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Review

Walking for health during pregnancy: A literature review and considerations for future research

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Abstract

Walking is the most commonly chosen type of physical activity (PA) during pregnancy and provides several health benefits to both mother and child. National initiatives have promoted the importance of walking in general, but little emphasis is directed toward pregnant women, the majority of whom are insufficiently active. Pregnant women face a variety of dynamic barriers to a physically active lifestyle, some of which are more commonly experienced during specific times throughout the pregnancy experience. Walking is unique in that it appears resistant to a number of these barriers that limit other types of PA participation, and it can be meaningfully integrated into some transportation and occupational activities when leisure-time options are unavailable. Preliminary intervention work suggests that walking programs can be effectively adopted into a typical pregnancy lifestyle. However, a great deal of work remains to administer successful pregnancy walking interventions, including developing and using validated methods of PA and walking assessment. This narrative review discusses the unique advantages of walking during pregnancy, provides recommendations for future intervention work, and outlines the need for pregnancy-focused community walking initiatives. Standard search procedures were followed to determine sources from the literature specific to walking during pregnancy for use in each section of this review.

Keywords: Ambulatory activity; Exercise behavior; Maternal-fetal health; Pregnant women

1. Introduction

With the U.S. Surgeon General's recent Call to Action,[1] the effort to increase walking and create walking-focused communities has been deemed a national priority and aligns with recently formed, national-level physical activity (PA) initiatives, such as Let's Move.[2] The overarching objective of such efforts is to reverse the clear trends of low PA and high sedentary behaviors within the United States,[3,4] a prodigious task. Walking offers several unique advantages in this effort that other exercise modalities do not, including that it may be resistant to several commonly experienced PA barriers and can realistically be ingrained within individuals' various daily activities (e.g., transportation, occupation, and leisure time). Accordingly, using walking to reach recommended intensities and volumes of PA (e.g., 150 min/week of moderate- to vigorous-intensity PA) should be a high priority for scientific investigators seeking to design effective PA intervention trials, particularly for individuals who are sedentary or not sufficiently physically active.[5] This may be particularly pertinent for investigators aiming to improve PA among pregnant women, a population sometimes overlooked in the health-behavior literature, yet one that essentially sets the postpartum health trajectory of both mother and child.[6,7]

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The few nationally representative investigations that have examined pregnancy PA trends suggest that the majority of pregnant women are active in some way,[8–10] but this participation often falls well short of optimal levels for maternal-fetal health. Indeed, it appears only a fraction (14%–23%) of pregnant women are meeting recommended levels of PA,[8,10] although to clarify this prevalence, more examinations of recent population-representative data and perhaps more robust PA assessment methods are needed. Further uncertainty arises when considering most of the previous research on PA trends within this population have focused on leisure-time activity and have not typically included PA performed as a part of a woman's occupation or for transportation. Additionally, few previous studies have used PA monitors (e.g., accelerometers, pedometers, and consumer-based activity trackers) as a means of understanding PA trends during pregnancy.[11–13] However, the majority of pregnancy PA likely involves walking, which is clearly the most commonly chosen PA modality among pregnant women.[8,10]

Given the unique physiologic changes that occur and the dynamic psychosocial experiences that many women report throughout pregnancy, a trimester-specific understanding of PA trends is important to facilitate future improvements in pregnancy PA. Previous investigations using both questionnaires and PA monitors indicate that PA levels decrease substantially as women progress from the 2nd to 3rd trimester,[9,14] but they may slightly increase in the 2nd trimester compared to the 1st.[9]

Huberty et al.[11] recently confirmed these trimester-specific trends, finding that total active time, light-intensity PA, and steps taken per day all increased some from the 1st trimester into the 2nd and then decreased considerably into the final trimester of pregnancy. Time spent in sedentary behaviors likewise increased from 2nd to 3rd trimesters. Although some PA barriers remain consistent throughout the duration of pregnancy (i.e., lack of time, childcare responsibilities, and concern for the child's health), others are more commonly experienced at specific pregnancy time points. The aforementioned findings of PA trends throughout pregnancy are likely as a result of the various trimester-specific barriers that pregnant women face, including pregnancy-induced nausea or extreme fatigue in the 1st trimester and general physical discomforts, increased weight, and body image concerns in the latter stages of pregnancy. Identifying and advocating for modalities and intensities of PA that are resistant to such barriers are likely important if overall pregnancy PA levels are to be increased. Walking offers the enticing prospect of substantial maternal-fetal health benefits while likely being somewhat resistant to commonly experienced PA barriers. Thus, the objective of this review is to provide scientific investigators and community health workers with necessary information to develop effective future studies on walking intervention and promote pregnancy-focused community walking initiatives.

