Dose and timing of text messages for increasing physical activity among pregnant women: a randomized controlled trial

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Abstract

Text4baby (T4b), a free nation-wide mobile health information service, delivers health-related text messages (SMS) to pregnant women. The objective of this study was to determine the effectiveness of physical activity (PA) specific SMS to improve PA in pregnant women (vs standard T4b) and the most effective dose/timing of PA-specific SMS to improve PA. Pregnant women ($N=80$) were randomized to one of four groups that differed in frequency and time of SMS. The Fitbit™ Flex measured PA. Data were analyzed using mixed model analyses. There were no increases in PA regardless of frequency or time. Those that received six PA SMS/week had greater decreases in activity and greater increases in sedentary time. SMS may not be a “potent” enough strategy to improve PA. Future studies should explore a modified focus on behavior change (e.g., decrease sedentary activity, increase light activity) and incorporate SMS as part of a multi-level approach with other evidence-based strategies.

Keywords

Mobile health, Physical activity, Pregnancy, Women

Introduction

Physical activity (PA) during pregnancy has significant positive health benefits, with minimal risk, for both the mother and fetus [1]. For the mother, PA is associated with prevention and control of gestational diabetes, excessive weight gain, reduction in low back pain, positive mental health, and timely vaginal delivery [2–5]. Fetal benefits include reduced stress response and healthier birth weight [1, 6]. The American College of Obstetricians and Gynecologists (ACOG) recommend that pregnant women achieve at least 150 min per week of moderate-intensity aerobic activity, such as brisk walking, during and after their pregnancy [7] while avoiding activities such as contact sports and supine position activities after 20-week gestation [8]. Similarly, the American College of Sports Medicine (ACSM) recommends that adults engage in at least 150 min per week of moderate intensity aerobic activity [9].

Implications

Practice: Enhanced PA SMS alone may not improve PA behavior in pregnant women. Pregnant women should consider using self-monitoring tools (e.g., fitbits and pedometers) for PA feedback while receiving SMS.

Policy: mHealth initiatives using SMS to improve PA in pregnant women may need to incorporate more motivational strategies (i.e., goal-setting) within SMS to encourage actual improvements in PA.

Research: Future studies should explore a modified focus on behavior change (e.g., decrease sedentary activity, increase light activity) or incorporate SMS-based education as part of a multi-level approach with other evidence-based strategies to improve PA in pregnant women.

Pregnant women increase their PA during the first and second trimesters, but the majority never reach ACOG-recommended levels of activity [3, 10]. Studies report that less than 20 % of pregnant women achieve PA recommendations and the majority are completely inactive by the third trimester of pregnancy [11]. Even in those who self-reported being active prior to pregnancy, about half cease activity during pregnancy [12]. Studies also report that low educational level and income are most frequently associated with lower levels of PA in pregnant women [10].

Pregnancy is often referred to as an “opportune time” to improve health behaviors (i.e., PA participation, healthy eating, tobacco, and alcohol cessation) because women are concerned with their health, healthy prenatal development, the healthy birth of their child, and/or a quick return to pre-pregnancy body weight [13–16]. Even in those who do not have healthy lifestyles before they become pregnant, ACOG suggest that women should view pregnancy as an opportunity to embrace healthier routines (e.g., commence PA) [17]. It has been demonstrated that women desire evidence-based strategies to help them

participate in PA during pregnancy [17–20]. Additionally, pregnant women report that if they were to receive consistent information regarding how to safely and effectively engage in PA, it would facilitate their engagement [20, 21]. A recent cross-sectional study reported that pregnant women are 2.5 times more likely to be active if they have exercise guidance during their prenatal care [12, 20, 21]. These findings underscore the need to identify effective strategies to disseminate evidence-based PA information to help women adopt and maintain PA participation during pregnancy.

Mobile health has emerged as a promising mechanism to deliver health behavior interventions with antecedent-based strategies including prompts and education and/or feedback in real time [22]. According to the PEW Research Center [23], over 90 % of women in the USA own a mobile phone with 80 % sending/receiving text messages (SMS) daily. In fact, SMS is the most frequently used basic feature of a smart phone (92–100 %). SMS as a delivery channel for health behavior interventions has wide population reach, is relatively low cost, does not require technological expertise, an app, or smartphone, and allows timely access to health advice/education [24–26]. Health researchers and providers are using SMS to communicate with and motivate individuals to engage in healthy behaviors, assist individuals with disease management, and remind individuals to improve compliance to medication or study protocols [26]. For example, smoking cessation SMS led to significantly increased “quit rates” of smokers after 6 weeks [27]. SMS may be an effective channel to provide pregnant women with evidence-based information about PA and to improve their PA participation during pregnancy.

