



Original Research

An Assessment of Mobile Applications Designed to Address Physical Activity During Pregnancy and Postpartum

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ABSTRACT

International Journal of Exercise Science 14(7): 382-399, 2021. Only 15% of women meet physical activity guidelines during and after pregnancy despite the well-established positive impacts on both the mother and the neonate. There is a clear lack of guidance on this topic, and mobile health interventions are a promising direction for future interventions to facilitate a necessary increase in physical activity during pregnancy and postpartum. The purpose of the study was to objectively assess the quality and perceived impact of existing free mobile apps that are designed to cover physical activity during and after pregnancy. The Mobile Application Rating Scale (MARS) was used by two independent reviewers to determine overall quality of mobile apps freely available in the U.S. iTunes store. The initial search for pregnancy and postpartum physical activity apps yielded 732 results. After careful screening, 567 apps were excluded, leaving 165 that went under further screening procedures. Upon further screening, 54 apps were downloaded and scored using the MARS system. Of the 54 apps included in the analyses, 20 apps contained physical activity information for pregnant women (37.0%), 11 apps contained information for postpartum women (20.4%), and 23 apps contained information pertaining to both pregnant and postpartum women (42.6%). Of note, 33 (61.1%) of the apps required hidden costs in the form of in-app purchases. The mean overall MARS score was 3.06 ± 0.94 out of 5 (1-*inadequate* and 5-*excellent*). Overall, the quality of existing apps appears low, and none of the existing apps had specific goal setting based on current recommendations for pregnant women. Due to low quality and perceived impact, existing mobile apps are insufficient to enable women to achieve recommended levels of physical activity during pregnancy and postpartum.

KEY WORDS: mhealth, mobile applications, exercise, pregnant, perinatal, postnatal

INTRODUCTION

Physical activity during and after pregnancy is beneficial to the short and long-term health of the mother and infant (8). Women who are pregnant experience substantial physiological and psychological changes, many of which contribute to low physical activity levels and more time spent sedentary (19). Sedentary behaviors have been associated with many unfavorable pregnancy conditions including gestational diabetes, pregnancy-induced hypertension, excessive gestational weight gain, risk of downstream overweight/obesity, diabetes, and cardiovascular disease development (19, 22). Despite scientific advances providing more evidence-based guidance promoting physical activity during pregnancy, nearly 85% of

pregnant women are not meeting physical activity guidelines and unfortunately continue to be insufficiently active during the postpartum period (19, 21).

Providing pregnant women with information through mobile technology could be a potential mechanism for eliciting changes in behavior. Digital media information (i.e. websites, blogs, online discussion forums, apps and social media platforms) have become widely used among women during pregnancy and postpartum periods (26). Smartphone apps (i.e. software programs downloaded by a user on a mobile app) specifically have become a useful way to provide information to women who are pregnant (12). A recent study found that 55% of pregnant women were using an app related to pregnancy, birth, and/or childcare (12, 25). In fact, 7% of all existing mobile health apps in 2015 were focused on women's health and pregnancy, making it the medical condition with the highest number of apps available (12, 36). While many apps are commercially available for numerous health-related conditions, it is a challenge for app users and health professionals to assess the quality of apps (17). In order to address this concern, the Mobile Application Rating Scale (MARS) was developed and serves as a reliable tool that provides a multidimensional measure of app quality (32). The MARS tool has been used to study app quality related to a large number of apps and health-related conditions (12), including apps looking at physical activity in children and young adults (30). Brown et al. (2019) utilized the MARS tool to investigate the quality of pregnancy apps, specifically in regards to pregnancy-specific nutrition information (12). The study found that existing pregnancy apps were mostly of low-quality (3.05 with 1 = *inadequate* and 5 = *excellent*), behavior change-techniques were rarely employed, and limited nutritional information prevent them from being an appropriate resource for pregnant women (12).

Given that existing physical activity apps for the general population had minimal theoretical content (16), we suspect pregnancy apps also have limited evidence-based physical activity information with perceived impact based on behavior change theory. This is important because apps based on theory tend to be better and more effective (16), and the inclusion of behavior change theories increases effectiveness of internet-based interventions such as mobile applications (12, 38).

Considering the low percentage of women who meet physical activity guidelines (19, 21), the lack of guidance provided on the topic (31), and the potential for mobile interventions to facilitate an increase of physical activity during and after pregnancy (15), an understanding of the quality of existing mobile apps is important. Therefore, the purpose of the study was to assess quality and perceived impact of current free mobile apps for physical activity during and after pregnancy in the US iTunes store using the MARS tool. We hypothesize that existing mobile apps designed to encourage physical activity among pregnant and postpartum women will be limited; and of those that do exist, they will be of low-quality and perceived impact (via the MARS tool) and lack evidence-based exercise information.

METHODS

Protocol

This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (28). Methods were adapted for exercise/physical activity during pregnancy based on a previous study done assessing the quality of pregnancy apps related to nutrition (12). In January 2020, a keyword search for apps in the United States iTunes Apple store using the following key words: *pregnancy, pregnant, postpartum, prenatal, postnatal, pregnancy exercise, pregnant exercise, postpartum exercise, prenatal exercise, postnatal exercise, pregnancy physical activity, pregnant physical activity, postpartum physical activity, prenatal physical activity, postnatal physical activity, pregnancy workout, pregnant workout, postpartum workout, prenatal workout, postnatal workout*. The search was also performed on <https://fnd.io/> to ensure all apps were included.

