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Remote gestational weight gain monitoring in a large low-risk US population

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Abstract

Background: Over the past decade there have been rapid advancements in telemedicine and mobile health technology (mHealth) and rapid increases in adoption of these technologies among OB-GYN providers. Mobile technology is routinely used in the general adult population to simplify monitoring of food intake and weight. Studies have demonstrated that weight loss achieved via remote monitoring, through use of wi-fi scales and web applications, is similar to weight loss achieved with in-person support. These technologies also increase flexibility for subjects and providers. However, there has been limited large-scale research to evaluate the use of these technologies to improve adherence to weight-gain recommendations during pregnancy.

Objectives: To evaluate gestational weight gain tracking in a large low-risk obstetrical population using remote patient monitoring and a mobile phone app.

Methods: Self-reported age, height, estimated due date, and weight data were extracted from low-risk, singleton pregnancies entered from 50,769 participants who were enrolled in the *BabyScripts*[TM] phone app between 1 January 2016 and 1 March 2020. After data cleaning, 15,468 participants were included the final analysis. Linear regression and Spearman's correlation were used to examine the relationships between total weight gain, rate of weight gain, body mass index (BMI), postpartum weight loss, and app engagement.

Results: The average weight gain in the first, second, and third trimester were 0.09 ± 1.8 kg, 4.2 ± 3.3 kg, and 3.9 ± 3.9 kg, respectively. The average rate of weight gain per week for the second and third trimesters were 0.5 ± 0.4 kg/wk and 0.6 ± 0.8 kg/wk, respectively. Participants with higher initial BMI had slower rate of weight gain than those with lower initial BMI ($r = -0.24$, $r = -0.05$, for second and third trimester, respectively). Overall, 21.4% of participants met the Institutes of Medicine (IOM) recommendation for total weight gain during pregnancy. Patients who were highly engaged with the mobile app had increased adherence to the IOM guidelines (29.8% vs. 9.4%, $p < 0.001$). A larger proportion of highly engaged patients adhered to the IOM guidelines for rate of weight gain in the second and third trimester, compared to the lowest engaged patients (12.7% vs. 6.8%, $p < 0.001$). On average, participants lost 8.8 ± 3.3 kg over an average of 8.1 ± 4.6 weeks in the immediate postpartum period. This weight loss was positively associated with engagement ($r = 0.3$, $p < 0.001$).

Comments: Engagement with the mobile app was associated with increased adherence to the IOM gestational weight gain guidelines and with increased postpartum weight loss. Use of remote patient monitoring in conjunction with mHealth technology may be a strategy to improve adherence to IOM guidelines.

KEYWORDS

connected health, gestational weight gain, remote patient monitoring, telemedicine

1 | INTRODUCTION

Several studies have demonstrated that both excessive and inadequate weight gain during pregnancy are associated with adverse maternal and neonatal outcomes.[1–4] Research has also demonstrated an association between excessive gestational weight gain, increased birth weight, and postpartum weight retention.[5] The Institute of Medicine (IOM) has developed specific weight-gain guidelines during pregnancy based on body-mass index (BMI).[6] These guidelines are widely accepted among obstetrical providers in the United States (US) and have been endorsed by the World Health Organization.[7] Increasing adherence to IOM weight-gain guidelines may help reduce maternal and neonatal morbidity and mortality.[8,9] Langford et al. found that compared to women who adhered to the IOM guidelines, overweight women who gained more than the recommended amount were 1.7 (1.5–1.9 95% CI) and 2.1 (1.9–2.3 95% CI) times more likely to develop preeclampsia and macrosomia, respectively.[10]

Mobile health technology (mHealth) is routinely used in the US adult population for management and prevention of chronic diseases such as obesity, diabetes, and hypertension. Over the past decade there have been rapid advancements in telemedicine and mHealth and rapid increases in adoption of these technologies among OB-GYN providers.[11,12] It is estimated that approximately 7% of all health apps focus on Women's Health and pregnancy.[13] Some health insurance companies have even developed proprietary mobile apps aimed at delivering "personalized coaching" during pregnancy.[14] Given both patient and provider satisfaction with mHealth apps and connected devices (scales, blood pressure cuffs), there exists potential to improve pregnancy outcomes and increase access to high-quality obstetrical care.[15–17]

