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A mixed-methods longitudinal examination of weight-related self-monitoring and disordered eating among a population-based sample of emerging adults

Samantha L. Hahn^{1*} , Caroline Bornstein², C. Blair Burnette³, Katie A. Loth⁴ and Dianne Neumark-Sztainer²

Abstract

Background Weight-related self-monitoring (WRSM) apps are used by millions, but the effects of their use remain unclear. This study examined longitudinal relationships between WRSM and disordered eating among a population-based sample of emerging adults.

Methods Participants ($n = 138$) were recruited from EAT 2010–2018 (Eating and Activity over Time study) to participate in a mixed-methods (quantitative and qualitative) longitudinal study to understand the impacts of WRSM. In 2018, participants ($M_{\text{age}} = 21.7 \pm 1.9$ years) reported motivations for use and types of WRSM apps used. Dependent variables collected in 2022 ($M_{\text{age}} = 25.7 \pm 1.9$ years) included past year total number of disordered weight control behaviors, disordered muscle building behaviors, compulsive exercise, and binge eating. Linear and logistic regressions were used adjusting for sociodemographics, body mass index, and baseline disordered eating. Semi-structured interviews ($n = 25$) were analyzed using inductive thematic analysis.

Results Participants using WRSM apps for weight management demonstrated an increase in disordered weight control behaviors over time ($\beta = 0.894, p = .012$). Using WRSM apps for “healthy” eating was marginally associated with an increase in disordered weight control behaviors. ($\beta = 0.673, p = .052$). Qualitatively, participants reported varied temporality between WRSM and disordered eating, but believed that app use encouraged restriction/binge cycles and normalized disordered eating.

Conclusions Findings suggest there may be individual variation in the relationships between WRSM and disordered eating, but that using WRSM apps with the motivation of managing eating or weight may increase disordered eating in some. Additionally, WRSM apps may normalize or encourage disordered eating. Therefore, safeguards, including screening and monitoring, are needed to ensure WRSM does not cause or escalate harm among WRSM users.

Plain English summary

For some, weight-related self-monitoring apps, like MyFitnessPal and Fitbit, may cause or worsen disordered eating over time among emerging adults. However, it seems as though the *motivation* for self-monitoring (e.g., for

*Correspondence:
Samantha L. Hahn
sam.hahn@cmich.edu

Full list of author information is available at the end of the article



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managing eating or weight) may be more important than *what* they are monitoring when it comes to disordered eating risk.

Keywords Self-monitoring, Disordered eating, Emerging adults, Qualitative research, Longitudinal cohort

Introduction

Weight-related self-monitoring (WRSM) apps, wearable devices, and other technologies that track weight, dietary intake, and/or physical activity have amassed millions of users in recent years [1–5]. Specific apps like FitBit and MyFitnessPal have tens of thousands of users every month. Historically, self-monitoring was most frequently used in clinical weight management, as an adjunct to counseling and medical supervision [6]. However, technologies like smartphone apps, smart watches, and wearable fitness trackers, have normalized the use of WRSM among the general population. Therefore, most people engaging with self-monitoring tools are likely doing so without the additional supports typically provided within the context of clinical care. Although WRSM has been considered beneficial for fostering positive behavior change [7], its widespread use outside of clinical care necessitates examining possible adverse effects.

Of critical concern is whether WRSM increases eating disorder risk, including body dissatisfaction, weight/shape preoccupation, and engagement in disordered eating behaviors such as fasting, purging, binge eating, compulsive exercise, and disordered muscle building behaviors. WRSM apps inherently involve bringing one's focus to eating and weight; for some the focus could lead to a preoccupation with eating and weight, thereby increasing eating disorder risk. Indeed, a growing body of research shows that WRSM is associated with higher eating disorder risk in the general population. Qualitative research among a clinical eating disorder sample showed that 75% of participants believed that MyFitnessPal, a dietary-focused tracking app, contributed to the *development* of their eating disorder [8]. Moreover, cross-sectional research has shown a strong and consistent association between dietary-focused and physical activity-focused WRSM and elevated likelihood of disordered eating among emerging adults [9–13].

Despite the established link between WRSM and eating disorder risk, the temporality and directionality of associations is unclear. Although it is possible that individuals already engaging in disordered eating are more likely to seek out and use WRSM apps, two studies found that disordered eating did not consistently predict later WRSM use [14, 15]. To date there are no known studies examining whether WRSM predicts increases in disordered eating over time, a critical first step in elucidating temporality. Establishing temporality is a critical component of understanding whether there is indeed a *causal* association between WRSM and increased disordered eating

risk, though not sufficient to establish causality. If WRSM does in fact lead to disordered eating, we would therefore expect that WRSM would be longitudinally associated with disordered eating. Clarifying the temporality of the association between WRSM and disordered eating is particularly important in emerging adult populations given they are most likely to use WRSM technologies and have high prevalences of disordered eating [16–18].