During the initial app search, the name, category, cost, version, description, and whether or not it contained exercise information were collected and recorded. Apps were considered eligible if they were in English, appeared free to download, designed to reach pregnant and/or postpartum women, and contained exercise information. Apps that met these criteria were included for further screening and downloaded onto an iPhone.

The apps were assessed by two trained reviewers using the validated and standardized MARS criteria (12, 32). Before completing the MARS tool on each app, basic data was collected including the population the app was designed to serve (pregnant, postpartum, or both), whether or not the app contains in-app purchases, the developer of the app, and the iTunes rating freely available to the public on iTunes by app users (1-5 stars).

The validated MARS tool uses four subcategories regarding specific app qualities. These include engagement (entertainment, interest, customization, interactivity, and target group), functionality (performance, ease of use, navigation, and gestural design), aesthetics (layout, graphics, and visual appeal), and information quality (accuracy of app description, goals, quality of information, quantity of information, visual information, credibility, and base of evidence). Each item is scored using a standardized 5-point Likert scale, which is as follows: 1-*inadequate*, 2-*poor*, 3-*acceptable*, 4-*good*, 5-*excellent*.

For example, the question that assesses entertainment, which is part of the engagement section asks, "*Is the app fun/entertaining to use? Does it use any strategies to increase engagement through entertainment (e.g., through gamification)?*" The response options include (a) *dull, not fun or entertaining at all*; (b) *mostly boring*; (c) *OK, fun enough to entertain user for a brief time (< 5 min)*; (d) *moderately fun and entertaining, would entertain user for some time (5–10 min)*; and (e) *highly entertaining and fun, would stimulate repeat use*. The overall quality MARS score is derived from the mean of the scores for the engagement, functionality, aesthetics, and information quality subscales. The MARS tool also yields a subjective quality score, which includes four subjective criteria pertaining to whether or not the reviewer would recommend the app to a pregnant or postpartum woman, how often they would use it if relevant to them, would they pay for it, and

what would they rank it (1-5 stars). To elaborate, the questions asked were based more on the opinion of the reviewers. For example, the first question asked, "Would you recommend this app to pregnant or postpartum women?" and the answers ranged from 1 (*Not at all- I would not recommend this app to anyone*) to 5 (*Definitely- I would recommend this app to everyone*). Each question had a 1-5 criteria assigned to responses and a mean subjective quality score was obtained from the MARS tool taking the average of these four questions. More details on the MARS tool and access to all questions can be found elsewhere (32).

Because apps that contain behavior change information are more effective (16), additional criteria from the MARS survey were added to assess the perceived impact of the app (app-specific questions). To elaborate, assessments included the perceived impact of the app on the user's knowledge, attitudes, intentions to change as well as the likelihood of actual change in the target health behavior (i.e. exercise). Specific scores obtained from these measures were *awareness, knowledge, attitudes, intention to change, help seeking, and behavior change*, which all relate to behavior change theories in varying capacities (3). For example, the question regarding attitudes states: *The app is likely to change attitudes toward physical activity during pregnancy and postpartum* with responses ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). According to the theory of planned behavior, for example, *intention* is the most important determinant of whether or not someone will actually change their behavior, and *awareness, knowledge, attitudes, and help-seeking* all fall under key constructs that contribute to intention to change behavior (9). The MARS app-specific questions ask specifically about these areas, thus, assessing likelihood for the app to ultimately change physical activity behaviors among pregnant and postpartum women. An *overall perceived impact score* was determined by adding all six of these subcategories together.

In addition, pregnancy-specific physical activity information for pregnant and/or postpartum women was carefully and systematically evaluated by exercise scientists using a set of pre-determined questions (Appendix A). One of these questions included whether or not the app contained exercise goal-setting and guidance in accordance with ACSM/ACOG (8). A list of specific exercise-related information contained in each app was made. For the three highest rated apps based on the overall MARS quality mean, subjective quality, and overall perceived impact scores, specific information about the features of the app is included in the manuscript (Table 3).