Text4baby (T4b) is a free, nation-wide, mobile health information service that delivers health-related SMS to pregnant women and during the first year postpartum. The standard T4b SMS content includes 267 messages addressing a wide range of maternal and child health topics (i.e., safety, nutrition, support, symptoms, screening, development). Studies by the US Department of Health and Human Services (HHS) [28] and Evans and colleagues [29] found that T4b improved health knowledge among its participants; T4b participants in the HHS evaluation (vs comparison groups) had a significantly higher level of health knowledge on four criterion topics—safe sleep, infant feeding, best time to deliver in a healthy pregnancy, and the meaning of full term. Both the HHS evaluation and Jordan and colleagues [30] found a positive association between T4b messaging and reported maternal influenza vaccination; additional studies of behaviors targeted by T4b are ongoing. However, at the time of the study, standard T4b content included only four messages that encouraged physical activities. Considering T4b is a free, already established service (began in 2010) that has reached over 940,000 women through November 2015 [28,

31], it presents a viable channel to reach pregnant women and encourage PA, if further PA content is incorporated.

The purpose of the current study was to determine the effectiveness of an SMS intervention to improve PA in pregnant women. A secondary purpose was to determine the most effective dose (e.g., frequency, time) of the SMS for improvements in PA. We hypothesized that women receiving a PA-specific SMS intervention would have higher levels of PA at the end of their pregnancy as compared to women who received standard T4b SMS. We also hypothesized that women receiving SMS at a greater frequency would have higher levels of PA at the end of their pregnancy as compared to women who received a lower frequency. Finally, we hypothesized that women receiving SMS at a chosen time would have higher levels of PA at the end of their pregnancy as compared to women who received SMS messages at the standard time (i.e., noon). The information gathered will inform existing T4b content and the design of other mHealth initiatives using SMS to improve PA in pregnant women.

Methods

Participants

Participants were recruited through posts to social media sites (e.g., Facebook, Twitter), fliers posted in obstetrics and gynecology provider offices and baby stores in the USA, word of mouth, e-mail listservs (e.g., foundations), and discussion boards (e.g., BabyCenter). Women interested in the study were directed to a confidential online eligibility questionnaire.

Women included in the study were as follows: (a) at least 18 years of age; (b) between 8 and 16 weeks pregnant; (c) owned a mobile phone with SMS capability; (d) had regular access to a computer; (e) able to speak/read/understand English; (f) resided in the USA; (g) willing to provide a cell phone number to receive SMS; (h) willing to wear a PA monitor throughout their pregnancy; and (i) were not meeting recommendations for PA (i.e., engage in at least 150 min per week of moderate-intensity aerobic activity) [32, 33] before their pregnancy or currently (self-reported). Additionally, women were excluded from the study if they were (a) considered a high-risk pregnancy (defined by The ACOG’s Position Statement on Exercise During the Pregnancy and Postpartum Period) [7] and (b) physically limited to exercise or instructed by a physician not to participate in exercise. Recruitment took place from June through September 2014. The Institutional Review Board at a large University in the Southwestern United States approved this study.

Procedures

After eligibility was confirmed, informed consent was obtained from all individual participants included in the study. Participants were asked to complete a demographic questionnaire, self-report PA using the

Table 1 | Examples of SMS

1. Constantly tired? Do something about it! Exercise can actually give you more energy throughout the day. (link)
2. Up to 18 % of women develop gestational diabetes during pregnancy. Exercise can help prevent & reduce side effects. (link)
3. Exercise can improve your mood and sense of well-being. Find out the other mental health benefits of exercising during pregnancy here: (link)
4. Maintaining strength and flexibility throughout pregnancy is the key to easier labor and delivery, and a speedier recovery. Here's how: (link)
5. Exercise benefits mom and baby! It can reduce risk of preterm birth, improve oxygen supplies for baby and ease labor. (link)
6. Exercise during pregnancy can improve your posture and decrease common discomforts. Check out the do's and don'ts here: (link)
7. Dealing with mood swings? We have the fix! Exercise causes your brain to release feel-good hormones that improve your mood. (link)

Modifiable Activity Questionnaire [34], and provide times for their telephone intake appointment. Online consent and the demographic and PA questionnaires were completed using Qualtrics (Provo, Utah). The intake appointment was approximately 15 to 20 min and included confirmation of eligibility and explanation of study procedures.