Excessive gestational weight gain has been associated with large for gestational age neonates (LGA), fetal growth restriction, and postpartum weight retention.[4] Increased birth weight has been associated with increased cesarean rate and increased newborn hospitalization. A large US cohort study following singleton pregnancies found that excessive early gestational weight gain occurred in 47% of pregnancies and over 90% of women with excessive early weight gain also had excessive total weight gain per IOM guidelines.[18] MacDonald et al. followed a cohort of women with and without gestational diabetes. They found that for each standard deviation increase in weight gain in the first trimester above their predicted weight-gain trajectory there was an associated 23% increased odds of developing gestational diabetes [95% CI: 0.2%, 51%].[16] Interestingly, second trimester weight gain trajectory was not associated with development of gestational diabetes. Kim et al. studied the contribution of obesity, excessive gestational weight gain, and gestational diabetes on fetal growth. Excessive gestational weight gain had the largest contribution to LGA.[19]

It has been clearly established that early excessive gestational weight gain significantly contributes to excessive total gestational weight gain and adverse maternal and neonatal outcomes. The American College of Obstetricians and Gynecologists recommends early and frequent monitoring of gestational weight gain. However, given inherent difficulties in not only correctly identifying at-risk women, but also ensuring increased access to at-risk women, providers tend to give broad, non-individualized, anticipatory guidance to patients based on their pre-pregnancy BMI. This is in lieu of frequent, concurrent monitoring of weight changes in the first and second trimesters with individualized counseling and intervention.[20] It is possible that mHealth and connected health technology may help patients better adhere to IOM guidelines. However, to date, there have been no large-scale studies that have evaluated the feasibility of these technologies.

To address this gap in the literature, weight data was abstracted from a database containing self-reported information from low-risk pregnancies. The database is maintained by *BabyScripts*™, a mobile pregnancy app that licenses its platform for use by obstetrical practices to remotely monitor patients during pregnancy and deliver customizable educational materials.[21]

2 | METHODS

Self-reported height, weight, age, and estimated due date, were extracted from 50,769 singleton, low-risk pregnancies of participants in the *BabyScripts*^{TM} app between 1 January 2016 and 1 March 2020. Low-risk pregnancies were defined as maternal age <40, singleton pregnancy, and lack of pre-chronic medical illness (diabetes, hypertension, cardiac disease, severe mental illness). Upon enrollment, all participants signed a data sharing agreement. Participants could upload their weight information either manually or via a provided Bluetooth connected scale. This study was approved by The George Washington University Institutional Review Board.

The *BabyScripts*^{TM} app is an online platform that individual obstetric providers purchase for their patients. The application has three main capabilities: (1) Targeted distribution of gestational-age specific education materials; (2) Interface to remotely monitor weight, blood pressure, blood glucose, and mental health; (3) Integration with electronic medical records to monitor trends in population health.[21]

A baseline early-pregnancy weight was defined as the earliest weight entry at less than 20 weeks gestation. This cut-off was chosen, given that the most dramatic maternal physiologic changes occur throughout the second and third trimester. Participants, who did not have an early pregnancy weight, were excluded. Participants who did not have at least three weights recorded over more than two trimesters were considered inactive and therefore excluded in the analysis (Figure 1). This eliminated 26,058 of our initial 50,369 participant pregnancies from the dataset. The validity of the dataset was verified by comparing the difference in recorded weights and the rate of weight change for each participant, with fluctuations of more than 4.5 kg/wk flagged for review. Approximately 10% of the database was flagged for review. All unexpected weight fluctuations were attributable to use of a Bluetooth scale, where, for example, an additional household member might have also utilized the scale. This resulted in additional elimination of 8,642 participant pregnancies from the initial dataset.

Due to the lack of availability of delivery information, we assumed that large majority of participants would have delivered by the 41st week of pregnancy as post-term pregnancies account for only 5% of all singleton pregnancies.[22] We therefore defined the immediate postpartum period as the time between the 41st week of pregnancy until the start of the 6th week postpartum. Participants were excluded from the postpartum weight loss analysis if they did not enter a weight in the first trimester.

2.1 | Data analysis

The final sample size was 15,468 participant pregnancies. Arithmetic means were calculated to determine the baseline characteristics of the study participants (Table 1). Linear regression and Spearman's correlation were used to understand the relationships between total weight gain, rate of weight gain, postpartum weight loss, BMI, age, and app engagement. Daily weight records were averaged to analyze data on a weekly level. The rate of weight loss per trimester was

TABLE 1 Baseline characteristics

Age	*N*	Percent	GA at Enrollment
<35	12,701	82.0	12.6 ± 8.0
>35	2,767	18.0	12.6 ± 8.0
BMI			
<18.5	392	2.5	12.6* ± 7.8
18.5–24.9	6,337	41.0	11.7 ± 8.50
25.0–29.9	4,347	28.1	13.2 ± 8.0
30.0–34.9	2,437	15.7	13.5 ± 7.40
>35	1,955	12.6	13.3* ± 7.0

Abbreviation: GA, Gestational age.
*$p < 0.001$.