2. Methods

This article represents a traditional narrative review of the literature. Although systematic review procedures were not used in drafting it, general guidelines were followed to determine sources from the literature to be used for each of the subsequent article sections, specific to walking during pregnancy. Thus, literature searches were performed with respect to health effects of walking during pregnancy, barriers to walking during pregnancy, interventions to increase walking during pregnancy, measurement of walking during pregnancy, and initiatives to walking during pregnancy. Combinations of some of the following keywords were specifically used in these searches: "pregnan*", "physical activity", "walk*", "exercise", "health", "intervention", "activity monitor", "pedometer", "acceleromet*", and "initiative". The study authors organized the results of these literature searches within individual sections, given the results aligned with our overarching objective, as previously mentioned. All literature searches were performed from January 2017 to February 2018 through the well-regarded literature databases PubMed, ProQuest, and Google Scholar. Additional sources of interest were identified by reviewing the references of previously identified articles. The focus of this review is specific to the PA modality of walking, and most of the sources used within this review are walking-specific investigations or interventions. However, other sources that we refer to focus more generally on leisure-time activity or pregnancy health and include a specific reference to walking therein. Sources referenced in this review include reports disseminated by multiple health and PA organizations, online information from past or current community health initiatives or programs, and 97 scientific articles published within 55 different peer-reviewed journals.

3. Health effects of walking during pregnancy

A number of prominent organizations have outlined the health benefits of PA during pregnancy as the basis for exercise, including the American College of Obstetricians and Gynecologists (ACOG)[15] and the U.S. Department of Health and Human Services (DHHS).[16] Additionally, the effects of PA during pregnancy, most commonly investigated in terms of general activity performed during leisure time, on various maternal and fetal health outcomes have been reported in a number of scientific reviews.[17–19] The specific focus of this review is that of walking during pregnancy, with various health benefits already evident, and advocating for increased walking behavior among pregnant women. Some health effects provided from walking during pregnancy are strongly supported in the scientific literature, indeed more so than any other specific exercise modality. Perhaps this is as a result of the popularity of walking for exercise among pregnant women. For the mother, evidence is strong that walking during pregnancy, particularly at a brisk pace, decreases the risk for several complications, including gestational diabetes mellitus (GDM),[20] preeclampsia,[21] and excessive gestational weight gain.[22] For the child, previous investigations suggest that walking during pregnancy leads to healthy birthweight[23–25] and may reduce the risk of preterm birth,[25,26] although the cumulative evidence is currently weaker than it is for maternal health.

3.1. Maternal health effects

Walking during pregnancy appears to have a prominent effect on preventing GDM; multiple investigations have shown walking to be associated with reduced risk of GDM.[20] Recently, Aune et al.[20] conducted a meta-analysis and found a cumulative 20% decreased risk of GDM among women who engaged in walking during early- to mid-pregnancy. Walking has an acute effect on maternal glucose levels during and after walking, as suggested by Ruchat et al.,[22] who found that blood glucose concentrations were 4%−21% lower after a 25- to 40-min low-intensity walking bout compared to before walking. Similarly, Aune et al.[21] found that walking during pregnancy was associated with a 33% decreased risk of preeclampsia. The risk of unhealthy gestational weight gain also appears to be decreased as a result of walking. Interventions beginning in early- to mid-pregnancy have found associations between walking and a 29%−44% decreased risk for weight gain outside of the amount recommended by the Institute of Medicine and National Research Council,[23,27] with both walking time and distance appearing to have effects. Stuebe et al.[28] found that each additional half-hour per day of walking in mid-pregnancy was associated with 0.25 kg lower gestational weight gain. Additionally, walking 10,000 steps per day in mid- to late-pregnancy has been found to be associated with a decreased risk of excessive weight gain.[29] Furthermore, there is evidence to suggest a dose−response relationship between steps walked during pregnancy and reduced risk of unhealthy gestational weight gain.[29] Walking during pregnancy is also associated with a lower risk of postpartum weight retention;[27] however, associations may differ for overweight and obese women.[30]

3.2. Fetal health effects

The evidence for beneficial effects of walking during pregnancy on fetal health, as with maternal health, is promising. An association between walking during pregnancy and decreased risk of birthweight outside the recommended range has been previously found. Specifically, walking in early to late pregnancy is associated with a 14%−39% decreased risk of macrosomia[23,24] and potentially with a decreased risk of low birthweight.[25] In contrast, randomized trials have shown no association between walking during pregnancy and birthweight.[27,31] Thus, the scientific evidence that walking reduces birthweight within a healthy range is mixed, much like effects of pregnancy PA in general.[19] Recent intervention findings by Kong et al.[30] suggest that walking during pregnancy may affect postnatal growth. Furthermore, walking during late in pregnancy is associated with a decreased risk of several adverse birthweight-related neonatal outcomes (including macrosomia, shoulder dystocia, hypoglycemia, and congenital anomalies).[32] In contrast, a recent study of walking and cesarean delivery risk did not find any association.[31] The relationship between walking during pregnancy and preterm birth is also unclear. Some previous investigations have indicated that leisure-time walking in early- to mid-pregnancy is associated with a 36%−64% decreased risk of preterm delivery.[25,26] In contrast, recent meta-analytic findings from Aune et al.[33] reveal that walking during pregnancy is not significantly associated with a reduced risk for preterm birth, although general leisure-time PA was found to be. Thus, there is evidence for fetal health effects from walking during pregnancy, but these have not been demonstrated as strongly in the scientific literature as have maternal health effects.