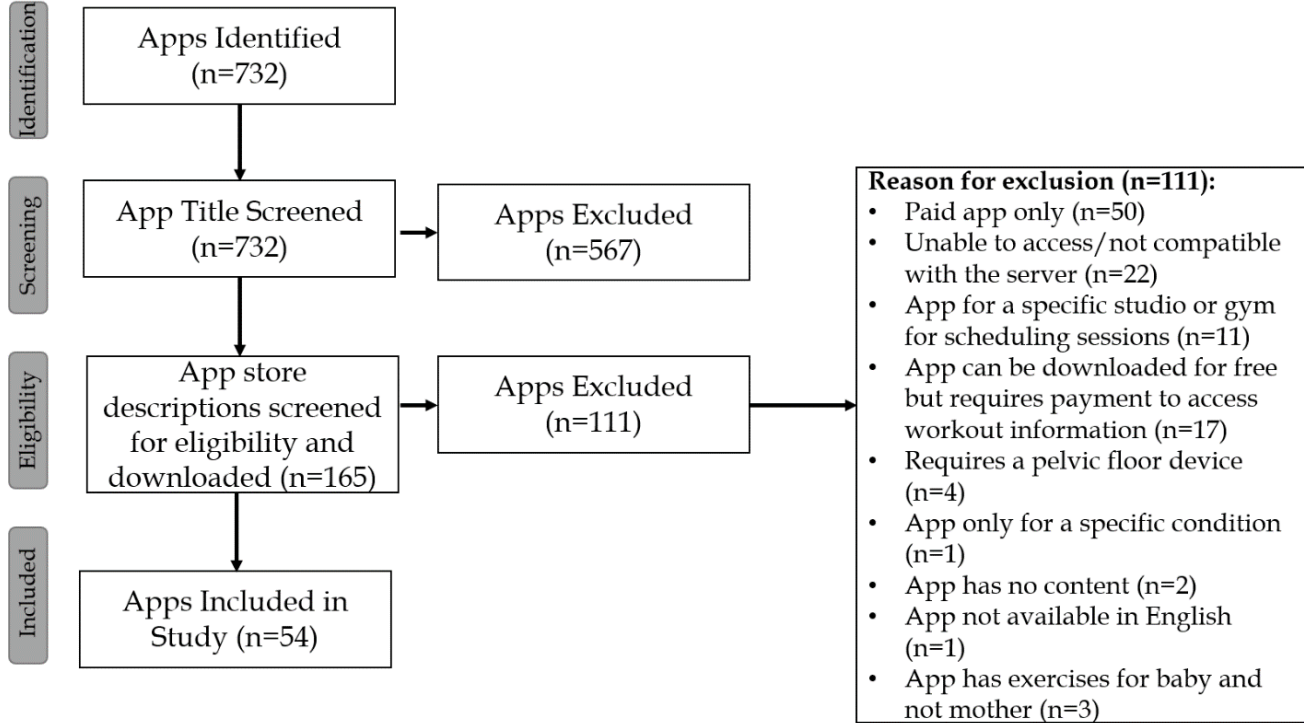
Statistical Analysis

Descriptive data (means and standard deviations) for all app scoring categories were calculated to assess the quality of existing apps as stated in the purpose and hypothesis of the study. Pearson-Product Moment Correlation Coefficients were run to determine if the MARS overall quality score was related to the user rating freely available on iTunes. As a secondary analysis, Student's Independent t-tests were run to compare scores between free and apps with in-app purchases. A one-sample t-test was run to determine whether the mean MARS overall quality score was significantly different from quality scores from other existing mobile health apps in other health domains (34). All data was imported into and analyzed in SPSS version 27.

RESULTS

The search results yielded 732 apps. After the titles and descriptions were carefully screened, 567 apps were excluded for not actually involving physical activity for pregnant and/or postpartum women, leaving 165 that went under further screening procedures. After excluding 111 from the 165 for various reasons, the remaining apps ($n = 54$) were downloaded and included in the final analyses and scored using the MARS system (See Figure 1).

Figure 1. Study Protocol of App Screening and Inclusion



Of the 54 apps included in the analyses, 20 apps contained physical activity information for only pregnant women (37.0%). Eleven apps contained information only for postpartum women (20.4%). Twenty-three apps contained information pertaining to both pregnant and postpartum women (42.6%). Out the apps 54 apps downloaded and included in the study, 33 (61.1%) of them required hidden costs in the form of in-app purchases.

The average app rating from other app users on iTunes was 3.8 ± 1.4 out of 5 stars for the apps that had available ratings. When our study team analyzed the apps using the MARS criteria, the overall MARS quality score (the mean of the four subcategories) was 3.06 ± 0.94 out of 5 (1-inadequate, 2-poor, 3-acceptable, 4-good, and 5-excellent) (Table 1), which is lower than existing mobile health apps (3.74 ± 0.59) as determined by a one-sample t-test ($p < 0.001$). Existing mobile helps apps have been deemed to be of “moderate” quality, thus, we feel it is appropriate to classify the apps included in the present study as of overall low quality. The iTunes user rating freely available on iTunes was moderately correlated with the overall MARS quality score determined by the study team ($r = 0.461, p = 0.002$), which is similar to other studies comparing MARS overall quality scores to iTunes user ratings (32).

When examining the apps that are truly free (i.e. free to download and content was available without in-app purchases), the overall mean MARS score was only 2.66 ± 1.08 , which was significantly lower than the apps that required in-app purchases (3.32 ± 0.74 , $p = 0.012$, 95% CI (0.59-4.60)). In addition, none of the apps contained goal-setting in alignment with ACSM/ACOG guidelines.

Examining the four subscales individually, *Functionality* had the highest mean with 3.32 ± 1.03 out of 5. *Aesthetics* had the next highest mean at 3.14 ± 1.20 . *Information* and *Engagement* were the lowest means at 3.01 ± 0.91 and 2.85 ± 0.93 , respectively. The three apps that had the highest overall MARS rankings (i.e. overall quality mean score) were *Every Mother* (4.91), *Juna Pregnancy Workouts* (4.86), and *The Snapback* (4.86). The *Snapback* app is designed only for postpartum women. The three highly rated apps required in-app purchases after being downloaded.

The study team (consisting of all women of childbearing age) evaluated each app with four subjective criteria including whether or not they would recommend the app to a pregnant or postpartum woman, how often they would use it if relevant to them, would they pay for it, and what would they rank it (1-5 stars). The mean subjective quality score from the MARS tool was 2.4 ± 1.3 . The same three apps (*Juna Pregnancy Workouts*, *Every Mother*, and *The Snapback*) scored highest on this subjective scale as well, all scoring an average of five.

Additional criteria were added to assess the perceived impact of the app on the user's knowledge, attitudes, intentions to change as well as the likelihood of actual change in the target health behavior (i.e. exercise) as part of app-specific MARS tool. Specific scores obtained from these measures were *awareness*, *knowledge*, *attitudes*, *intention to change*, *help seeking*, and *behavior change*. Scores are presented in Table 2. For all questions, scores ranged from 1 = strongly disagree to 5 = strongly agree. Among all of these categories, mean scores were low, ranging from 1.57 ± 0.66 (*help seeking*) to 2.02 ± 0.93 (*intention to change*). An *overall perceived impact* score was determined as the sum of all subcategories, and the same three apps scored highest among all apps for potential to influence a user's behavior (*Juna*: 27, *Every Mother*: 23, and *The Snapback*: 22).