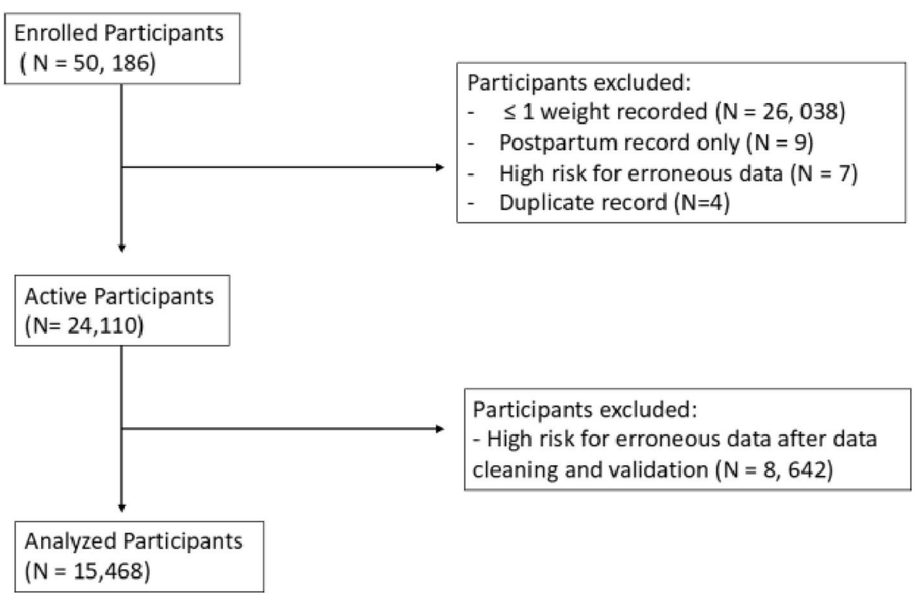

FIGURE 1 Flow diagram of participants

calculated by linear extrapolation. The number of weight entries was used as a proxy for app engagement. Four distinct engagement categories were defined as the following: "Low" engagement, for participants who logged 5 or less weeks; "Low-moderate" engagement, for participants who logged between 6 and 10 weeks; "moderate-high" engagement, for participants who logged between 11 and 20 weeks; and "high" engagement, for participants who logged 20 or more weeks. To determine the postpartum weight loss, the peak weight in the late third trimester was subtracted from the participant's last entry in the 7 weeks past the subjects estimated due date.

3 | RESULTS

Of the 50,769 patients who downloaded the app, 15,468 were eligible for inclusion in our study. Baseline characteristics of eligible patients are consistent with a low-risk obstetrical population (Table 1). Eligible participants enrolled and utilized the app early in pregnancy, without a clinically significant difference with respect to age or BMI (Table 1).

3.1 | Gestational weight gain

The average weight gain in the first, second, and third trimester were 0.09 ± 1.8 kg, 4.2 ± 3.3 kg, and 3.9 ± 3.9 kg, respectively. The average rate of weight gain per week for the second and third trimesters were 0.5 ± 0.4 kg/wk and 0.6 ± 0.8 kg/wk, respectively. Participants with higher initial BMI had slower rate of weight gain throughout pregnancy than those with lower initial BMI ($r = -0.24$ for 2nd trimester, $r = -0.05$ for 3rd trimester, $p < 0.0001$ for both) (Table 2).

Patients who started recording their weight earlier in their pregnancy had higher initial BMI than patients who started recording later ($r = -0.13$, $p < 0.0001$). However, participants with lower initial BMI had more weeks recorded than those with higher initial BMI ($r = -0.15$, $p < 0.0001$). Older patients at first recording had slightly higher initial BMI than younger patients ($r = 0.10$, $p < 0.0001$) (Table 2).

3.2 | Postpartum weight loss

On average participants lost 2.6 kg in the immediate postpartum period. The majority of participants who logged weights in the postpartum period were in the "high" engagement group (1289/2706, 48%). Weight loss in the postpartum period was not associated with initial BMI ($r = -0.02$) or rate of weight gain in the first or second trimester ($r = -0.02$, $r = -0.05$), but was positively associated in with "engagement" ($r = 0.30$, $p < 0.0001$) and negatively associated with the rate of weight gain in the third trimester ($r = -0.36$, $p < 0.0001$). Additionally, when weight gain was averaged across the entire pregnancy, participants who gained more on average during their pregnancy lost less weight in the postpartum period ($r = -0.34$, $p < 0.0001$) (Table 3).

