautioned to consider that increasing popularity of health apps may have influenced the different rates of use between groups. However, given the magnitude of those differences, the present study reflects a meaningful contribution to the literature based on the information available now. There were differences in the data collection methods between the studies: the Pew Tracking for Health study was conducted over the phone. Participants were contacted on both landline and cellular phones. Participants in the NWCR were contacted via email, which could have influenced the proportion of individuals that had access to additional Internet capabilities because they were required to have access to the Internet to take the survey. Similarly, this recruitment difference could have affected the rates of smartphone ownership found in each sample, although this is impossible to determine. Future studies should aim to use the same recruitment methods for all participants. Additionally, the NWCR participants reported higher mean annual incomes compared with the national sample. NWCR participants therefore likely had greater access to technology, although disparities in access to technology appear to be closing rapidly.

(4,5). It was impossible to perfectly match both samples on demographics, although we believe the study's findings are reasonable and informative given that controlling for demographic differences did not affect the pattern of results. While the Pew Tracking for Health Survey is an exceptional resource for researchers, the dataset does not include questions of particular interest related to weight loss and maintenance, such as use of fitness trackers. Limitations of this study also include its retrospective and cross-sectional nature: individuals were surveyed about their current technology use after already achieving and maintaining significant weight loss, so it is impossible to differentiate the contribution of technology to weight loss versus weight loss maintenance. Respondents were not asked about their motivation to track their health, and neither group reported what additional health conditions or behaviours they need to change to reach a more optimal health status. Finally, they were also not surveyed about specific app features they frequently use or find useful. Sophisticated fitness trackers (capabilities beyond a pedometer), including Fitbit, were less widely available at the time of the Pew survey; had the Pew study included questions on fitness trackers, results may have demonstrated that respondents would have been less likely to own a fitness tracker than NWCR participants who were surveyed 2 years later. Given increasing availability and popularity of digital health technologies that interface with smartphones (e.g. Fitbits), future studies should examine rates of use and influences on behaviour in individuals managing substantial weight loss.

Shortly after the data were collected in this study, Jakicic et al. published the outcomes of the Innovative Approaches to Diet, Exercise, and Activity (IDEA) randomized clinical trial, which found that adding a wearable physical activity tracker and associated Web-based resources to group-based behavioural obesity treatment did not produce additional weight loss or improvements in other outcomes beyond what was achieved via the addition of a self-monitoring website alone (36). This study received considerable attention amongst obesity professionals and the lay public because of the broad conclusion that 'Devices that monitor and provide feedback on physical activity may not offer an advantage over standard behavioral weight loss approaches.' Furthermore, some readers appear to have generalized the findings of the IDEA trial to other types of electronic and mobile health technology, concluding that these technologies confer few, if any, benefits.

The current study provides an important and interesting counterpoint to the findings of Jakicic et al. in that it demonstrates the popularity of self-monitoring tracking technology amongst a population of individuals who have

achieved a high degree of success with weight loss and long-term weight loss maintenance. While this study is cross-sectional and therefore cannot determine whether the use of self-monitoring tracking technology is associated with better weight loss outcomes in the NWCR sample, the high rates of adoption suggest that this population has found benefit in its use. In the IDEA trial, on the days that participants wore the fitness trackers (worn on a band on the upper arm against the skin under clothing), they wore them for approximately 4 hours (36). In the 2 years since data collection ended, some individuals may have become more willing to wear a more comfortable fitness monitor even if it cannot be concealed under clothing, and they may be more willing to wear a fitness tracker for the entire day; some commercially available trackers are even available with corresponding fashion accessories created by famous brands and designers. Given the public's growing interest in using these tools, as evidenced by millions of downloads of tracking apps and tracking devices purchased, it is incumbent on researchers not to dismiss the potential of the technology, and instead continue to conduct research to determine exactly how, when and for whom self-monitoring tracking technology can best facilitate weight management and related health behaviours. Consistent with the findings of Jakicic et al., this study suggests that using technology solely for the purpose of tracking weight-related behaviours and outcomes is insufficient to produce improvements in behaviour, particularly after substantial behaviour change has already been made as was the case in the NWCR sample. Additionally, adherence to wearing the device may need to be high, particularly during waking hours. Rather, additional functionality and structured intervention that capitalizes on the tracking data may be needed in order to enhance outcomes. For example, Pourzanjani et al. demonstrated that individuals who more frequently logged their fitness and dietary intake using digital fitness trackers lost more weight than individuals who logged less (37). Similarly, Burke et al. demonstrated that a higher proportion of individuals using electronic monitoring achieved a clinically significant weight loss than those using paper diaries (a finding other research groups have replicated (38)), and monitoring with a personal digital assistant was higher than monitoring with paper diaries (14).

It is also important to note that while Jakacic et al. focused on the effect of a physical activity tracking device provided in the context of a structured weight loss program, the current study focused on the use of tracking apps used by a self-selected group of individuals with established weight loss and weight loss maintenance success. The two different types of technology may have different benefits and challenges, particularly when used

in different contexts. For example, it seems plausible that a fitness tracking device provided in the context of a weight loss intervention could interfere with weight loss outcomes if study participants assume that merely wearing the device is enough to ensure weight loss and/or if their effort and attention are focused primarily on the device instead of other, more established and reliable, strategies for weight loss. Taken together, the findings of Jakicic *et al.* and the current study suggest that we currently have an inadequate understanding of how best to use self-monitoring tracking technology in the context of weight management, but interest in self-monitoring tracking technology is high. Not all technologies are equivalent, particularly when used in different contexts. Furthermore, certain populations such as the NWCR may be able to teach us how to better capitalize on the potential of self-monitoring tracking technology to improve weight and related behaviours.

Conclusion

Findings from this study suggest that successful weight loss maintainers frequently use digital health technology for self-monitoring, and they use self-monitoring technology more often than the national US population, indicating that these individuals continue engaging in active self-monitoring (one of the cornerstones of behavioural weight loss) even after achieving significant weight loss. In particular, they were far more likely to use an app for weight management than individuals in the Pew sample. However, NWCR participants were less likely than the Pew sample to behave differently based on their health tracking data. This may indicate that NWCR participants are mostly able to persist in their weight maintenance behaviours. Alternatively, it may indicate that they could benefit from interventions focused on using self-monitoring technology to facilitate self-regulation strategies for maintaining weight loss given that many of them are already using digital tracking tools. Smartphone apps and online trackers may be useful self-monitoring and self-guided intervention tools for individuals wishing to maintain significant weight loss provided these individuals can make the best use of the data they gather.

Author Contributions

C. M. G. and J. G. T. conceived of the project and carried out data collection. R. W. founded and implements the NWCR, making the sample and data available. C. M. G. primarily wrote the paper with J. G. T. providing feedback on the writing and analytic plan. C. M. G., J. G. T., R. W. and D. B. were involved in data interpretation and editing

the paper. All authors were involved in writing the paper and had final approval of the submitted and published versions.

Conflict of Interest Statement

Drs. Goldstein, Thomas, Wing and Bond have nothing to disclose.

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