In addition to establishing whether WRSM longitudinally predicts disordered eating, more work is needed to understand what aspects of WRSM increase its potential adverse consequences (e.g., type of WRSM, frequency of use, motivations for use). It is possible that the type of WRSM (i.e., dietary or physical activity-focused) is a greater factor than the motivation behind its usage. For instance, dietary-focused WRSM may potentiate eating disorder risk more than physical activity-focused WRSM, given the focus on calories and requirement of active user participation in dietary-focused WRSM compared to the more passive nature of physical activity monitoring. Alternatively, it could be that motivation is a more potent predictor of eating disorder risk. For example, using WRSM with the goal of changing your weight/shape may be the strongest driver of disordered eating rather than the specific behaviors being tracked. Research in related fields, such as the physical activity literature, shows that motivations for physical activity are differentially associated with a myriad of outcomes including sustainability of behavior change [19] and body image [20]. Therefore, it is plausible that the motivation for WRSM could impact disordered eating risk. However, to our knowledge associations between WRSM and disordered eating have not separately examined motivation and type of WRSM.

Therefore, the present study used surveys and semi-structured interviews to explore whether WRSM, both by motivation and type, was longitudinally associated with disordered eating among a population-based sample of emerging adults. We hypothesized that WRSM would be associated with increases in all measures of disordered eating. We further hypothesized that associations would be stronger for motivations of WRSM rather than WRSM type. The integration of qualitative and quantitative data will not only allow us to examine temporality, but also enrich our understanding of the complex associations between WRSM and disordered eating.

Methods

Study participants

To answer our research question and study the longitudinal and nuanced associations between WRSM and disordered eating, we designed the current study, Tracking-EAT. Participants in the Tracking-EAT study were a subsample of participants from the EAT 2010–2018 (Eating and Activity over Time) study, a population-based study that aims to examine the eating, activity, and weight-related health of young people. Participants were originally recruited from public middle and high schools in the Minneapolis-St. Paul, Minnesota area in the 2009–2010 school year and completed a second survey in 2017–2018. For the current study, Project EAT staff identified a pool of study participants with complete data from 2018 for key variables, with no other inclusion, exclusion, or selection criteria, which was approximately one half of the entire EAT 2018 sample ($n=691$). Invitations to participate in the Tracking-EAT study were emailed to all identified subjects, which included 346 individuals who reported WRSM in 2018 and 345 individuals who were non-users of WRSM in 2018, and was therefore an approximate 1:1 ratio of WRSM app users to non-WRSM users. There were no differences in gender, race/ethnicity or socioeconomic status between users

and non-users sent the invitation to participate in Tracking EAT. Recruitment emails with a survey link were sent to the 691 potential participants, with up to two email reminders per person. A total of 138 people who were diverse in gender, ethnicity/race, and socioeconomic status completed the survey for the Tracking-EAT study (Table 1) and 52.9% of those who completed the survey had been WRSM app users in 2018. The sociodemographic characteristics of the Tracking-EAT study sample were also very similar to the full EAT 2010–2018 sample [14].

A sub-sample of Tracking-EAT survey respondents who reported WRSM use in the past year were recruited for the qualitative semi-structured interview portion of the study. Specifically, we intentionally sampled Tracking-EAT survey respondents across the spectrum of disordered eating behaviors (i.e. no disordered eating, one disordered eating behavior, numerous disordered eating behaviors), but did not utilize any other selection criteria. We recruited across a spectrum of disordered eating to ensure that when assessing motivations for and impacts of WRSM, that results could be generalizable to all WRSM users in our sample, rather than just those who experienced disordered eating. We invited participants in batches of five until we reached our pre-determined

Table 1 Sociodemographic characteristics of sample

	Overall sample <i>n</i> = 138	WRSM app users <i>n</i> = 73 (52.9%) <i>n</i> (%)	Non-users <i>N</i> = 65 (47.1%)
<i>Gender</i>			
Cisgender man	35 (25.6)	19 (26.0)	16 (25.0)
Cisgender woman	73 (53.3)	37 (50.7)	36 (56.3)
Gender non-binary/fluid/transgender	18 (13.1)	12 (16.4)	6 (9.4)
Prefer not to answer	11 (8.0)	5 (6.9)	6 (9.4)
<i>Highest Education Achieved</i>			
High school degree or less	29 (21.0)	14 (19.2)	15 (23.1)
Some college, associate, vocational	52 (37.7)	29 (39.7)	23 (35.4)
Bachelor, graduate degree	57 (41.3)	30 (41.1)	27 (41.5)
<i>Race/ethnicity</i>			
Asian American	25 (18.1)	11 (15.1)	14 (21.5)
Black/African American	22 (15.9)	11 (15.1)	11 (16.9)
White	43 (31.2)	21 (28.8)	22 (33.9)
Hispanic/Latinx	27 (19.6)	16 (21.9)	11 (16.9)
Mixed/Other	21 (15.2)	14 (19.2)	7 (10.8)
<i>Socioeconomic status</i>			
Low	42 (30.9)	23 (31.9)	19 (29.7)
Low-Middle	27 (19.9)	13 (18.1)	14 (21.9)
Middle	21 (15.4)	14 (19.4)	7 (10.9)
High-Middle	23 (16.9)	13 (18.1)	10 (15.6)
High	23 (16.9)	9 (12.5)	14 (21.9)
		Mean (SD)	
Age (Years)	26.5 (1.9)	26.4 (1.9)	26.7 (1.9)
BMI	28.7 (7.7)	29.6 (7.5)	27.7 (7.9)