3.3 | App engagement

Participants frequently recorded weights throughout their pregnancy (average 11.7 ± 8.1 weeks, range – 46 weeks). The majority of patients were in the "low-moderate" (35%) and "moderate-high" (28%) category (Table 3). Patients with higher "engagement" had slower

TABLE 2 Gestational weight gain according to BMI

BMI	N	Age	Wks recorded	T2 (kg/Wk)	T2 (Total gain)	T3 (kg/Wk)	T3 (Total gain)	Total pregnancy
<18.5	392	28.8 ± 5.4*	9.9 ± 7.80	0.6 ± 0.5	4.2 ± 3.2*	0.7 ± 0.8*	4.2 ± 3.7*	7.5 ± 5.5*
18.5–24.9	6,337	30.6 ± 4.8	13.0 ± 8.5*	0.6 ± 0.4	4.9 ± 2.9*	0.7 ± 0.7*	4.1 ± 4.0*	7.9 ± 5.1*
25.0–29.9	4,347	30.6 ± 5.0	11.5 ± 7.4*	0.5 ± 0.4*	4.3 ± 3.3*	0.7 ± 0.8*	3.9 ± 3.9*	6.7 ± 5.4*
30.0–34.9	2,437	30.2 ± 5.1	10.6 ± 7.4*	0.4 ± .45*	3.4 ± 3.3*	0.6 ± 0.7	3.5 ± 4.0	5.2 ± 5.5*
>35	1,955	30.4 ± 5.1	9.6 ± 7.0	0.3 ± 0.5*	2.3 ± 3.3*	0.5 ± 0.8	3.3 ± 4.1	3.5 ± 5.4*

Abbreviations; T2, second trimester; T3, third trimester.
*$p < 0.001$.

TABLE 3 Gestational weight gain according to level of engagement

Engagement	N	Initial BMI	Age	Wks recorded	T2 (kg/Wk)	T2 (Total gain)	T3 (kg/Wk)	T3 (Total gain)	Total pregnancy
Low	3,209	28.5 ± 6.8*	30 ± 5.3*	3.5 ± 0.6*	0.5 ± 0.6*	2.4 ± 2.9*	0.7 ± 0.9	3.9 ± 3.9*	3.1 ± 4.1*
Low-moderate	5,339	28.0 ± 6.6*	30 ± 5.1*	7.1 ± 1.7*	0.5 ± 0.5*	3.5 ± 3.2*	0.8 ± 0.9	4.1 ± 3.9*	5.7 ± 5.0*
Moderate-high	4,365	27.0 ± 6.0*	31 ± 4.9	14.9 ± 2.9*	0.5 ± 0.3	5.2 ± 3.0*	0.6 ± 0.7	3.9 ± 3.7*	8.7 ± 5.3*
High	2,555	26.0 ± 5.5*	31 ± 4.3*	26.2 ± 4.3*	0.5 ± 0.2*	6.0 ± 2.7*	0.3 ± 0.4*	3.3 ± 4.2*	9.2 ± 5.7*

Note: Low engagement, <5 weeks; low-to-medium, 5–10 weeks; medium-to-high, 11–20 weeks; high, >20 weeks.
Abbreviations: T2, second trimester; T3, third trimester.
*$p < 0.001$.

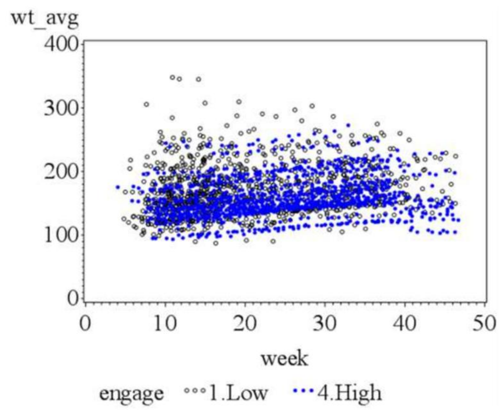

FIGURE 2 Scatterplot of a randomly selected approximately 1000 subjects from both the highest and lowest engagement groups

rates of weight gain in the third trimester than those with lower levels of "engagement" ($r = 0.19$, $p < 0.0001$; Figure 2). Medium-high and high engagement patients had the lowest rate of weight gain in the second and third trimester.