4. Barriers to walking during pregnancy

For the past decade, investigators have attempted to obtain a comprehensive understanding of the PA barriers perceived by pregnant women.[34] Quantitative and qualitative studies have revealed a number of specific perceived factors that impede PA during pregnancy, which can be generally categorized as physical, environmental or lifestyle, or psychosocial (Table 1). Findings from initial examinations of these barriers have been limited by mostly homogeneous samples (i.e. white, affluent) but have provided some evidence to suggest that a lack of time, fatigue or lack of energy, and physical discomforts were the 3 most common reasons why pregnant women are not physically active.[35−37] More recent investigations have used more ethnically and culturally diverse samples or focused on a specific underrepresented subgroup of pregnant women.[38−42] Findings from these investigations have provided confirmation of some prominent physical and environmental or lifestyle barriers and also have illuminated a myriad of perceived psychosocial barriers that pregnant women routinely experience (Table 1). Qualitative methodology, particularly, has allowed for a deeper examination of these complex factors as they pertain to specific subgroups and cultural predispositions.

Perceived barriers to walking-specific behavior have been investigated previously among various nonpregnant

Table 1
Perceived barriers to physical activity during pregnancy.

Physical	Environmental or lifestyle	Psychosocial
Back/leg pain[35,36,38−41,47−50]	Lack of time[35,36,39,41,49,50,53,54]	Lack of support[35,38,39,42,50,53,54]
Nausea[38,40,48,49,53]	Childcare responsibilities[35,39,41,49,50]	Conflicting advice[35,39,47]
Fatigue[35,36,38−42,48,49,53,54]	Work responsibilities[36,38,41,48,50,53]	Concern for baby[35,38,40,47,49,50]
Body size[38−40,51,52]	Lack of activity resources[38,39,54]	Lack of motivation[35,36,38,40−42,49,50]
	Weather restrictions[35,36,38−40,42,49,50]	Body image[38,42,49]
		Lack of confidence[38,41,47,54]

populations.[43–45] However, the barriers to walking among pregnant women have rarely been explored, and only through qualitative investigations in which perceived factors, be they facilitating or impeding, may influence general PA behavior during pregnancy and postpartum. To an extent, this limits our understanding of what influences walking behavior during pregnancy. However, recent investigations focusing on individual barriers to pregnancy PA during leisure time specifically discuss pregnant women's perceptions toward walking, or behaviors undertaken during a typical day that involve walking. These allow for a clearer understanding of how walking participation may be less affected by some factors that commonly impede other modalities of activity among pregnant women.

Walking is by far the most common form of PA during pregnancy[8,10] and is frequently chosen instead of other modalities at various times during pregnancy. Findings from a recent qualitative investigation[46] examining barriers experienced by prenatal walking groups suggest that walking is an integral part of many women's daily activities, such as for transportation or with childcare responsibilities. Furthermore, some women from this study generally disliked the idea of walking purposely for exercise, citing feelings of boredom and monotony. Despite intentions to exercise via other modalities, most women did not engage in non-walking exercises during pregnancy because of the barriers previously cited.

Lack of time has often been cited as the most formidable barrier to pregnancy PA.[35,36,47–50] Walking is unique compared to other modalities (e.g., running, swimming, and strength training) in that it may be more purposefully integrated into transportation or occupational time.[5] Walking, even at a brisk pace, can be performed while running errands, going to or from work, socializing with friends, or even talking on the phone. Within this "lack of time" context, pregnant women have cited childcare responsibilities as a reason for an inactive lifestyle.[35,39,41,49,50] With the assistance of a stroller or child carrier, pregnant women can perform walking as a part of leisure-time PA or for transportation without requiring childcare. Moreover, walking is an activity in which all family members, including older children, can participate. Thus, less support is required for walking, particularly given that it can be meaningfully performed as a part of various daily tasks or errands.

Participation in some PA modalities is limited for those without access to requisite equipment, facilities, or instructor guidance. In contrast, walking is one of the few PA options that can be performed independent of these, and indeed, can take place in appropriate outdoor settings. However, inclement or hot and humid weather are formidable objective barriers to various outdoor activities,[51,52] and thus, have been perceived by pregnant women to limit PA participation.[36,38–40,42] Yet, a variety of public indoor locations (e.g., shopping malls, large stores) may serve as satisfactory venues for walking during pregnancy in the event of suboptimal weather conditions or less pedestrian-friendly outdoor routes.