Table 1. App Scores based on MARS criteria

	Pregnancy, postpartum, or both	In-app purchases	Rating (out of 5 stars)	Developer	Engagement Mean	Functionality Mean	Aesthetics Mean	Information Mean	Overall Quality Mean Score	Subjective Quality Mean Score
Mean (SD) of all apps			3.8 (1.4)		2.85 (0.93)	3.32 (1.02)	3.14 (1.20)	3.01 (0.91)	3.06 (0.94)	2.40 (1.31)
<i>Every Mother</i>	both	yes	4.7	Sustainable Fitness, Inc	4.8	5	5	4.8	4.9	20
<i>Juna- Pregnancy workouts</i>	both	yes	4.6	Juan media LLC	4.6	5	5	4.8	4.9	20
<i>The Snapback</i>	postpartum	yes	4.8	The Snapback health and parenting Ltd	4.6	5	5	4.8	4.9	20
<i>Pregnancy +</i>	pregnancy	no	4.7	Unknown	4.2	5	4.7	4.2	4.5	17
<i>MoovBuddy</i>	both	yes	4.9	Unknown	4.2	4.8	4.3	4.2	4.4	16
<i>Baby2Body: Pregnancy Wellness</i>	pregnancy	no	4.7	Baby2Body limited	4	4.5	4.7	4.3	4.4	18
<i>Ovia Pregnancy Tracker</i>	pregnancy	yes	4.9	Oculi even Inc.	4	4.5	4.7	4.3	4.4	16
<i>Mamamend: Postpartum Health</i>	postpartum	no	4.1	Mamamend	4	4.5	4.7	4.3	4.4	16
<i>Preggo by Ilove9months</i>	pregnancy	no	NR	Rajkumar VK	3.6	3.5	4.3	3.3	3.7	14
<i>Glo Yoga and Meditation</i>	both	yes	4.9	YogaGlo, Inc	3.6	3.5	4	3.7	3.7	16
<i>Yoga wave: workouts and poses</i>	both	yes	4.3	Bending Spoons Apps IVS	3.4	3.8	4	3.6	3.7	11
<i>Pregnancy Workout Plan</i>	both	yes	1	Samantha Roobol	2.4	4	4.7	3.5	3.7	12
<i>Parents Magazine</i>	both	no	5.0	Meredith Corporation	3	3	4	3.8	3.5	10
<i>30 Day Fit Mommy Challenge</i>	both	yes	3.7	Stefan Roobol	2.8	4	3.7	3.3	3.5	10
<i>Free Pregnancy App Baby Chronicles Baby Pregnancy Planner</i>	both	no	5	Dania Lebovics	3.4	3.8	3.7	3.2	3.5	7
<i>PRONatal Fitness</i>	both	yes	NR	Turning Pointe, LLC	3.4	3.8	4.3	2.5	3.5	12
<i>Post-Natal Workouts</i>	postpartum	yes	4	postnatal workouts for moms	3.2	3.8	4	3	3.5	11
<i>exercise during pregnancy</i>	pregnancy	yes	5	Stefan Roobol	3	4	4	3.8	3.5	12

<i>iBirth daily pregnancy, postpartum & baby tracker</i>	both	yes	3.2	Lula B, LLC	3.6	3.8	2.7	3.8	3.5	1
<i>expectful meditation & sleep</i>	both	yes	4.7	Expectful, Inc	3.2	3.5	3.7	3	3.4	9
<i>Yanita Yancheva</i>	both	yes	NR	BodyPlan Fitness Inc	3	3.3	4.3	3	3.4	15
<i>Prenatal Yoga/Down Dog</i>	pregnancy	yes	4.9	Yoga Buddhi Co.	3.4	3.8	3.7	2.8	3.4	12
<i>Kegel Talent PFM Exercises</i>	pregnancy	yes	5	hsin hua lai	3.4	3.8	2.7	3.2	3.3	16
<i>Busy Mom's Fitness and Recipes</i>	both	no	NR	Kari Sarl	3	3.5	3.3	3.2	3.3	12
<i>The Pregnancy Pilates Videos with Caroline Sandry</i>	both	yes	1	New Shoot Pictures Ltd	1.6	4.5	3.3	2.8	3.1	5
<i>Losing Weight After Pregnancy</i>	postpartum	yes	NR	Samantha Roobol	3	2.8	3.3	2.7	3.0	10
<i>Yoga During Pregnancy</i>	pregnancy	yes	NR	Samantha Roobol	3	2.8	3.3	2.7	3.0	10
<i>Tone it up: Workout & Fitness</i>	both	yes	4.2	Tone it up LLC	3	4.3	4.7		3.0	17
<i>Pregnancy Workouts - Prenatal</i>	pregnancy	yes	4.3	Vidthug Pte Ltd	2.8	4	2.7	2.7	3.0	10
<i>Pregnancy and Due date tracker</i>	pregnancy	yes	4.8	Wachanga Inc.	3.8	4	3.7	n/a	2.9	13
<i>Easy Kegel</i>	pregnancy	yes	4.8	Joseph Williamson Olson applications limited	3.4	3.8	2	2	2.8	1
<i>Kegel Training PFM exercises</i>	both	no	4.7	HappyMums Solutions Ltd	2.4	3	3	2.8	2.8	7
<i>FitMama Lite Postnatal Workout</i>	postpartum	yes	NR	HappyMums Solutions Ltd	2.8	2.5	2.7	3	2.8	7
<i>WellMama Lite Postnatal Yoga</i>	postpartum	no	5.0	HappyMums Solutions Ltd	2.8	2.5	2.7	3	2.8	7
<i>Prenatal yoga pregnancy fitness</i>	pregnancy	yes	4.1	Truehira, LLC	2	3	3	3	2.8	9
<i>Yoggy: Pregnancy Yoga Workouts</i>	both	yes	4.5	Millefeuille Agency	2	3.3	2.7	2.8	2.7	8
<i>Kegel Trainer</i>	pregnancy	no	4.5	Alex Marchant	1.8	3.3	2.3	3.2	2.7	4
<i>Pregnancy Exercise and Yoga</i>	pregnancy	no	3.9	Ahmad Nakore	1.8	3.3	3	2.7	2.7	7
<i>30 Days of Pilates - Personal Trainer</i>	both	yes	3.4	Do Tri	2.2	3	2.7	2.3	2.6	5