3.4 | IOM guidelines

Overall, 21.4% of participants met the Institutes of Medicine (IOM) recommendation for total weight gain during pregnancy. Patients with an initial BMI in the overweight category (BMI 25–30) were most likely to meet the total weight gain recommendation (25.3%), while participants with initial BMI <18.5 were least likely (18.6%, $p < 0.0001$). Participants who were least engaged with the app were least likely to meet the IOM recommendations for total weight gain during pregnancy compared to participants with the highest level of engagement (9.4% least engaged vs. 29.8% most engaged, $p < 0.0001$).

Only 8.8% of participants met the IOM recommendations for the suggested rate of weight gain during pregnancy. Initial BMI was found to be inversely related to whether a participant met the rate of weight gain recommendation. Among participants with the lowest initial BMI, 14.5% met this recommendation versus 7.6% of those with the highest BMI, $p < 0.0001$. Achieving the IOM recommendations for the suggested rate of weight gain was positively associated with the level of engagement. For patients with "low", "low-medium", "medium-high", and "high" engagement, the proportion of patients who met the recommendations were 6.8%, 7.3%, 10.1%, and 12.7%, respectively ($p < 0.0001$).

4 | DISCUSSION

To our knowledge, this represents the largest obstetrical population followed via mHealth and connected health technology during pregnancy. Remote weight monitoring on the *BabyScripts*^{TM} mobile application was successful in a low-risk, nationally diverse, obstetric population, evidenced by both the large percentage of participants in the "low-moderate", "moderate", and "high" engagement groups, as well as the large percentage of participants eligible for inclusion in the dataset.

Although only approximately 20% of the participants met the IOM guidelines for gestational weight gain, this is consistent with previous studies.[23] Importantly, our dataset revealed that participants who had "high" engagement were more likely to meet both the total weight gain and rate of weight gain goals set by the IOM guidelines. An app that easily allows participants to track their weight during pregnancy and provides immediately accessible educational content, may be one modality by which to improve adherence to IOM guidelines.

Few studies have characterized weight loss in the immediate postpartum period. Our low-risk population lost, on average, 2.7 kg in the immediate postpartum period. The results from this study may be used to provide anticipatory guidance for women in the immediate postpartum period. Establishment of an expected range for postpartum weight loss may also help identify women at risk for postpartum weight retention and adverse health outcomes later in life.

Future use of mobile applications may allow obstetrical providers to have closer, more frequent monitoring of their patients throughout pregnancy, thereby, allowing real time intervention. Furthermore, while this study only considered low-risk pregnancies, high-risk pregnancies and patients with limited access to care, may significantly benefit from the use and deployment of remote monitoring during prenatal care. As mHealth technology continues to increase in prevalence, it will be important to ensure inclusion of higher risk populations in future research studies.

It is important to note this study has several significant limitations. First, weight data and estimated due date were self-reported by participants. Second, we were unable to review pregnancy outcomes and subsequently had to estimate the actual date of delivery. Third, other demographic information was not uploaded by users in the database and therefore unavailable for reporting. Fourth, high-risk populations (morbid obesity, diabetes, chronic hypertension) were excluded from participation, serving to limit the generalizability of the study. And lastly, each practice group is able to modify the *BabyScripts*^{TM} mobile app to their preference, and thus participants may have had divergent experiences based on their practice group affiliation.

Despite these limitations, given the large number of moderately and highly engaged participants, we believe that remote gestational weight monitoring in low-risk pregnancies is an effective method for weight tracking during pregnancy. More research is needed to continue to address the safety, cost-effectiveness, and patient-provider satisfaction with use of remote patient monitoring technology and mHealth platforms during pregnancy. Additionally, studies focused on the use of targeted interventions for those at high risk should be performed.

CONFLICT OF INTERESTS

Dr. Marko is a content advisor to Babyscripts LLC. She receives no financial compensation. Anish Sebastian is the founder and CEO of Babyscripts Rx, he was not involved in the data analysis or manuscript preparation. Ethan A. Litman, Tanaya Kavathekar, Richard Amdur report no conflicts of interest.

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AUTHOR CONTRIBUTIONS

Ethan A. Litman and Kathryn Marko devised the study protocol. Ethan A. Litman and Tanaya Kavathekar were responsible for data extraction. Ethan A. Litman and Richard Amdur performed the statistical analysis. Anish Sebastian was responsible for the data abstraction and data integrity.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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