Discouragement of PA during pregnancy from family and friends or even from healthcare providers has been well documented and reflects a lack of crucial social support of PA during pregnancy.[34,39,53,54] As a commonly performed activity within many daily tasks and errands, walking may be perceived by social support sources as being "safer" for both mother and child and thus not discouraged by others to the same extent as other modalities of PA (e.g., jogging, strength training). Likewise, recent findings have shown that pregnant women perceive walking to be more beneficial to both maternal and fetal health than any other exercise modality, suggesting less concern for the common stigma that exercise during pregnancy may harm the child. Some prominent physical discomforts during pregnancy may certainly impede walking participation (e.g., severe fatigue, back pain, and feelings of nausea). However, limited qualitative findings suggest that walking may alleviate some of these commonly reported pregnancy discomforts.[40]

5. Interventions to increase walking behavior during pregnancy

To overcome barriers and increase PA levels, behavior-change interventions specifically for pregnant women have been developed and evaluated. To date, most pregnancy-specific interventions have focused on improving PA behaviors in general rather than focusing on walking as the recommended form of PA and evaluating walking behavior, specifically, as an outcome measure. Walking-based interventions have been found to be successful in increasing PA within nonpregnant populations,[55,56] yet PA promotion via walking remains an underused method.

Results supporting the impact of pregnancy PA interventions are equivocal. Some have achieved success in maintaining or increasing PA over the course of pregnancy,[57,58] whereas others have resulted in no impact.[59,60] Although published findings from walking-based interventions during pregnancy (in contrast to general PA promotion) are few, some have been found to be effective in increasing PA or walking behavior (increase of approximately 30 min of moderate-intensity walking or approximately 4000 steps).[24,61] Unfortunately, comparison of outcomes among studies is difficult because methods of assessment (self-report, device-based, such as pedometer or accelerometer), PA types and domains (e.g., walking, group exercise, leisure-time PA, occupational PA, *etc.*), and PA outcome measures (e.g., steps per day, minutes of PA, minutes of moderate- or vigorous-intensity PA, walking intensity, or cadence) all vary greatly. Some successful interventions have also varied with regard to the specific details of intervention delivery and design, with many having used unsupervised, home-based walking program and recommendations[24,30] in contrast to supervised, group-walking sessions.[61–63] Overall, the intervention delivery method does not seem to impact walking behavior significantly, as findings vary across intervention designs. Although home-based walking programs appear advantageous for multiple reasons (e.g., cost, study staff time, participant burden, *etc.*), lack of supervision may have also contributed, in part, to participant attrition in many studies.[64] Many previous PA interventions among pregnant women have targeted overweight and obese women,

given that a primary intervention outcome has been the prevention of gestational diabetes and other pregnancy-related maladies for which women in these weight categories are at higher risk.[65] Recently, Kong et al.[23] noted that a walking-based intervention resulted in maintenance of moderate-intensity PA among overweight, but not obese, women over the course of their pregnancies. Pregnant women within normal-weight ranges also experience difficulty in achieving adequate levels of PA[10] and could likewise benefit from walking programs. Therefore, future studies should evaluate the feasibility and efficacy of walking-based interventions in pregnant women within these normal-weight ranges and in pregnant women in overweight and obese weight categories. The greatest strength of many walking-based interventions (in comparison to general PA interventions) may be the inherent inclusion of self-monitoring (via a pedometer, logging of PA, *etc*.) because this strategy has been shown to be highly effective in eliciting behavior change[66] and is not regularly included in most pregnancy-specific PA interventions.

When evaluating walking-based interventions implemented among samples of pregnant women, multiple variations become apparent with regard to the behavioral strategies and health behavior theories used to increase or maintain PA. Outside of walking-specific interventions in pregnancy, it appears that many pregnancy-specific behavioral PA interventions have not resulted in a significant impact on PA behavior or intention, and methodological weaknesses across studies have decreased their validity.[66,67] Specifically, conclusions from 1 analytic review indicated that among behavioral randomized controlled trials aimed at increasing PA during pregnancy, many effective behavior change intervention techniques (e.g., modeling, self-monitoring, goal setting, and problem solving) were underused.[67] In contrast, less-effective techniques (e.g., feedback and information or education) were most prevalent among the evaluated behavioral interventions.[67] Furthermore, a great deal of work remains in incorporating behavioral strategies within walking-based interventions in pregnancy because few available studies focused on intervention design for walking during pregnancy are grounded within any behavior-change theory. Incorporation of these elements is critical if interventions are to be successful in helping women overcome the multitude of perceived barriers to PA encountered during pregnancy.