<i>Perineum Exercises</i>	pregnancy	no	NR	Alessandro La Pergola	2.4	3	2.3	2.7	2.6	9
<i>Super Diet Plans/ Weight Loss</i>	both	yes	3.8	Vigour3d	3	2.8	2	2.5	2.6	6
<i>Weight Loss Fitness & Workout</i>	both	yes	3.7	Juraj Chochlik	2.4	2.3	3	2.7	2.6	6
<i>Postnatal Pilates (Lite)</i>	postpartum	yes	NR	Reform Fitness LTD	2.2	3.3	2	2.8	2.6	6
<i>Pregnancy Magazine HD</i>	pregnancy	no	2.4	Pregnancy Magazine Group	1.4	3.3	2.3	3	2.5	8
<i>iMom Workout • postpartum</i>	postpartum	yes	1.8	OB Science S.R.L	2	3	2	2.7	2.5	7
<i>Baby Workout</i>	postpartum	no	5	appicdesign	3	2.8	1.3	2.5	2.4	7
<i>New Mom Workout Free: Post Pregnancy Exercises with Baby</i>	postpartum	yes	4.3	Power 20	2.8	2.5	2	2.3	2.4	4
<i>Pregnancy Workout Advisor</i>	pregnancy	no	1.0	ORGware	2.2	2.5	2	2.3	2.3	1
<i>Pregnancy Tips for iPhone</i>	both	no	NR	XLabz Technologies Pvt. Ltd.	1.4	1	1	3	1.6	4
<i>Weight Loss After Pregnancy</i>	postpartum	yes	1	Nipon Phuhoi	1.6	1.8	1	1.5	1.5	1
<i>Free Pregnancy App Baby Chronicles</i>	pregnancy	yes	5.0	Dania Lebovics	1	1.75	1	1.3	1.3	4
<i>Pregnancy Planner</i>	pregnancy	yes	1	SparkPeople, Inc	1.8	1	1	1	1.2	4
<i>Pregnancy Health & fitness week by week</i>	pregnancy	yes	1	SparkPeople, Inc	1.8	1	1	1	1.2	4
<i>Bellefit Postpartum Shape App</i>	postpartum	no	3.4	Bellefit Inc	1.4	1	1.3	1.2	1.2	4
<i>Pregnant with diabetes</i>	both	yes	1.3	Soren Rasmussen	1	1	1	1	1	4

NR: Not Rated or Not Enough Ratings Available

n/a: Not applicable/cannot be scored using the MARS subcategory

Table 2. Additional App Scoring Items Focused on Perceived Impact on User's Behavior

	Awareness	Knowledge	Attitudes	Intention to Change	Help Seeking	Behavior Change	Overall Perceived Impact
Mean (SD) of all apps	1.71 (0.80)	1.96 (0.82)	1.94 (0.90)	2.02 (0.93)	1.57 (0.67)	1.88 (0.83)	11.1 (4.6)
<i>Juna-Pregnancy Workouts</i>	5	4.5	4.5	5	4	4	27
<i>Every Mother</i>	3.5	4	4	4	3.5	4	23
<i>The Snapback</i>	4	3.5	4	4	3	3.5	22
<i>Baby2Body: Pregnancy Wellness</i>	3	3.5	3	3.5	3	3	19
<i>Pregnancy Health & fitness week by week</i>	2.5	3	2.5	3	2	2.5	15.5
<i>Pregnancy Workout Plan</i>	2	2.5	3	2.5	2	2.5	14.5
<i>Prenatal Yoga Down Dog</i>	2.5	2.5	2.5	2.5	2	2.5	14.5
<i>Super Diet Plans/Weight Loss</i>	2.5	2.5	2.5	2.5	2	2.5	14.5
<i>Preggo by Ilove9months</i>	2.5	2.5	2.5	2.5	2	2.5	14.5
<i>Yoga wave: workouts and poses</i>	1.5	2.5	3	3	2.5	2	14.5
<i>Busy Mom's Fitness and Recipes</i>	1.5	2.5	2.5	2.5	2	3	14
<i>exercise during pregnancy</i>	2	3	2.5	2.5	1.5	2.5	14
<i>Tone it up: Workout & Fitness</i>	2	2.5	2.5	2.5	2	2.5	14
<i>The Pregnancy Pilates Videos with Caroline Sandry</i>	1.5	2.5	3	3	1.5	2	13.5
<i>Glo Yoga and Meditation</i>	2.5	2	2.5	2.5	1.5	2.5	13.5
<i>Pregnancy Workout Advisor</i>	2.5	2.5	2	2.5	2	2	13.5
<i>Pregnancy Workouts - Prenatal</i>	2	2.5	2.5	2.5	1.5	2.5	13.5
<i>30 Day Fit Mommy Challenge</i>	1.5	2	2.5	2.5	2	3	13.5
<i>Post-Natal Workouts</i>	2	2	2.5	2.5	1.5	2.5	13
<i>Yoggy: Pregnancy Yoga Workouts</i>	1.5	2	2.5	2.5	1.5	2.5	12.5
<i>Yoga During Pregnancy</i>	1.5	2.5	2.5	2.5	1.5	2	12.5
<i>Yanita Yancheva</i>	1.5	1.5	2.5	2.5	1.5	2	11.5
<i>Baby Workout</i>	1.5	2	2.5	2.5	1	2	11.5
<i>PRONatal Fitness</i>	1.5	2.5	2	2	1.5	2	11.5
<i>iMom Workout • post-partum</i>	1.5	2	1.5	2.5	1.5	2.5	11.5
<i>New Mom Workout Free: Post Pregnancy Exercises with Baby</i>	1	1.5	2.5	2.5	1.5	2.5	11.5
<i>Losing Weight After Pregnancy</i>	1.5	1.5	2.5	2	1.5	2	11
<i>Pregnancy +</i>	2.5	1.5	1.5	2.5	1.5	1.5	11
<i>MoovBuddy</i>	1.5	1.5	2	2	1.5	2	10.5
<i>Kegel Talent PFM Exercises</i>	1.5	2.5	1.5	2	1	2	10.5