Study design

We conducted a stratified, 4-arm randomized controlled trial. We stratified according to ethnicity (white/non-white) to facilitate equal representation of minorities in each study arms. We randomly assigned to one of four groups: (a) *Standard* (three T4b SMS from the standard content of 267 SMS; standard T4b content included only two PA SMS across entire pregnancy) per week (M,W,F) at noon); (b) *Plus One* (three SMS; two PA and one T4b per week (M, W, F) at noon); (c) *Plus Six* (seven SMS; one T4b and six PA per week (Su-Sa) at noon); and (d) *Plus Six Choice* (seven SMS; one T4b and six PA per week (Su-Sa) at the time of day they choose).

Decisions about the doses were based upon what T4b may be able to offer within their existing health education SMS in the future. Decisions about the intervention groups (i.e., dose) were also made to add to the currently limited evidence based on optimal dosage for mobile health initiatives [35] and so that *T4b could* (1) add the PA SMS content to their curriculum (they currently only have four SMS related to PA in their standard curriculum), (2) use the information to determine how many times per week T4b SMS should include content related to PA to improve PA participation, and (3) gain perspective on whether participant choice for time of day to receive their SMS may enhance the overall effectiveness of T4b on positive health behaviors.

Intervention

Text4baby content was originally developed by the National Healthy Mothers, Healthy Babies Coalition [36] in collaboration with and approved by the T4b Content Development council composed of leading and national medical health organization and federal

partners. Topics were identified according to evidence-based guidelines (e.g., ACOG, Bright Futures Guidelines for Health Supervision of Infants, Children, and Adolescents) [37]. T4b granted permission to use their standard SMS content for this research.

Our team conducted formative research and developed SMS targeted for PA behavior to extend T4b content. Details about the development for the PA-targeted SMS are reported elsewhere [38]. Briefly, we used a user-centered and iterative design process. First, we reviewed the literature and conducted interviews with 15 pregnant women (did not participate in the intervention) to develop several SMS prototypes. Women were asked questions about how symptoms and/or fears related to being active during pregnancy, how they overcame those in order to remain active, reasons they chose to be active during pregnancy, and how they thought non-active pregnant women should be prompted to be active. Two major themes were identified (i.e., knowledge and support) with categories and subcategories derived from those themes. Knowledge included basic education and information (e.g., dispelling myths, activity ideas (i.e., modifications, lifestyle activity), time (e.g., strategies to make time), safety, and benefits/consequences of activity). Support included motivators (e.g., resources to help with motivation, accountability), social environments (e.g., activity with other pregnant women/moms), and praise (e.g., how to encourage activity). Fourteen SMS prototypes were developed from the interview data using behavior change strategies (i.e., personal, environmental, and behavioral factors) from the Social Cognitive Theory (SCT) that coincided with the themes [39, 40]. Next, we conducted 17 interviews with obstetric and gynecologic providers and inactive pregnant women (not meeting guidelines) using our prototypes to gather feedback and begin to work on content for PA-targeted SMS. A total of 168 SMS were developed as a result of this process. Table 1 presents sample SMS content used in our interventions. SMS were limited to 160 characters or less and included a mobile-friendly link to a Health on the Net Code of Conduct (HON Code) certified Web site (i.e., ethical, reliable online source

*Participants may have been ineligible for more than one reason

Fig. 1 | Participant enrollment flow chart including reasons for ineligibility and discontinued participation

for health information) [41]. To be HON Code certified, a Web site must provide the qualifications of authors, cite all sources of information, ensure privacy, complement information provided by physicians, provide accurate contact information, disclose financial conflicts, and have appropriate types of advertising [41]. Finally, we conducted a survey in pregnant women ($N=326$; did not include those who interviewed) to inform the dose of our intervention groups. Half of the women thought that three SMS per week was "about right" and 72 % preferred a similar amount of SMS across all trimesters. When asked how acceptable PA information sent via SMS would be, 60.7 % ($n=168/277$) felt that it would be acceptable/very acceptable.

Measures

After assignment to one of the four groups (i.e., (a) *Standard* (three T4b SMS from the standard content per week (M,W,F) at noon); (b) *Plus One* (three SMS; two PA and one T4b per week (M,W,F) at noon); (c) *Plus Six* (seven SMS; one T4b and six PA per week (Su-Sa) at noon); and (d) *Plus Six Choice* (seven SMS; one T4b and six PA per week (Su-Sa) at time chosen by participant), participants were mailed a Fitbit™ Flex (San Francisco, CA) and instructions about how to wear and sync this wrist-worn activity monitor. Participants were instructed to wear the Fitbit™ throughout pregnancy (up to 40 weeks), 24 h a day, except during showers or swimming, on their non-dominant wrist.