Researchers should 1st aim to build interventions based on health-behavior theories deemed effective in pregnant populations, such as the social ecological model, transtheoretical model, social cognitive theory, theory of planned behavior, and the health belief model, and incorporate proven behavior-change therapies. Second, given the attrition rates observed in many studies using an unsupervised, home-based program, researchers might consider developing a fully or partially supervised intervention program to improve compliance. Among the studies reviewed for this article,[24,30,57–63] supervised walking programs appear to demonstrate the lowest attrition rate (13%).[61] However, this approach requires significantly more administrative resources (e.g., time, labor, and money) and may not be an ideal option for many pregnant women, especially those reporting environmental or lifestyle barriers, such as lack of time or childcare responsibilities.[46] As a part of Kong et al.'s[23] walking-based intervention design, participants were provided with a treadmill for home use. However, results indicated that only one-third (33.8%) of the sample reported actually using the treadmill, citing that it helped to alleviate some barriers (e.g., childcare, weather). Future research should consider other novel, yet cost-effective, ways to help women build PA self-efficacy and overcome barriers, ultimately improving program adherence.

A recent qualitative investigation by Currie et al.[46] highlighted the importance of involving the target population for the intervention throughout all stages of study development. Though walking groups have been effective at increasing PA among nonpregnant populations,[56] Currie et al.'s qualitative analysis of pregnant women's experiences suggests unique challenges within the pregnant population. Specifically, pregnant women reported walking as a mode of transportation rather than "fun",[46] and multiple barriers were apparent to limit women's participation, including time, weather, and childcare. Though this sample may not be generalizable to all pregnant women, it highlights the importance of obtaining perceptions, thoughts, and views of the target population within varying geographic and socioeconomic conditions to guide the development of efficacious PA interventions.

6. Measurement considerations for future interventions

Methods previously used to measure walking during pregnancy include various questionnaires and PA monitors. As will be discussed, some questionnaires provide limited information on walking behavior through a limited number of questions, but these items have not been assessed for validity. PA monitors provide the opportunity to capture walking behavior in terms of volume and intensity, but only a few specific devices have been assessed for validity or reliability and only in a handful of investigations. Although walking at a brisk intensity is likely to reach the moderate-intensity level recommended within the current PA guidelines for pregnant women, walking at lower intensities is meaningful and is certainly preferred to pregnant women being sedentary. However, walking at slower speeds appears to result in diminished PA monitor accuracy, which is a notable concern particularly during late pregnancy.

6.1. Questionnaires

Questionnaires are often used to determine current or past PA behaviors for an individual. Although questionnaires are prone to inaccurate or biased recall, they are simple, inexpensive, and quickly capture PA behavior; therefore, they have utility in certain contexts.[68] In general, purposeful or higher-intensity PA can be recalled with higher accuracy than incidental or lower-intensity PA.[69] Because walking is used for many different purposes (e.g., exercise, transportation, household activities, *etc*.), it is likely that some walking activities will be easily recalled, whereas others will be more difficult to assess accurately.

When using questionnaires to assess PA, it is important to choose one that will capture the activities being completed by the user. Although PA participation is low in both pregnant and nonpregnant women, PA patterns during pregnancy are often different from non-pregnancy, with walking representing the primary mode of pregnancy PA.[70] Theoretically, using PA questionnaires for pregnant women that were developed for use in nonpregnant populations may result in less accurate PA estimates by failing to capture activities in which pregnant women participate. However, studies comparing questionnaires to PA monitors generally show moderate agreement at best. The Pregnancy Physical Activity Questionnaire (PPAQ) is among the oldest and most commonly used pregnancy-specific PA questionnaires and includes 32 activities classified into 5 different categories: household/caregiving, occupational, sports/exercise, transportation, and inactivity (e.g., sedentary behaviors).[71] The PPAQ has been compared to waist-worn accelerometers or pedometers in several studies, with poor or moderate correlations between PPAQ and accelerometer or pedometer ($r = 0.021-0.565$).[71–75]

A questionnaire developed for the 3rd Pregnancy Infection and Nutrition (PIN3) study attempted to improve accuracy over the PPAQ by adding questions about different perceived intensities that occur as pregnancy progresses, but agreement with a waist-worn accelerometer was also poor to fair ($r = 0.20-0.31$).[76] Given similar correlations of the PPAQ and PIN3 with accelerometer and findings by Shephard,[68] who described the difficulty with individuals self-reporting PA intensity, it does not seem that assessing PA intensity as a construct independent from activity type results in improved PA assessment. Other questionnaires developed for pregnant and nonpregnant individuals have shown similar agreement with device-based measures.[14,77–82] Collectively, these findings indicate the agreement between questionnaires and activity monitors in pregnant women is modest at best.

Questionnaires for pregnancy PA assessment have several strengths and weaknesses. They are often used in large-scale epidemiological studies because they are inexpensive, easily administered to many participants, and require little effort from the participants. However, these methods are limited in that they require the participants to accurately recall their PA, which appears prone to poor memory or bias, perhaps even more so during pregnancy.[83] Additionally, although most questionnaires assess walking behaviors, none have been validated solely for assessment of walking behaviors, rendering their use for the independent assessment of walking unknown. Additional details of the strengths and weaknesses of questionnaires provided in Table 2 indicate they are not optimal tools for use among pregnant women. However, it should be noted that poor to moderate correlations between various self-report

Table 2
Methods used to assess physical activity and walking during pregnancy.