<i>FitMama Lite Postnatal Workout</i>	1.5	2	1.5	1.5	2	2	10.5
<i>Postnatal Pilates (Lite)</i>	1.5	2	1.5	1.5	2	2	10.5
<i>Perineum Exercises</i>	1	2	1.5	2	1	1.5	9
<i>Free Pregnancy App Baby Chronicles Pregnancy Planner</i>	1.5	1.5	1.5	1.5	1.5	1.5	9
<i>expectful meditation & sleep</i>	1	2	1.5	1.5	1	1	8
<i>Prenatal yoga pregnancy fitness</i>	1.5	1.5	1.5	1.5	1	1	8
<i>iBirth daily pregnancy, postpartum & baby tracker</i>	1.5	2	1	1	1	1	7.5
<i>Easy Kegel</i>	1	2	1	1	1	1	7
<i>Pregnancy Exercise and Yoga</i>	1.5	1.5	1	1	1	1	7
<i>Mamamend: Postpartum Health</i>	1.5	1	1	1	1.5	1	7
<i>Weight Loss After Pregnancy</i>	1	1.5	1	1	1.5	1	7
<i>30 Days of Pilates - Personal Trainer</i>	1	1.5	1	1	1	1	6.5
<i>Kegel Trainer</i>	1.5	1	1	1	1	1	6.5
<i>Kegel Training PFM exercises</i>	1	1	1	1.5	1	1	6.5
<i>Ovia Pregnancy Tracker</i>	1.5	1	1	1	1	1	6.5
<i>Pregnant with diabetes</i>	1.5	1	1	1	1	1	6.5
<i>Free Pregnancy App Baby Chronicles Baby Pregnancy Planner</i>	1	1	1	1	1	1	6
<i>Pregnancy Tips for iPhone</i>	1	1	1	1	1	1	6
<i>Weight Loss Fitness & Workout</i>	1	1	1	1	1	1	6
<i>Parents Magazine</i>	1	1	1	1	1	1	6
<i>Pregnancy and due date tracker</i>	1	1	1	1	1	1	6
<i>Pregnancy Magazine HD</i>	1	1	1	1	1	1	6
<i>Bellefit Postpartum Shape App</i>	1	1	1	1	1	1	6
<i>WellMama Lite Postnatal Yoga</i>	1	1	1	1	1	1	6

The three highest rated apps based on MARS overall quality scores, subjective quality scores, and overall perceived impact scores (*Juna*, *Every Mother*, and *the Snapback*) were carefully reviewed and critiqued by exercise scientists. However, all three highly-rated apps are cost-prohibitive (i.e. 100-300 times as expensive as commonly used apps (1)) once actually downloaded and utilized beyond a brief trial period. Also, the *Snapback* only contained information related to postpartum. Additional details on each app is included in the table below (Table 3).

Table 3. Detailed Review of Content for Three Highest Rated Apps Mean Quality Scores and Overall Perceived Impact Scores