When sleeping or taking a nap, women were instructed to switch the Fitbit™ mode to "Sleep".

Physical activity was measured using the Fitbit™ device. The Fitbit™ has been shown to be a valid measure of steps under laboratory conditions [42, 43]. The Fitbit™ provides estimates of "sedentary," "light," "fairly active," and "very active" minutes as daily accumulated totals. Fitbit™ describes fairly active minutes to represent activities occurring at >3.0 metabolic equivalents (METs; energy cost of physical activities) [44] and very active minutes >6.0 METs [45]. While no precise definition of sedentary and light categories is provided by Fitbit™, common activities <3.0 METs include leisurely walking, household chores, and other lifestyle activities [44]. Sedentary behavior has been defined as seated activities at <1.5 METs [46].

Researchers registered participants' Fitbits™ online while creating user accounts authorizing access to the Fitbit™ data for study personnel. Fitbit™ accounts were blinded to the participants such that they did not have access to Fitbit™ data. Participants were instructed to download Fitbit™ software and sync/charge every 5 days. Research assistants monitored compliance to syncing Fitbit™, and participants were sent an email reminder if they had not synced the Fitbit™ within the last 5 days. Days with "0" minutes of registered activity at any intensity level were considered non-valid and set to missing. Women were able to keep the Fitbit™ as compensation for participating.

Table 2 | Baseline demographics by intervention group

Variable	Intervention group				Total
	1	2	3	4	
N	21	21	20	18	80
Age, years (M ± SD)	30.83 ± 5.22	31.05 ± 5.52	31.48 ± 5.44	31.44 ± 4.16	31.19 ± 5.05
Race, n (%)					
Caucasian	17 (21.30)	19 (23.80)	17 (21.30)	16 (20.00)	69 (86.30)
African-American	2 (2.50)	0 (0.00)	0 (0.00)	1 (1.30)	3 (3.80)
Asian	0 (0.00)	1 (1.30)	1 (1.30)	0 (0.00)	2 (2.50)
American Indian	0 (0.00)	1 (1.30)	0 (0.00)	0 (0.00)	1 (1.30)
Other	2 (2.50)	0 (0.00)	2 (2.50)	1 (1.30)	5 (6.30)
Ethnicity, n (%)					
Hispanic	3 (3.8)	0 (0.00)	1 (1.30)	3 (3.80)	7 (8.80)
Non-Hispanic	18 (22.50)	20 (25.00)	19 (23.80)	15 (18.80)	72 (90.00)
Education, n (%)					
<High school	1 (1.30)	0 (0.00)	1 (1.30)	1 (1.30)	3 (3.80)
High school diploma	0 (0.00)	0 (0.00)	1 (1.30)	0 (0.00)	1 (1.30)
Some college	7 (8.80)	7 (8.80)	4 (5.00)	3 (3.80)	21 (26.30)
Associates/2-year degree	0 (0.00)	1 (1.30)	2 (2.50)	1 (1.30)	4 (5.00)
Bachelors degree	5 (6.30)	7 (8.80)	10 (12.50)	7 (8.80)	29 (36.30)
Graduate school or above	8 (10.00)	6 (7.50)	2 (2.50)	6 (7.50)	22 (27.50)
Household income, n (%)					
≤\$20k/year	2 (2.50)	0 (0.00)	1 (1.30)	0 (0.00)	3 (3.80)
\$21k–\$40k/year	3 (3.80)	3 (3.80)	3 (3.80)	4 (5.00)	13 (16.30)
\$41k–60k/year	5 (6.30)	5 (6.30)	3 (3.80)	2 (2.50)	15 (18.80)
≥\$61k/year	11 (13.80)	13 (16.30)	13 (16.30)	12 (15.00)	49 (62.30)
Marital status, n (%)					
Partnered/in a relationship	4 (5.00)	1 (1.30)	2 (2.50)	2 (2.50)	9 (11.30)
Married	16 (20.00)	20 (25.00)	18 (22.50)	16 (20.00)	70 (87.50)
Divorced	1 (1.30)	0 (0.00)	0 (0.00)	0 (0.00)	1 (1.30)
Number of chronic conditions, n (%)					
0	13 (19.40)	10 (14.90)	16 (23.90)	14 (20.90)	53 (79.10)
1	2 (3.00)	4 (6.00)	3 (4.50)	4 (6.00)	13 (19.40)
2	0 (0.00)	1 (1.50)	0 (0.00)	0 (0.00)	1 (1.50)
Trimester at enrollment, n (%)					
1 (1–12 weeks)	8 (10.10)	11 (13.90)	5 (6.30)	8 (10.10)	32 (40.50)
2 (13–27 weeks)	12 (15.20)	10 (12.70)	15 (19.00)	10 (12.70)	47 (59.50)