Method	Questionnaires	Pedometers	Accelerometers
Specific tools	Pregnancy Physical Activity Questionnaire (PPAQ);[71–75,77] Recent Physical Activity Questionnaire (RPAQ);[80] Australian Women's Activity Survey (AWAS);[80] PIN3 Physical Activity Questionnaire;[76] Leisure-Time Exercise Questionnaire (LTEQ);[14] Leisure-time Physical Activity questions (from IPAQ);[78,79] Activity Questionnaire for Adults and Adolescents (AQuAA)[81]	New Lifestyles (NL1000, NL2000);[85,88] Digiwalker (SW-200, SW-701);[14,77,85,87,88] Omron (HJ-720);[88] Accusplit;[82] Modus StepWatch[27]	Actigraph (7164, GT1M, GT3X);[79,85,87,88] SenseWear Armband;[91–93] Wrist-worn GENEA[94]
General results	Correlations range from very low to moderate with activity monitor or step data; moderate correlation with physical activity diary data; good reproducibility	Step-count accuracy tends to decrease with increase in weeks of gestation; some monitors (e.g. Omron, New Lifestyles) seem to be better than others at estimating steps across range of speeds	Energy-expenditure estimates are significantly different for most activities; waist-worn monitors tend to underestimate steps
Strengths	Easy and inexpensive to administer; low participant burden	Not subject to recall bias; objective measure of activity; works well for counting steps when walking at speeds ≥2.0 mph	Allow for estimates of energy expenditure; intensity of activity is accessed; can be worn on body locations other than hip for comfort or accuracy
Weaknesses	Limited efficacy for use in pregnant women; unknown comparability of data when collected by different questionnaires	Tilt angle and slower movement speeds could cause decreased accuracy throughout pregnancy; some monitors are more accurate than others	Algorithms are not specific to pregnancy; tilt angle and slower movement speeds could cause decreased accuracy throughout pregnancy
Future directions	Studies determining comparability of data collected from different questionnaires are needed; comparability of questionnaire and device-based (e.g., pedometer and accelerometer) measures are needed	Alternate monitor placement locations (e.g., wrist, ankle) should be assessed to avoid issues with tilt angle and improve accuracy for slow walking and nonrhythmic movements; more free-living validity and reliability studies needed	Pregnancy-specific energy-expenditure or activity-intensity algorithms are needed; alternate or multiple monitor placement locations should be assessed to improve accuracy and avoid tilt angle issues; between-brand comparisons are needed; more free-living validity and reliability studies are needed

Abbreviations: IPAQ = International Physical Activity Questionnaire; mph = miles per hour; PIN3 = the 3rd Pregnancy Infection and Nutrition.

methods and PA monitors may partly be a result of limitations in the monitors, including data-processing methods and placement of activity monitors on the waist. A vital question remains: are PA monitors valid tools for assessing PA and walking in pregnant women?

6.2. PA monitors

More than 20 years before the validity of using pedometers was established in pregnant women, PA monitors were being used in pregnant women to monitor changes in PA over the course of pregnancy.[84] Despite the potential validity considerations discussed next, Downs et al.[14] found that women were 100% agreeable to using waist-worn pedometers for assessment over multiple days during pregnancy. Therefore, waist-worn activity monitors appear to be a feasible option for assessment of PA and walking in pregnant women.

Traditionally, most activity monitors (e.g., pedometers and accelerometers) are worn at the waist. This location could potentially be problematic during the 2nd and 3rd trimesters of pregnancy because of the increase in waist circumference, which can change the orientation of the activity monitor and potentially affect its accuracy. DiNallo et al.[85] investigated the validity of 3 different waist-worn activity monitors during treadmill walking at 20- and 32-weeks' gestation. As expected, waist circumference was significantly larger at 32 weeks, as were the activity monitor tilt angles on the belt.[85] Although criterion-measured energy expenditure was not different across 4 walking speeds assessed between trimesters, predicted PA measures were significantly lower from each activity monitor at 32 weeks compared to 20 weeks.[85] Another laboratory-based study by Crouter et al.[86] found that waist circumference of nonpregnant individuals influenced the tilt angle of pedometers and influenced accuracy for some brands but not others. These studies provide mixed evidence regarding the influence of a changing waist circumference during pregnancy on activity monitor accuracy.

In free-living settings, several pedometers have been tested in pregnant women and showed moderate or high agreement for step counting compared to the ActiGraph accelerometer.[79,87] However, it is worth noting that similar models of both monitors used in these 2 studies were found to underestimate steps in pregnant women in laboratory settings.[88] Therefore, the use of the ActiGraph as the gold standard for the assessment of steps in pregnant women is questionable. Walking speed is also known to influence monitor accuracy in both pregnant and nonpregnant populations, with speeds below 2.0 mph generally having lower accuracy for some, but not all, hip-worn devices.[89] Given that gait parameters change and preferred walking speeds decrease during pregnancy,[90] there is reason for concern that hip-worn activity monitors will have questionable accuracy for the assessment of walking during pregnancy, especially in the 3rd trimester. Therefore, alternative activity monitor placement locations may be desirable to increase validity for the measurement of walking activities.