App Name	Strengths	Weaknesses
<i>Juna</i>	<ul style="list-style-type: none"> Tracks each week of the user’s pregnancy/postpartum journey. The nutrition page has recipes for the user to follow along with the recipes of the week. The fitness tab has exercise programs for “trying to conceive”, first, second, and third trimester, postpartum recovery, postpartum beginner, and postpartum intermediate. The exercise videos range from 3-45 minutes. The exercise page has a library section for the user to create their own workout plan. The app has a planned exercise program if the user wants to follow a day-to-day program and incorporates a rest day. Has notifications, can turn on audio guidance during a workout, and share with friends The app monitors safety for each exercise. 	<ul style="list-style-type: none"> The app requires a subscription to <i>Juna</i> to open the app: Cost ranges from \$9-\$19.99 per month depending on the plan selected. The app is not tailored by the individual’s weight status or exercise status. The app does not track the ACSM/ACOG guidelines for exercising 150 min/wk. Unclear what credentials the creator of the app has for designing the content. Difficult to understand whether or not the information in the app is trustworthy or safe despite the safety monitoring feature.
<i>Every Mother</i>	<ul style="list-style-type: none"> The subscription program options are <i>EMbody Reclaim</i>, <i>EMbody Surpass</i>, and <i>EMbody Prepare</i>. The <i>EMbody Reclaim</i> and <i>EMbody Surpass</i> are both designed for postpartum women, with <i>reclaim</i> specifically designed for women with diastasis recti. The <i>EMbody Prepare</i> program is described as suitable if the user is in any stage of pregnancy. All programs include daily workouts (core and full-body), as well as educational content for each trimester or timepoint. The content does seem to evidence-based as recommended exercises for women with diastasis will differ greatly for those without. Peer support available Customized programming 10-30minutes per day The founder of the app is a certified personal trainer and is collaborating with research universities on the app. Link to published studies on the app included on the resources OB-endorsed 	<ul style="list-style-type: none"> This app is cost-prohibitive. After choosing a program, the user must subscribe to one of the programs to continue the app and see what is included. There are 3 subscriptions to choose from and are \$44.99 for every 3 months or \$119.99 per year. The app does not discuss or encourage women to reach the ACSM/ACOG exercise guidelines of 150 min/wk.

The Snapback

- The app starts with week 0, day 1, and finishes at week 14 postpartum.
- The weeks are specific to recovery and timepoint post-delivery (Week 0-2 focuses on recovery and rehab. Week 3-6 focuses on pelvic floor and core rehab. Week 7-10 focuses on postpartum exercises. Week 11-14 focus on increasing activity.)
- Contains health tips (educational component) on baby, healthy snack ideas, and mental health information.
- Contains places to track important infant postpartum variables (feed, diaper, pumping, journal, and photo).
- User can create a community of other users
- Tool tab contains a calendar, reminders, to-do lists, and workout library.
- The health profile allows the user to put in their weight, height, program (pregnant or postpartum), delivery method, breastfeeding option, and delivery date.
- The baby profile allows the user to put the infant's name, weight, height, and head size.
- The app allows the user to pick their current fitness level and tailor a program based on that information.
- The app has a feature to remind the user to exercise and take any medications prescribed.
- The creator has a doctorate in pharmacy as well as a certification in personal training with an emphasis on pre and postnatal exercise (pre and postnatal exercise specialist).
- A "one-stop shop" for postpartum maternal and infant health.
- Only contains content for postpartum women
- Requires payment to have full access. Users can purchase one week for free, then it costs \$19.99- \$29.99 per month depending on the plan selected.
- The app does not track how much activity the user has completed or keep track of the user's weight (no goal-setting).
- The app does not have a section to monitor symptoms for safety.
- The program appears to be set (i.e. user is unable to pick any exercises or tailor their own program).

DISCUSSION

This is the first study to review all free commercially available physical activity apps for pregnant and/or postpartum women in the US utilizing a validated tool (MARS). Overall, the quality of existing apps appears low and few apps contain high-quality evidence-based information in alignment with guidelines. Our findings are substantiated by other general app users as the iTunes user rating was correlated with the overall MARS quality score determined by the study team. Previous work in nearly 1,300 mobile health apps across 15 different health domains, that found quality of existing apps is moderate (overall mean MARS score of 3.74) and 98.4% do not contain evidence-based information (34). Given the mean score of the mobile apps included in the present study was 3.06, the quality of apps for physical activity during pregnancy is even lower than moderate/acceptable, and thus, we determined of low-quality.

None of the existing apps had specific goal setting in line with the American College of Obstetricians and Gynecologists (ACOG) and the American College of Sports Medicine (ACSM) recommendation for pregnant women (8). There are several pregnancy and/or postpartum apps that exist currently that may be a good resource for women based on both quality and perceived

impact (MARS tool), these include *Every Mother*, *Juna*, and *The Snapback*. However, one is only for postpartum women and may be cost-prohibitive (*The Snapback*). *Every Mother* scored well and contained evidence-based information and appropriately credentialed creators (which *Juna* lacked); however, both apps are also expensive limiting their ability to reach and impact pregnant and postpartum women. Taken together, existing mobile apps are not recommended for use among pregnant and postpartum women (and will likely not enable women to achieve recommended levels of physical activity) for one or more of the following reasons: low-quality, low perceived impact, lack of evidence-based information in accordance with guidelines, and/or high price-point; therefore, there is not an existing mobile app that is recommended for physical activity guidance for pregnant and postpartum women.

Mobile apps being expensive and potentially cost-prohibitive poses several concerns regarding likelihood to actually reach and/or impact pregnant or postpartum women. Recent data suggests only 5-10% of app users will pay for in-app purchases (5) and average app prices for commonly used apps is \$0.94 (4). The three highest rated apps in the current project were all well-above this amount (ranging from \$108-\$360 per year, which would cover a pregnancy and 3 months postpartum), and all required in-app purchasing. Not only does cost provide a significant barrier for many pregnant and postpartum women (i.e. lack of access to resources or equipment) (10, 33), but it is also suggestive of potential conflicts of interests within the apps as the creators have financial incentives to increase user activity. Physical activity information for pregnant and postpartum women needs to be freely available in order to effectively reach as many women as possible. It is also easier for obstetric providers to recommend app usage if there is not a cost associated with it. While ideally, insurance coverage could be available at some point to better support physical activity resources during pregnancy (similar to dietary resources during pregnancy (2)); this does not appear to be a clinical change occurring in the near future. Allowing patients access to physical activity resources (e.g. mobile apps) would provide an important opportunity to receive all of the information they need without increasing the demands placed on the obstetrician. Depending on app content, it could also integrate physical therapists, fitness professionals, and/or other health care professionals into the health care team, which is an idea that ACOG has suggested to improve patient outcomes (6, 35).