Gestational age at enrollment, weeks (M ± SD)	12.80 ± 2.22	12.81 ± 2.94	13.68 ± 2.64	12.67 ± 2.22	12.99 ± 2.52
All physical activity at enrollment (reported), MET•hrs/wk (M ± SD)	5.87 ± 4.44	5.36 ± 7.21	4.19 ± 3.95	5.62 ± 4.95	5.26 ± 5.25
Walking at enrollment (reported), MET•hrs/wk (M ± SD)	3.35 ± 3.87	4.10 ± 7.07	2.47 ± 3.05	2.89 ± 3.11	3.22 ± 4.60
Group 1: 3 T4b messages per week at noon on M, W, F					
Group 2: 2 physical activity messages, 1 T4b message per week at noon on M, W, F					
Group 3: 6 physical activity messages, 1 T4b message per week at random time					
Group 4: 6 physical activity messages, 1 T4b message per week at time of choice					

Table 3 | Descriptive physical activity outcomes by study arm

Variable	Intervention group				Total					
	1	2	3	4						
Monitoring period, days	87.14	±54.95	113.62	±47.73	108.95	±50.66	92.39	±52.33	100.73	±51.71
Total time, min/day†	944.25	±195.26	962.04	±225.13	962.64	±232.26	960.86	±208.64	957.49	±213.95
Sedentary, min/day	976.54	±189.24	948.78	±169.96	1019.56	±202.00	973.09	±141.16	979.23	±176.49
Light activity, min/day	111.48	±56.00	122.89	±30.47	105.42	±44.54	112.49	±41.60	113.18	±43.81
Fairly active, min/day	51.44	±25.61	53.24	±23.07	47.27	±26.55	52.57	±21.76	51.12	±24.03
Very active, min/day	6.19	±6.02	5.14	±5.37	3.79	±2.44	4.01	±2.49	4.82	±4.49
Steps/day	4287.31	±2047.39	4372.34	±1603.15	3746.99	±1723.54	4125.54	±1447.02	4138.15	±1713.52
Total time was defined as all recorded minutes, except for sleep, on days with any registered activity										

†Total time was defined as all recorded minutes, except for sleep, on days with any registered activity

Table 4 | Mixed model-based intervention effects for active time, steps, light activity, and sedentary time by study arm

	b	SE	<i>p</i>
Active (min)			
Time (linear)	−0.055	0.018	0.002
Time (quadratic)	1.536	0.328	<.001
Standard T4b (control)	ref		
Plus One	−0.013	0.040	0.751
Plus Six	−0.120	0.040	0.004
Plus Six Choice	−0.001	0.043	0.991
PA SMS interventions (pooled)	0.004	0.375	0.992
Steps			
Time (linear)	−3.206	1.179	0.008
Time (quadratic)	110.576	21.341	<.001
Standard T4b (control)	ref		
Plus One	−0.994	2.639	0.708
Plus Six	−7.812	2.671	0.005
Plus Six Choice	−0.550	2.864	0.848
PA SMS interventions (pooled)	−5.026	24.338	0.837
Light activity (mins)			
Time (linear)	0.075	0.027	0.006
Time (quadratic)	2.314	0.578	<.001
Standard T4b (control)	ref		
Plus One	−0.033	0.061	0.590
Plus Six	−0.226	0.061	0.001
Plus Six Choice	−0.053	0.066	0.423
PA SMS interventions (pooled)	0.400	0.663	0.549
Sedentary (mins)			
Time (linear)	0.746	0.175	<.001
Time (quadratic)	−10.878	2.147	<.001
Standard T4b (control)	ref		
Plus One	0.264	0.405	0.517
Plus Six	1.110	0.411	0.009
Plus Six Choice	1.303	0.435	0.004
PA SMS interventions (pooled)	1.780	2.437	0.469

b unstandardized beta coefficient, *SE* standard error

Intervention effects shown are time (linear) × study arm comparisons with control as the reference. Time (quadratic) × study arm effects were not significant (not shown)

Data analysis

Mixed model analyses were chosen because of the intensive repeated measures design and statistical power within this framework. Mixed model analyses have been shown to be more robust to missing data than standard general linear model approaches where subjects are excluded listwise [47]. Main effects for time and time × study arm interactions were tested. Linear, quadratic, and cubic time parameterizations were included in all models to adjust for any overall changes in PA during the course of pregnancy not associated with the intervention assignment. The first purpose was to determine whether an SMS intervention targeting PA behavior would improve PA. For this purpose, the three PA study arms were pooled and compared to the standard T4b intervention content.