The validity of monitors worn on alternative locations in pregnant women is sparse. Several studies using the now-discontinued, upper-arm-worn SenseWear Armband found mixed results regarding accuracy for energy-expenditure prediction, overestimating some activities and underestimating others compared to criterion (i.e. metabolic analyzer measured energy expenditure) and questionnaire methods.[91–93] Using a wrist-worn accelerometer (GENEA) and measured energy expenditure using doubly labeled water, van Hees et al.[94] found that wrist acceleration data were modestly correlated ($r = 0.33$) with PA energy expenditure in pregnant women, indicating potentially poor tracking of energy expenditure using a wrist-worn device. Yet, as with questionnaires, walking-related activities were not investigated independently in any of these studies, so the accuracy of activity monitors worn on the upper arm and wrist for assessing walking in free-living pregnant women is unknown. Other activity monitor locations, including the thigh and ankle, have shown promise for assessment of PA and walking in nonpregnant populations and at slow speeds, but have not yet been tested in pregnant women.[95,96] For example, although the ankle-worn StepWatch pedometer has not been validated in pregnant women, it has been used by Kong et al.[23] to track walking during pregnancy and has also shown high accuracy for assessing free-living steps in nonpregnant populations,[97,98] making it a potentially attractive option for assessing pregnancy PA. Additionally, activity monitors placed on the wrist show moderate or high validity for tracking steps taken in nonpregnant populations, but accuracy appears lower for tracking energy expenditure.[99] Because of a lack of testing of these locations in pregnant women, their accuracy and potential for use remains unknown. Additional details on PA monitors used within investigations among pregnant women are provided in Table 2.

6.3. Measurement-related conclusions

In reviewing studies on the assessment of walking-related behaviors in pregnant women, it is evident that there is substantial work needed in this area. PA questionnaires have been used frequently to assess pregnant women, but their accuracy has not been determined for assessing walking behaviors, and their agreement with device measures is, at best, modest. Additionally, a gold-standard assessment method during free-living PA has yet to be established. Although some PA monitors (NL 2000; New-Lifestyles, Inc., Lee's Summit, MO, USA) and Omron HJ-720ITC (Omron Healthcare, Inc., Bannockburn, IL, USA) have been found to be valid for laboratory-based walking in pregnant populations,[88] much of the validity literature continues to use monitors that appear to be poor in their assessment of walking in pregnant populations. Future research is needed to establish valid methods for assessing PA and walking throughout pregnancy using both self-reported and device-based methods. With improved technology available for both self-reported and device-based measurement methods, it may be that tactics such as momentary sampling sent to a smartphone (i.e. self-reported assessment) or small, noninvasive activity monitors worn on one or more body locations (i.e., device-based assessment) may result in improved PA and walking measurement throughout pregnancy.

7. Community pregnancy walking initiatives

Despite considerable evidence that walking during pregnancy provides an array of maternal-fetal health benefits and that walking may be purposefully integrated into activities of daily living, there is little indication that public health initiatives are being developed to increase walking in this population. There are, however, initiatives ongoing to promote walking in the general population; for example, the Centers for Disease Control and Prevention (CDC) and the U.S. Surgeon General have released a call to action called *Step It Up! The Surgeon General's Call to Action to Promote Walking and Walkable Communities*.[1] This document specifically calls for many sectors of public life, including community design and land use, schools, colleges and universities, parks and recreational facilities, and worksites to contribute to developing and sustaining walkable communities. The emphasis is directed toward infrastructure and administrative changes that might make walking more feasible for all.

The Partnership for Prevention in conjunction with the CDC has also published an action guide titled *Social Support for Physical Activity: Establishing a Community-based Walking Group Program to Increase Physical Activity Among Youth and Adults*[100] to provide clear instructions to the layperson regarding how to develop a group-walking program from the beginnin, and how to maintain it following a successful start. The American College of Sports Medicine (ACSM) and Kaiser Permanente together have introduced the *Every Body Walk* initiative[101] to promote walking as a tool to decrease chronic disease risk among Americans. Prescription pads for health and fitness professionals to dispense to clients and patients can be requested from ACSM.