In 2018, ACOG identified challenges to providing individualized care during pregnancy including healthcare costs, availability of the provider, patient wait times, and limited time for education and support (7). While physical activity is only one facet of this problem, it has the potential to improve a number of serious outcomes including excessive weight gain, gestational diabetes, pregnancy-related high blood pressure (8, 13, 18). A high-quality physical activity mobile app is one potential method to overcome some of these challenges and improve outcomes during and after pregnancy.

The overall rating on iTunes for the included apps was 3.8 out of 5 stars, which correlated with the quality scores from the MARS tool in the present study. While some apps were rated well on iTunes (i.e. *Ovia* (4.9) or *Parents Magazine* (5.0)), the majority of these highly scored apps were general pregnancy apps and contained very little information or assistance specific to physical activity during and/or after pregnancy. Therefore, the high scores noted from iTunes are not

relevant to the needs of pregnant and postpartum women searching for a physical activity resources. The apps that were highly rated on iTunes and focused on physical activity during pregnancy were also highly rated by our study team using the physical activity-focused MARS criteria and are discussed further (i.e. *Juna, The Snapback, Every Mother*).

The overall mean quality score (mean of the four subscales) for the apps included in the study was of moderate quality (3.06 out of 5). Our mean quality score was similar to that by Brown et al. who investigated nutrition-based pregnancy apps (12). Also similar to Brown et al., the subscale with the highest rating was *Functionality*, which is also in line with several reviews that determined *Functionality* to be the highest scoring subcategory among health-related mobile apps (11, 30). *Information* was among the lowest two scoring subscales, which was not surprising given the lack-of consistent, evidence-based guidance available to pregnant and postpartum women regarding exercise (20, 29). This finding is consistent with other reviews that suggest *Information* is often scored poorly (11, 30). In further support of this finding, mobile apps on other health-related topics (particularly weight management) tend to lack evidence-based information within their content (11, 30, 37).

During pregnancy, not only is there a lack-of evidence-based information available (20, 29), but also an abundance of misinformation surrounding physical activity during the pregnancy and postpartum periods (23, 24). Some women may even choose not to participate in physical activity during pregnancy out of fear to cause harm to the fetus (20). Because mobile apps on other health-related topics often lack appropriate guidance (11, 30, 37) (and the same appears to be true for the present study on pregnancy apps for physical activity), mobile apps could inadvertently increase stress, fear, and anxiety regarding exercise during pregnancy (36). It is also likely that existing mobile apps could even be dangerous if the information being shared is not evidence-based and consistent with ACOG recommendations, as appears to the case with existing mobile apps for physical activity during and after pregnancy. Taken together, we support the notion from both Brown et al. and Bardus et al. that health-related apps need to be more diligent about incorporating evidence-based information into the app's content (11, 12).

A previous study by Saligheh et al. found that among postpartum women, the lack of high-quality exercise programs was a major barrier to exercise after having a baby (29). An important opportunity exists to update traditional practices and services (14, 36), which could be accomplished through technology and evidence-based exercise advice for pregnant and postpartum women. Unfortunately, no existing mobile apps appear to be of high-quality with appropriate evidence-based information that is readily available to women regardless of socioeconomic status. One of the best strategies to accomplish the goal of developing high-quality mobile technology for physical activity during and after pregnancy would be for future app developers to work in collaboration with fitness professionals, physical therapists, and obstetric care providers to create and design mobile apps that comply with evidence-based guidelines and are freely available to all women.

Limitations of the study are similar to those of Brown et al. (12). The first is many apps (61%) contained in-app purchases which made it difficult to carefully evaluate all of the content; the

study team could only evaluate the features available without the expensive subscriptions. Therefore, conclusions can only be drawn based on content freely available. Another limitation is that all reviewers were exercise scientists, thus, no health care providers were included; however, the use of multiple reviewers is a strength of the study. Next, the apps were only tested using iPhones; therefore, the app may have scored differently on other platforms (e.g. android). Another limitation is that while apps being cost-prohibitive and/or of low-quality are issues identified and discussed, formal definitions for these terms have not been established and may vary by the user, making the usage of these terms somewhat arbitrary. However, quality scores in the present study were similar to those in previous work and thus, characterized similarly (i.e. low quality). A final, and very important limitation to acknowledge, is that app development is a fast-moving and constantly-evolving process; it is possible that the apps included in the manuscript have updated versions with new content that could impact the scoring and/or evaluation.

Overall, the study suggests that currently available free apps on iTunes are not recommended for pregnant women to use to as a resource for physical activity information due to low-quality, low perceived impact, lack of evidence-based information in accordance with established guidelines, and/or high hidden costs. Previous research has made it clear mobile apps can positively impact health behaviors, including physical activity (27); therefore, a unique and timely opportunity exists to positively influence physical activity behaviors among pregnant and postpartum women through mobile app development. Mobile health platforms need to be used to engage and educate pregnant women regarding physical activity during pregnancy utilizing evidence-based information. Future work should consider collaborations between health care providers, fitness professionals, and app developers to successfully reach and positively influence physical activity behaviors during and after pregnancy.

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