The second purpose was to determine which dose of SMS was optimal for PA. This analysis included testing all intervention arms, relative to control and one another. Appropriate Bonferroni

corrections were applied to adjust for multiple comparisons. Full-information maximum likelihood estimation was used as part of the SPSS version 22.0 software to accommodate missing data in the models. The significance level for all statistical analyses was set at $P < 0.05$.

Results

Participants

Of the 838 women who completed eligibility screening, 84 % were not eligible (see Fig. 1 for participant enrollment). This was mainly because women self-reported meeting ACOG guidelines before pregnancy (64 %) or at the time they completed eligibility (i.e., during pregnancy) (61 %). There were 134 women eligible for the study, 85 enrolled, and 80 (94 % of enrolled) completed the intervention. Five women dropped out due to exercise restrictions from their physicians ($n = 2$), miscarriage ($n = 1$), skin reactions to the Fitbit™ ($n = 1$), and no reason provided ($n = 1$). Participant demographics are in Table 2. Mean age

Fig. 2 | Graphic display of model-based estimates for sedentary behavior, light-intensity activity, active time, and steps

was 31.19 (± 5.05) years and 13 weeks (± 2.52) pregnant at enrollment. Women were mostly Caucasian (86 %), married (87.5 %), and had no chronic conditions (79 %), and there were no demographic differences by study arm. The majority of Fitbit™ data sampled was in the second trimester (n observations = 4645, n participants = 80, 61.2 % of overall data) followed by the third (n observations = 2570, n participants = 58, 33.8 % of overall data) and first (n observations = 380, n participants = 30, 5.0 % of overall data) trimesters. Table 3 presents descriptive data from the Fitbit™ collapsed over all time by study arm. There were no differences in monitoring days or total time by study arm.

Overall PA trajectories and differences in PA targeted SMS interventions vs standard T4b SMS content

Table 4 displays unstandardized beta coefficients, standard errors, and p values for mixed model

analyses. Overall trajectories (across all study arms) were similar for all dependent variables. Active time, light intensity time, and steps all showed significant linear decreases and significant quadratic decline over time. This pattern can be described as a modest, but significant, decrease in activity over the course of the pregnancy with a precipitous and accelerated decline in activity in the final trimester. Sedentary time showed a similar pattern, but opposite in direction (linear and quadratic increase over time). In order to compare overall trajectories among targeted SMS interventions vs standard T4b SMS, all three PA intervention arms were collapsed and compared to the standard T4b arm (control). As shown in Table 4, when combined, there were no significant differences in linear trajectories between the targeted SMS interventions and the standard T4b SMS content. Differences in quadratic trajectories were also not significant.

Differences between PA SMS intervention arms relative to standard T4b SMS content

Table 4 also displays mixed model results comparing each PA intervention arm relative to the control arm. Figure 2 graphically displays model-based estimates. Patterns of differences were similar across outcome variables. In general, there were few differences in linear trajectories by study arm relative to the control arm. However, across all outcomes, the Plus Six SMS study arm had greater decreases in activity (active time, light activity, and steps) and greater increases in sedentary time relative to the control arm (i.e., Standard). This was also true for sedentary time in the Plus Six Choice PA SMS arm. Differences in quadratic trajectories (i.e., the rate of precipitous decline in third trimester) were not significantly different among any of the study arms.

Discussion

The purpose of the current study was to determine the preliminary efficacy of a SMS-delivered intervention, mainly consisting of antecedent-based educational content, to improve PA in pregnant women. A secondary purpose was to determine the most effective dose (e.g., frequency, time) of the SMS messages for improvements in PA. There were no increases in PA as a result of the SMS intervention, regardless of frequency (3×/week, 7×/week) or time of delivery (standard, choice). Across all groups, the Plus Six group had greater decreases in activity and greater increases in sedentary time. This was also true for sedentary time in the Plus Six Choice group. Not surprisingly, there have been few studies, regardless of intervention type, that have been successful at significantly improving PA in pregnant women [48]. In a recent review of randomized controlled trials aimed to increase PA in pregnant women, only three of nine studies had statistically significant positive results for PA [49], and no studies in the review were mHealth or SMS-based. Despite the lack of intervention effects, this study adds to the literature related to SMS PA interventions during pregnancy by informing others on what does not work for promoting PA (within the context of an already existing public health service; T4b) and may help inform design of future SMS interventions specific for this population and when working with industry partners such as T4b.