Abbreviations BMI, body mass index; SD, standard deviation

sample of 25. A sample size of 25 for the qualitative survey was determined a priori based on literature suggesting saturation is often achieved with 9–20 participants [21, 22], as well as prior experience from the research team [23–26].

Survey measures

WRSM app use was examined both by motivation and by type in the EAT 2018 survey. To assess WRSM use by motivation, participants were asked, “In the past year, did you use a mobile app, tracker device (such as Fitbit), or web-based programs to help you...” The three assessed motivations were: “make healthy eating choices”, “be physically active”, and “manage your weight”. Each motivation had a yes/no response option and was therefore treated as dichotomous (use versus no use). To assess the type of WRSM app use, participants were asked, “Thinking about the mobile apps, tracker devices, and web-based programs you’ve used in the past year to help you manage your eating, activity or weight, please list up to 3 and tell us how often you currently use them.” Participants listed apps and rated their use to be: “never”, “rarely”, “sometimes” or “often”. Coders reviewed apps to determine their main functionality and apps were classified as physical activity-focused (e.g., Fitbit), dietary-focused (e.g., MyFitnessPal), or another function (e.g., water intake only tracking apps). Each type of WRSM use was treated dichotomously (any use vs. no use), to be consistent with WRSM use by motivation. Participants could report more than one motivation for WRSM and/or using more than one WRSM app.

Disordered eating was assessed at both 2018 and 2022 to evaluate whether WRSM longitudinally predicted changes in disordered eating. At both time periods there were an array of disordered eating behaviors measured including disordered weight control behaviors, disordered muscle building behaviors, compulsive exercise and binge eating. Disordered weight control behaviors were assessed with the question, “Have you done any of the following things in order to lose weight or keep from gaining weight during the past year?” [27]. Behaviors assessed (yes/no) included fasting, eating very little food, using a food substitute, skipping meals, vomiting, abusing laxatives, using diuretics, taking diet pills, and smoking more cigarettes (test–retest agreement in 2018=85%). A sum of the number of disordered weight control behaviors used in the past year was used in all analyses (possible range 0–9). Disordered muscle building behaviors were assessed using the stem question, “Have you done any of the following things in order to increase your muscle size or tone during the past year?” [28, 29]. Behaviors assessed (yes/no) included using protein powder or shakes, pre-workout, and steroids. A sum of the number of disordered muscle building behaviors

used in the past year was used in all analyses (possible range 0–3). Compulsive exercise was assessed using three questions from the Obligatory Exercise Questionnaire [30]: (1) “When I miss a scheduled exercise session, I may feel tense, irritable, or depressed” (2) “If I feel I have over-eaten I will try to make up for it by increasing the amount I exercise” and (3) “When I don’t exercise, I feel guilty”. Response options ranged from “never” to “always”. Scores from the three questions were summed for a composite score with higher scores indicating higher levels of compulsive exercise (test–retest in 2018 $r=.81$, possible range in 2018 of 3–12, possible range in 2022 of 3–12; response options differed because the scale was updated in 2022 to have response options match those in the original measure). In the parent EAT 2010–2018 study, because of the large number of health topics covered in the survey, there was not sufficient space for the entire Obligatory Exercise Questionnaire. For consistency, we elected to use the same three questions in 2022 that were used in the baseline data collection. Binge eating was assessed with the following two questions from the Questionnaire on Eating and Weight Patterns-Revised [31]: “In the past year, have you ever eaten so much food in a short period of time that you would be embarrassed if others saw you (binge-eating)?” (test–retest agreement=90%) and, “During the times when you ate this way, did you feel you couldn’t stop eating or control what or how much you were eating?” (test–retest agreement=75%). Both were yes/no questions, participants who answered yes to both questions were considered to have binge eaten in the last year.