Despite the increase in both government-funded and privately sponsored walking initiatives for the general population, there is, to our knowledge, no formal published assessment of the success of these initiatives. This makes the development of evidence-based community programs challenging, if not impossible. This may be because of the newness of the programs or because these initiatives are designed to encourage development and implementation of walking programs in smaller communities and organizations rather than throughout a state or the nation. Still, it is unclear whether these initiatives are having the desired effect. In 2017, the CDC released a status update to the *Step It Up Call to Action*, in which they reported data such as page views for the *Call to Action* website, the number of chief executive officers (CEOs) who had signed pledges as part of the *CEO Pledge for Physical Activity Initiative* (National Coalition for Promoting Physical Activity) by month, the number of chapters of *Walk with a Doc* (a program for physicians to promote walking with their patients) formed by month, and the number of monthly requests from ACSM for exercise prescription pads. These data suggest that there is an increasing interest in promotion of PA in general and walking, in particular, but more rigorous and controlled assessments of specific initiatives are needed to better understand which programs are successfully promoting healthy behaviors and the specific population subgroups that are being impacted.

As reported by Currie et al.,[46] a barrier that can affect the success of walking programs in pregnant women is lack of childcare. For women who are already caring for at least 1 child, stroller-walking programs may be a way to combat this particular barrier.[55] Though not specifically targeted toward pregnant women, the *Strollers Pramwalking Program* in Australia was a community-based initiative to increase PA (particularly walking) in women with young children.[102] Similar programs in the United States are few, but some have been initiated. These include the Colorado-based *Aurora Ambles*, with specific routes designed for mothers pushing strollers,[103] a program called *Stroller Warriors*, a running club with multiple chapters designed for group runs for mothers pushing strollers,[104] and Kaiser Permanente's *Walk to Thrive* program in the Sacramento, California area, which provides reoccurring walks.[105] To date, no data have been published regarding the success of these initiatives.

There are, to our knowledge, no public health initiatives in the United States specifically designed to increase walking in pregnant women. *Mass in Motion*, a program of the Massachusetts Department of Public Health, is designed to "promote wellness and reduce obesity in Massachusetts with a focus on healthy eating and PA at home, at work, and in the community".[106] This is pertinent to the current review because there is a pregnancy-specific webpage linked from the *Mass in Motion* website that details the 2008 DHHS Guidelines specific to pregnant women,[16] but no other information specific to pregnancy is provided. The California Department of Health has similar information on its website that provides information about PA during pregnancy, but it is not specific to walking.[107] It is certainly possible that local organizations, groups, or church organizations design and initiate PA programs for local pregnant women within the community, but it is challenging if not impossible for researchers to identify and locate all of these. Because walking during pregnancy provides exceptional health benefits and is particularly resistant to common PA barriers, there is a critical need to develop local initiatives and a dedicated national movement to promote walking among pregnant women specifically. Concomitantly, there is a need for researchers to formally evaluate these efforts, as suggested by Baker et al.[108] and Hoffman et al.,[109] so that successful evidence-based programs can be implemented within other communities. This would effectively allow local organizations to administer community-focused pregnancy-walking programs and initiatives under the umbrella of a larger program, perhaps eventually at the state or province level.

8. Conclusion

Walking during pregnancy has multiple benefits, particularly when compared with other PA modalities. In addition to being the preferred PA modality among pregnant women, walking provides an array of maternal-fetal health benefits and may be minimally affected by commonly experienced barriers. Consequently, walking appears to be the ideal modality of PA to target within well-designed interventions focusing on this population, particularly among pregnant women who are

sedentary or who are minimally physically active. However, to this point, walking-based interventions during pregnancy are few and limited by lack of valid assessment methods within this population. Previous investigations have used questionnaires and PA monitors to assess walking behaviors during pregnancy, assuming that demonstrated validity of such instruments in nonpregnant populations will translate to the pregnant population. This assumption appears erroneous with respect to activity monitors, given the anatomic and physiologic changes that occur and manifest in altered-gait parameters in mid to late stages of pregnancy. Investigators should consider pursuing validation work of both consumer- and research-grade devices for walking behaviors undertaken during leisure time and as a part of occupational activities. Walking-specific questionnaires for this population may also be developed and validated, particularly if they are to be used for assessment of large sample sizes or baseline and follow-up assessments of walking behavior within community-based activity programs. Future research on walking interventions during pregnancy should integrate health behavior-based theories in the study design and use contemporary methods to reduce study attrition rates and improve quality of data collected. Furthermore, investigators may consider pairing walking and other activities during pregnancy with regular social interaction, such as pram (stroller) walking and prenatal activity classes, within such interventions. Previous investigations have found that social interaction is critical for many women to increase and maintain their PA levels during pregnancy, likely because it may decreases feeling of social isolation and loneliness. The findings from such future investigations will be crucial to designing and promoting successful community-based walking initiatives. Although some of these initiatives have recently begun to emerge, few are focused on pregnant women or family health specifically, and their efficacy has not yet been established. More work is needed to promote the promising utility of walking for PA during pregnancy, both in the forms of scientific intervention work and community-based initiatives.

Authors' contributions

CPC, SAC, AHKM, MRM, RAS, and SEB reviewed the literature and drafted this review manuscript; JMP provided meaningful edits and comments to this review. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interests

The authors declare that they have no competing interests.

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