The consistency of PA patterns across intervention arms points to the significant challenge to promote PA in pregnant women via SMS content aimed at PA. Pregnant women have to overcome partially non-modifiable barriers to PA such as significant physical and physiological symptoms that occur during pregnancy (e.g., nausea, fatigue, weight gain, swelling, back and pelvic pain) and are often compounded by common modifiable barriers to PA (i.e., time, motivation, enjoyment) reported in both the general population and pregnant women [50, 51]. In a survey of 1535 pregnant women (27–30 weeks gestation), 85 % reported intrapersonal barriers to PA (e.g., time,

motivation), of which two-thirds were related to health (e.g., tiredness, low energy, musculoskeletal (e.g., back or pelvic pain), and shortness of breath) [52]. Women in our study also had similar patterns of PA across the pregnancy, regardless of being in the intervention or standard arms (increases into the second and beginning of third trimester, declines in third trimester) [53]. Nationally, even in women who report being active (i.e., meeting guidelines) prior to pregnancy, less than 50 % participate in regular PA during pregnancy [10, 50]. Additionally, similar to what is observed in the literature [10, 50], women in our study did not achieve the recommendations for PA at any time during the pregnancy.

Others have also reported that regardless of trimester, pregnant women are not able to achieve recommended PA guidelines [54]. In addition to encouraging regular moderate-intensity exercise, perhaps efforts should also focus on more achievable targets such as decreasing sedentary time and increasing light-intensity activities (e.g., “stand up and move”). Encouraging frequent, short bouts of light activity throughout the day may address pregnant women’s barriers to more moderate or vigorous PA intensity (e.g., fits into lifestyle, not as fatiguing as more intense PA). Of late, there are a number of studies suggesting the independent health benefits of reducing sedentary time [54]. This has not been explored in pregnant women. There is a need to explore both the maternal and infant health benefits associated with reductions in sitting time during pregnancy.

One of the innovations of our study was that the SMS platform (i.e., T4b) already existed. We explored the utilization of an existing health education SMS service to deliver PA content. Utilizing existing platforms such as T4b provides a resource-friendly opportunity to reach and potentially impact a large, diverse population of women. Although evidence suggests that SMS may be promising for smoking cessation, diabetes control, and vaccination uptake in maternal and child health populations, the use of SMS for PA in pregnant women has not been established [55]. Evidence suggests that T4b may improve knowledge and beliefs about specific health behaviors (i.e., smoking, alcohol consumption) during pregnancy [29, 56]. Thus, it is important to test such platforms to not only change how women think about or perceive PA but to determine if actual PA behaviors can be increased using educational content, which is a higher threshold for success than changing one’s knowledge or willingness to engage in PA. However, use of SMS content with links to Web sites was not enough to improve PA behavior in our sample of pregnant women. In another study [34], daily SMS after one education session about the benefits of PA was not more effective than an education session alone for improving PA in healthy adults.

We hypothesized that delivering antecedent informational messages 7×/week as a “heavier” frequency would improve PA [35]. There were greater decreases

in activity (active time, light activity, and steps) and greater increases in sedentary time observed in the Plus Six group and greater increases in sedentary time observed in the Plus Six Choice group (i.e., highest SMS doses). Conversely, one randomized controlled trial found that when dosage was considered, the high-dose (most SMS over the course of pregnancy) T4b participants were more than two times as likely to report they abstained from drinking at post-partum follow-up as compared to low-dose participants (least SMS over the course of pregnancy) [35]. The findings from our study suggest that informational-based PA content delivered via SMS content should not be delivered daily to pregnant women. The findings also suggest that frequent SMS messages that provide quality information to improve knowledge (i.e., education) and support (i.e., non-contingent praise and motivators), which rely on antecedent strategies, may actually be aversive or inhibit women from becoming physically active. This is possibly through reactance (i.e., less activity due to feeling as if choices are taken away) or habituations (i.e., diminishing response with repeated stimulus) [57]. It is not clear from the current SMS literature in adults what the most effective frequency of antecedent-based messaging is for improving PA. A recent meta-analysis [26] demonstrated that SMS frequency ranging from 1×/week to 7×/week had large variability in observed effect sizes on PA outcomes when compared to a control group. Many of the SMS-based interventions included in the meta-analysis incorporated additional behavioral components (e.g., educational material, in-person consultations, feedback on PA level) to the SMS making it even more difficult to interpret effects of SMS on PA. Our study provides evidence that in pregnant women, “more is not better.” Yet, there is a need to continue to explore appropriate doses and content to improve PA using SMS in pregnant women.