Other demographics collected include ethnicity/race (2010), socioeconomic status (SES, 2010), BMI (2018), age (2018), gender (2022), and highest educational attainment (2022). SES was a composite variable determined based on parent education and family financial assistance. SES as an adolescent was included in all analyses as a covariate because adolescent SES is shown to have long-term impacts on health behaviors [32].

Semi-structured interviews

Two graduate research assistants conducted semi-structured interviews after being trained by the principal investigator/first author. One interviewer was the second author, a White woman completing her Masters of Public Health in Nutrition. The other interviewer was a Black woman completing her PhD in Social and Behavioral Epidemiology who has a Masters of Public Health in Nutrition and is also a registered dietitian with clinical experience working with disordered eating and in weight management. Interviews covered a range of topics including how individuals were introduced to WRSM, the impact of WRSM on their lives, and potential modifications to WRSM to improve health outcomes for users.

Questions from the semi-structured interview guide specific to disordered eating can be found in Table 2.

Given the semi-structured nature of the interview, additional probing questions were used to facilitate deeper exploration and clarification based on initial participant answers. Interviews occurred online via Zoom, were audio recorded, and professionally transcribed. Participants provided informed consent online prior to data collection and verbal consent to be recorded for interviews before commencing the interview. The University of Minnesota's Institutional Review Board Human Subjects Committee approved all study protocols.

Data analysis

Descriptive statistics were run for all demographic information, predictors (WRSM) and outcomes (disordered eating). WRSM motivations and types were all treated individually as binary predictors. We then used linear (disordered weight control behaviors, disordered muscle building behaviors, and compulsive exercise) and logistic (binge eating) regressions to examine whether WRSM (by motivation and type) predicts later disordered eating, adjusting for baseline level of the outcome and demographic information (i.e., adolescent SES, BMI at 2018, age, gender, race/ethnicity). All analyses were conducted in SAS v9.4 and were considered statistically significant if $p < .05$.

Qualitative analyses began with professional transcription of semi-structured interviews, which were then analyzed using inductive thematic analysis with NVivo12 software. Four individuals reviewed the transcripts to generate preliminary codes (both interviewers, primary investigator, and an additional research assistant). The team then met to discuss and refine codes. Each transcript was then coded by the first and second author and discussed until agreement was reached. Iterative changes to the codebook were discussed and made as needed. After coding, the first and second author created a preliminary thematic map with themes/sub-themes, which was finalized after input from the entire study team. Only results pertaining to disordered eating are included in the

present paper to add additional insight into the relationships between WRSM and disordered eating in our study population.

Results

Our sample was diverse in gender, with approximately one half identifying as a cisgender woman (53.3%), one quarter as cisgender man (25.6%), 13.1% as gender non-binary, gender fluid, or transgender, and 8.0% that preferred not to answer about their gender (Table 1). Further the sample was predominantly low socioeconomic status (30.9%). Race/ethnicity was also diverse, with 18.1% identifying as Asian American, 15.9% as Black or African American, 31.2% as White, 19.6% as Hispanic/Latinx, and 15.2% who identified as more than one race/ethnicity or another identity.

Descriptives of WRSM and disordered eating

The most common motivation to use WRSM was to be physically active (39.9%); an approximately equal proportion of participants reported using WRSM to make healthy eating choices (30.4%) and manage their weight (29.7%, Table 3). However, despite nearly a third of participants reporting using WRSM apps to eat more healthfully, when examining WRSM by app type, only 12.3% of the overall sample reported using dietary-focused WRSM apps. Similarly, only 20.0% of study participants reported using a physical activity-focused app.

Participants reported using an average of 1.3 different disordered weight control behaviors in the past year at baseline and 2.1 behaviors in the past year at follow-up. The prevalence of fasting, eating little food, food substitutes and skipping meals all increased from baseline to follow-up. The average number of disordered muscle building behaviors was also higher at follow-up (0.4 at baseline, 0.7 at follow-up), with increases in all forms of disordered muscle building behaviors. The proportion of participants who reported binge eating nearly tripled from baseline (11.7%) to follow-up (29.0%). Average compulsive exercise score was 5.7 at baseline and 4.9 at follow-up.

Table 2 Relevant part of semi-structured interview guide

I'd like to ask you some questions about your experience with certain types of eating and exercise behaviors that you may have used to lose weight, change your shape, or build muscle. Specifically, I'm interested in things like exercising in an extreme or compulsive manner, skipping meals, fasting, taking diet pills, laxatives, or diuretics, making yourself sick, taking steroids or using protein powders or other supplements with the goal of changing your body in some way – like weight loss or changing your body shape or building muscle.

a. Can you tell me a little bit about your history with these types of eating and exercise behaviors, if any? **if none, skip to next question.*

b. Some people talk about feeling like WRSM can lead to the use of these types of eating and exercise behaviors, others feel like these types of monitoring can help them to stop these types of behaviors, and sometimes something else – what has been your experience? Which came first, these eating and activity behaviors or using WRSM apps?