The content we developed was based on our formative work, and others who have suggested women want resources for PA information and are not always confident about the source in which they get information online [15, 38]. Our formative work to develop validated SMS ensured that women received quality information through various sources. However, our findings suggest that education alone delivered via SMS is not enough. SMS may serve a purpose to improve awareness and knowledge, but strategies that augment SMS or include SMS as part of a multi-level approach should be explored. For example, in our work to inform the SMS, women reported wanting support and links to other pregnant women/moms to help motivate them for PA [15, 38]. Social support is a well-known facilitator to PA behavior in women [58, 59] and may be a component that could serve as an additional strategy to the SMS content. Joseph and colleagues [60] recently implemented a theory-based SMS and Facebook intervention in African American women to improve PA behaviors. Similar to our study, women received three SMS per week with content related to improving PA. Women in the intervention

group (i.e., SMS + Facebook) had decreased sedentary time and increased light and moderate to vigorous PA as compared to the control (i.e., print-based group). More research exploring ways in which to combine SMS with social support is warranted.

We purposefully designed the study so that the Fitbits™ would not impact PA levels. However, SMS in addition to simple Fitbit™ goals may help women achieve PA recommendations during pregnancy. In a recent study by Adams and colleagues [53], adaptive goal-setting SMS with reinforcement had significantly greater increases in PA as compared to the static intervention group. SMS with adaptive goal setting may be especially useful to improve PA in pregnant women because the adaptive components (i.e., adapted to daily PA level) would account for individually varying factors that impact PA in these women over time (e.g., gestational age, physical barriers (i.e., nausea, swelling, low back pain)). More research is needed to determine the best multi-level approach for using SMS to improve PA in pregnant women.

Limitations

This study provides information that can be used to inform the design of SMS interventions in the future, especially in pregnant women. However, there are some limitations to note. First, our sample size was predominantly Caucasian and educated, limiting its generalizability. Furthermore, because our sample was relatively small within each study arm, it is possible we did not have adequate power to detect between-arm differences. Second, we did not measure proximal outcomes such as self-efficacy, behavioral beliefs, or social feedback. These outcome measures may have demonstrated shifts in awareness and knowledge related to PA. We also did not provide performance-based feedback or reinforce women's PA improvements during the study because we wanted to first test whether increasing the dose of static PA message content was effective, as T4b could have easily and quickly integrated this content if effective. Determining the impact of SMS with feedback or reinforcement related to PA may help establish the role SMS that could play in multi-level theory-based interventions. The use of the Fitbit™ as an outcome measure was a limitation in terms of the accuracy of classifying activity intensity and the unavailability of a validated non-wear algorithm. However, the use of the Fitbit™ as a continuous, ongoing measure of activity is novel and provides new insights into the trajectory of activity over the course of pregnancy. Also, because it was not possible to enroll participants early in pregnancy, our estimates of PA during the first trimester are based on small amounts of data and therefore should be interpreted with caution. This is also true for the last portion of the 3rd trimester. The strength of these analyses, given the representation of data, is during the 2nd trimester and earlier part of the 3rd trimester. Finally, because the study was built within the current context of an already existing SMS service, we were not able to track if the

SMS was delivered, if the participant opened the SMS, or if they used the links to the Web site provided in the SMS. This information would be valuable for future examinations of SMS-based PA interventions.

Conclusions

This study leveraged content from an existing platform that delivered health education to a diverse population of pregnant women across the USA and serves as an example for how to examine dose when developing and assessing SMS interventions. Increasing the dose of PA content via SMS to pregnant women was not effective in increasing PA despite increasing the number of PA messages and offering user-specified times to deliver these SMS. Similar to the general population, pregnant women have both intrapersonal and interpersonal barriers to PA (e.g., time, motivation, resources) that are further compounded by major physical barriers to pregnancy (e.g., nausea, fatigue, low back pain). SMS-based education alone may not be a “potent” enough strategy to improve PA behavior. However, future studies should explore a modified focus on behavior change (e.g., decrease sedentary activity, increase light activity) or incorporate SMS-based education as part of a multi-level approach with other evidence-based strategies (i.e., social support, goal-setting, feedback) to improve PA in pregnant women. The use of SMS in pregnant women to improve PA behavior is still in its infancy.

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Ethical approval: “All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.”

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Informed consent: All study participants were required to complete an informed consent prior to participating in the study. Animals were not included in this study.

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