Another eating behavior that we're interested in learning about is what we call binge eating, which is when you eat a large amount of food and while you're eating that food, you feel like you lost control of your eating.

a. Can you tell me a little bit about your history with binge eating, if any?

b. Did you start binge eating or using WRSM apps first?

c. What do you think the relationship is between your binge eating you're your WRSM apps use?

Table 3 Descriptive statistics of weight-related self-monitoring app use and disordered eating

Weight-related self-monitoring app use by motivation^a, n (%)	
To make healthy eating choices	30.4 (42)
To be physically active	39.9 (55)
To manage weight	29.7 (41)
Weight-related self-monitoring app use by type^a, n (%)	
Dietary-focused	12.3 (17)
Physical activity-focused	29.0 (40)
Any app	37.0 (51)
Disordered eating baseline & follow-up	
Disordered weight control behaviors ^b (possible range: 0–9), Mean (SD)	
Baseline	1.3 (1.7)
Follow-up	2.1 (2.0)
Fasting, n (%)	
Baseline	23 (16.8)
Follow-up	65 (47.5)
Ate little, n (%)	
Baseline	54 (39.4)
Follow-up	76 (55.1)
Diet pills, n (%)	
Baseline	14 (10.2)
Follow-up	16 (11.8)
Vomiting, n (%)	
Baseline	7 (5.2)
Follow-up	9 (6.6)
Laxatives, n (%)	
Baseline	2 (1.5)
Follow-up	15 (11.0)
Diuretics, n (%)	
Baseline	3 (2.2)
Follow-up	4 (3.0)
Food substitutes, n (%)	
Baseline	25 (18.3)
Follow-up	44 (31.9)
Skipped meals, n (%)	
Baseline	43 (32.1)
Follow-up	68 (49.3)
Smoked more cigarettes, n (%)	
Baseline	9 (6.6)
Follow-up	6 (4.6)
Disordered muscle building behaviors ^b (possible range: 0–3), Mean (SD)	
Baseline	0.4 (0.7)
Follow-up	0.7 (0.9)
Pre-workout, n (%)	
Baseline	15 (10.9)
Follow-up	36 (26.3)
Protein powder, n (%)	
Baseline	37 (26.8)
Follow-up	59 (43.4)
Steroids, n (%)	
Baseline	1 (0.7)
Follow-up	5 (3.7)
Compulsive Exercise score ^c (possible range: 3–12), Mean (SD)	
Baseline	5.7 (2.4)

Table 3 (continued)

Follow-up	4.9 (3.5)
Binge Eating, n (%)	
Baseline	16 (11.7)
Follow-up	40 (29.0)

^aCategorized app use which were not mutually exclusive

^bCalculated as the number of behaviors reported

^cScale of compulsive exercise differed – same questions were asked, but more response options given in 2022

Longitudinal associations between WRSM and disordered eating

In regression models adjusting for demographics, BMI, and baseline disordered eating, certain motivations for WRSM use were associated with an increased number of disordered weight control behaviors, whereas WRSM app type was not significantly associated with disordered weight control behaviors (Tables 4 and 5). Using WRSM to make “healthy” eating choices was marginally associated with an increase in disordered weight control behaviors over time ($\beta=0.67$, $p=.052$). Meaning that those who used WRSM to make “healthy” eating choices used an additional 0.67 types of disordered weight control behaviors in 2022 compared to those who did not use WRSM to make healthy eating choices, accounting for baseline number of disordered weight control behaviors and demographic characteristics. Using WRSM for weight management was also associated with increased number of disordered weight control behaviors ($\beta=0.89$, $p=.012$). Using WRSM for any of the three motivations was not significantly associated with disordered muscle building behaviors, compulsive exercise, or binge eating. Further, all associations between specific types of WRSM (e.g., dietary-focused) and disordered eating were not statistically significant in our sample. However, there were effect estimates comparable in magnitude to our significant findings that did not reach statistical significance (e.g., WRSM for healthy eating and compulsive exercise, $\beta=0.82$, $p=.197$).

Relationships between WRSM and disordered eating from participant perspectives

We found three themes related to disordered eating from the semi-structured interviews: (1) the temporality of WRSM and disordered eating varies; (2) WRSM encourages restrict/binge cycles; and (3) WRSM can normalize disordered eating. Examples of themes are embedded into the text below and shown in Table 6.

The Temporality of WRSM and Disordered Eating Varies. Participants reported four main temporal patterns between WRSM and disordered eating. Some participants reported that WRSM preceded and contributed to the development of their disordered eating, which reinforces quantitative findings. Other participants noted

Table 4 Adjusted longitudinal association between weight-related self-monitoring motivation and disordered eating^a

	Disordered weight control behaviors		Disordered muscle building behaviors		Compulsive exercise		Binge eating	
	β	<i>p</i>	β	<i>p</i>	β	<i>p</i>	OR	95% CI
Healthy Eating	0.67	0.052	0.19	0.272	0.82	0.197	1.37	(0.51–3.67)
Be Physically Active	0.38	0.274	−0.04	0.819	0.43	0.491	0.72	(0.27–1.92)
Weight Management	0.89	0.012	0.12	0.483	0.12	0.853	0.82	(0.29–2.27)

^aAll models adjust for gender, age, BMI, race/ethnicity, education, socioeconomic status, and baseline disordered eating

Table 5 Adjusted longitudinal association between weight-related self-monitoring type and disordered eating^a

	Disordered weight control behaviors		Disordered muscle building behaviors		Compulsive exercise		Binge eating	
	β	<i>p</i>	β	<i>p</i>	β	<i>p</i>	OR	95% CI
Dietary-focused	0.43	0.374	0.01	0.953	0.41	0.648	1.11	(0.27–4.63)
Physical activity-focused	0.20	0.568	0.09	0.595	0.63	0.319	1.43	(0.52–3.95)
Any app	0.53	0.118	0.07	0.669	0.70	0.249	1.28	(0.47–3.51)

^aAll models adjust for gender, age, BMI, race/ethnicity, education, socioeconomic status, and baseline disordered eating

Table 6 Qualitative results from semi-structured interviews

Theme	Quote
The Temporal-ity of WRSM and Disordered Eating	WRSM came first, contributed to development of disordered eating: "And I just became more restrictive and more restrictive with it at my fingertips. So I would say I definitely aided in those behaviors..." -Elise
Varies	WRSM exacerbated existing disordered eating: "I wanted the best intentions, but it becomes obsessive in the way that I'm quite harsh to my body, and the apps took full advantage of that, whether that was on purpose or not." - Laura Disordered eating came first, WRSM did not affect disordered eating: "And so I think more recently, that's I've been using it for, is to be like, 'You aren't overeating.' Because I started to really judge myself. Everything I was eating, I was like, 'I shouldn't be eating that'... But I'm like, 'You're allowed to eat breakfast'... And so I started to use it like, 'Okay, I actually only ate 1,800 calories today. It's not as much as I thought it was.'" - Lisa Never experienced disordered eating: "I don't think it triggered any harmful behaviors when it came to under eating, overeating... For me, it just kept me aware of what I was eating." - Pao
WRSM Encourages Restrict/Binge Cycles	"I think if I was hungry and I had already eaten the amount that I thought I should have eaten for the day, either anxiety or panic would kind set in. And if I allowed myself to eat something after that, I think it was just the, 'Oh, well I messed up. So I might as well just let myself go.'" -Elise
WRSM can Normalize Disordered Eating	"One time I had a banana and it was like, oh, see why bananas might be holding you back. I was like, but it's a banana. What are you talking about? It can't hold me back. It's a fruit. Fight me." -Olga

*Names of participants have been changed to preserve their identity

they were already engaging in some disordered eating when they began WRSM, but felt WRSM exacerbated symptoms and/or reinforced these behaviors. Another reported experience from participants was that their disordered eating preceded and was not worsened or reinforced by later WRSM. Lastly, there were some participants who used WRSM but did not report any disordered eating.

WRSM Encourages Restrict/Binge Cycles. In contrast with quantitative findings, participants reported that aspects of WRSM, including the encouragement of maintaining a caloric deficit and/or increasing the length of time between meals (i.e. intermittent fasting), encouraged by WRSM led to cycles of restriction and binge eating. For example, following the low caloric limits set forth by WRSM apps left participants hungry, increasing negative effects like feeling guilty for eating beyond the calorie

limit in the app, and escalating the likelihood of binge episodes. When describing how WRSM lead to binge episodes for him, one participant said, "There have been times ... when being very hungry just takes away a little bit of humanity from me and I just crave anything that's in front of me."

WRSM can Normalize Disordered Eating. Many features of WRSM apps appeared to normalize and even encourage disordered eating behaviors according to participants. For example, one participant reported that the dietary-focused app she was using told her to watch her sugar intake after logging a banana because of the sugar content in the banana. Other participants reported WRSM apps encouraging extreme caloric restriction, meal-skipping, fasting, supplement use, and compulsive or excessive exercise. Notably, these are all behaviors

included in our validated assessment of disordered eating behaviors.

Discussion

In this mixed-methods (quantitative and qualitative) longitudinal study, we found that using WRSM with the underlying motivation of trying to manage weight or eat “healthfully” was associated with increases in the number of disordered eating behaviors used over time. Conversely, the type of WRSM used (i.e. physical activity-focused or diet-focused) was not significantly associated with changes in disordered eating over time. These findings suggest that an individual’s motivation for using a WRSM app (e.g. to eat “healthfully”), rather than the type of tracking done on the app (e.g. tracking food) may be a more important predictor of eating disorder risk. Our qualitative findings also suggest that WRSM apps may encourage some disordered eating behaviors (e.g., fasting, compulsive exercise). However, whether disordered eating precedes or results from WRSM appears to vary widely. These findings suggest that although WRSM is often thought of and marketed as a “healthy” tool for behavior management, this may not always be the case. Clinicians and public health officials should create and modify recommendations so that WRSM is not encouraged among vulnerable individuals. Further, safeguards, such as screening and monitoring, are needed to ensure WRSM does not cause or escalate harm among WRSM users.

The literature to date, including the present study, shows an association between WRSM and higher likelihood of a variety of types of disordered eating [8–13]. In contrast, the present study did not find a statistically significant longitudinal relationship between WRSM and disordered muscle building behaviors, compulsive exercise, or binge eating. The lack of significant quantitative findings may have been due to lack of power and the inclusion of binary measures of binge eating; alternatively lack of statistical significance may have been due to individual variability that was masked in overall associations. Interestingly, despite no significant quantitative associations between WRSM and binge eating, participants qualitatively reported that WRSM app use encouraged participation in restrict/binge cycles. Specifically, participants described in interviews that they restricted to meet goals set by apps, but then experienced subsequent guilt, shame, and/or anxiety when these goals were not met. Additionally, the rigid and low-calorie limits set by the apps often induced extreme hunger when followed. Both the negative mood induction and strong hunger levels led to binge eating episodes among some participants. These findings mirror the literature on the strong association between dietary restriction and binge eating [33–37], as well as the literature connecting negative affect and binge

eating [38, 39]. Despite the lack of significant quantitative findings, our qualitative data suggest that WRSM can foster binge eating for some individuals. Qualitative data provide critical lived experience insights that cannot be gleaned from quantitative data alone. Future work should explore mechanisms and moderators of the association between WRSM and binge eating to clarify the magnitude and nuances of the associations.

The potent qualitative findings, but inconsistent quantitative findings in our study may be due to individual differences in the relationships between WRSM and disordered eating. Firstly, while WRSM and disordered eating are strongly cross-sectionally related [9–13], we did not find consistent longitudinal relationships in quantitative analyses. Less consistent longitudinal associations may be due to individual differences in the temporality between WRSM and disordered eating which could mask overall quantitative associations. In fact, we did find in our qualitative results that there was a great deal of variety in the temporal relationship between WRSM from participant’s perspectives. Specifically, some felt that WRSM led directly to the development of their disordered eating, which is consistent with prior qualitative work with a clinical eating disorder sample [8]. Conversely, some participants reported that disordered eating preceded their use of WRSM but that participation in the apps escalated these behaviors; these results suggest that WRSM can operate as both a *risk* and *maintenance* factor for disordered eating. In addition to individual differences in temporality, it is possible that for some WRSM does increase disordered eating risk, but for others it does not. Prior work using both quantitative and qualitative methods found that WRSM did not yield statistically significant increases in eating disorder risk for low-risk individuals in the overall sample, but a subset of individuals did experience negative effects [26, 40]. The results in the present study were very similar, as there were few statistically significant associations, but we had individuals report that they believed WRSM contributed to developing disordered eating while others never experienced disordered eating. Given that we also saw statistically significant associations only for specific WRSM motivations, it is possible that the variety of experiences reported in interviews of the effects of WRSM was in part due to differences in WRSM motivations. This is in line with the physical activity literature, which shows the motivation for engaging in physical activity can have differential effects on body image [20]. Overall, these results suggest that depending on the individual, WRSM may operate as a risk and/or maintenance factor for disordered eating or may have no impact on disordered eating at all. Findings underscore the need for more work that elucidates why WRSM appears to contribute to the onset and escalation of disordered eating for some but not

others. However, because WRSM is recommended for and used by millions of people, interventions are needed to reduce potential risk of disordered eating to vulnerable people who use WRSM apps. Such interventions could include disordered eating screening embedded into apps that connects individuals who screen positive with resources, regulations to eliminate the ability for WRSM advertisements to target minors, or changes in the apps themselves to reduce potential risk (e.g., removing encouragement of intermittent fasting).

One characteristic of WRSM apps identified by participants as a potential area of concern was the normalization of disordered eating. Participants described the apps as encouraging disordered eating via the setting of very low-calorie limits, assigning moral labels to foods (i.e., too much sugar is “bad”), and encouragement to do always do more (i.e., get a little bit more physical activity each day with no limit). Users may believe that goals set forth from WRSM are inherently health promoting, as WRSM apps are often marketed as such and are routinely recommended by trusted health professionals. It is also possible that people especially motivated to meet app-determined eating and activity goals are those most likely to be harmed by the normalization of disordered eating on WRSM apps. For example, it has been posited that the goal-directed nature of WRSM apps may escalate disordered eating risk among individuals high in perfectionism [41]. Those high in perfectionism may experience a stronger compulsion to achieve calorie and activity goals, relative to those lower in perfectionism, even if those goals may be harmful. In our study, one participant reported that they would get out of bed at night (despite being tired) to go on a run to meet their daily activity goals (i.e., “close their rings”) and to make sure they did not lose their “streak” within the app, behaviors emblematic of compulsive exercise. Such factors within WRSM apps encourage competition, both with oneself and with other users. These app characteristics may be particularly problematic for those with a high perfectionism and drive for goal-attainment, thereby motivating and even encouraging compulsive exercise (as was the case for our participant). Although prior research on the link between WRSM and disordered eating has typically focused on the type of WRSM used (i.e., physical activity-focused or dietary-focused), people’s motivation for app usage may also be a critical factor in understanding associations between WRSM and disordered eating risk. For instance, recent evidence found that engagement with appearance-based content was a stronger predictor of disordered eating than time spent on social media [42] and as described above, motivation for physical activity is associated with body image [20]. Although using WRSM to monitor physical activity may not be inherently harmful for all, doing so with the motivation to change one’s

body weight/shape may escalate disordered eating risk. Future research should examine perfectionism, motivations for use, and their interaction, to enhance understanding of who is at greatest risk for disordered eating when using WRSM. Findings could be used to create algorithms within WRSM apps to screen for those at risk for disordered eating, allowing those who are identified to be at risk to be connected with resources. Connection to resources from WRSM apps would promote knowledge on disordered eating, which may be particularly important given our findings on the normalization of disordered eating on WRSM apps, as well as resources to enhance secondary prevention and treatment accessibility and utilization.

The present study had a number of strengths, including the longitudinal study design utilizing both quantitative and qualitative analyses, and the use of a socioeconomically, gender, and racially/ethnically diverse, population-based sample. The study design allowed us to examine temporality of associations, which to our knowledge has not been done prior in a population-based sample. Further, the qualitative results allowed us to get a more nuanced understanding of the relationship between WRSM and disordered eating, which greatly increased our ability to interpret our results. We also included several types of WRSM and disordered eating behaviors in our quantitative analyses, which allows for a more wholistic understanding of the associations between WRSM and disordered eating that does not focus on behaviors more common among women and those striving for a thin ideal. A key limitation of this study was the relatively small sample size for quantitative analyses, which precluded examination of more nuanced and intersectional associations (e.g., how using WRSM for more than one motivation or tracking behavior affected specific disordered eating behaviors). Given our sample size, we were also not able to examine differences in associations by gender, which warrants further research. Our results also may not be generalizable to other demographics (e.g., different age ranges) and future research is needed to understand if these associations are found in populations with differing demographics.

Conclusions

Our findings suggest that WRSM leads to increased disordered weight control behaviors over time, but that motivation for app usage rather than type of WRSM may be more indicative of risk. Further, our results suggest that there may be individuals for whom using WRSM is harmful but others for whom it is not. It is important to recognize that the associations between WRSM and both positive and negative health outcomes are likely nuanced, and research and policy should recognize the complex nature of these relationships. As such, more research is

needed to identify factors that can differentiate those at risk of developing disordered eating from using WRSM vs. those who can use WRSM apps with minimal to no harm. Until we can answer these questions, it may be best to take a “first do no harm” approach by acknowledging that WRSM may increase the risk of disordered eating and therefore should not be broadly recommended and assumed to be healthful.

Abbreviations

BMI	Body Mass Index
SD	Standard Deviation
WRSM	Weight-related self-monitoring

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Author contributions

SLH, CBB, and DNS conceptualized the research question. SLH and DNS determined the methodology and acquired funding. SLH and CB conducted formal analysis. SLH wrote the initial draft and all authors were involved in significantly editing and reviewing the final paper.

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Data availability

The datasets generated and/or analyzed during the current study are not publicly available but may be available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

All protocols for Project EAT and Tracking-EAT were reviewed and approved by the University of Minnesota Institutional Review Board. Participants provided informed consent online prior to data collection and verbal consent to be recorded for interviews before commencing the interview.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

¹Central Michigan University College of Medicine, 1280 East Campus Drive, Mount Pleasant, MI 48859, USA

²Division of Epidemiology & Community Health, University of Minnesota School of Public Health, 1300 S 2nd St, Suite 300, West Bank Office Building, Minneapolis, MN 55454, USA

³Department of Psychology, Michigan State University, 316 Physics Rd, East Lansing, MI 48823, USA

⁴Department of Family Medicine and Community Health, University of Minnesota Medical School, 717 Delaware St SE, Minneapolis, MN, USA

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