THEMED REVIEW

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Monitoring Physical Activity Intensity During Pregnancy

Abstract: *For apparently healthy pregnant women, regular physical activity is recommended. The American College of Obstetricians and Gynecologists (ACOG) created recommendations for physical activity and exercise during pregnancy in 1985. At that time, pregnant women were advised to not exceed a heart rate of 140 beats per minute with physical activity. The heart rate recommendation was subsequently removed with the recommendations published in 1994, 2002, and 2015. In 2020, the ACOG updated its recommendations on physical activity for pregnant and postpartum women. The recommendation included exercising at a "fairly light to somewhat hard" perceived intensity and at less than 60–80% of age-predicted maximum heart rate, usually not exceeding a heart rate of 140 beats per minute. Women often seek advice from healthcare providers on physical activity during pregnancy, yet providers report concern about giving appropriate physical activity guidance. This paper summarizes the key scientific literature on monitoring absolute and relative exercise intensity in relation to the current ACOG recommendations, providing background on intensity-related concepts used in the recommendation. This paper also provides practical guidance to assist healthcare providers in relaying this information to pregnant women.*

Keywords: exercise prescription; heart rate; intensity; perceived exertion; pregnancy; postpartum

During pregnancy, women who are physically active can derive numerous benefits, such as prevention of excessive gestational weight gain and gestational diabetes mellitus; decreased risk of preeclampsia; and reduced length of labor and incidence of lower back pain.[1,2] Uncommon acute risks of physical activity during pregnancy include hyperthermia, musculoskeletal injury, and reduced uteroplacental blood flow that could injure the fetus or cause fetal growth restriction.[2,3] Yet, despite the supportive evidence for physical activity, pregnant women from the United States are insufficiently physically active during pregnancy.[4,5]

Women often seek guidance about physical activity during pregnancy from their healthcare providers[6,7,8]; those who seek advice are more likely to report exercising during pregnancy, particularly in the later stages.[9,10] However, some pregnant women characterize provider advice about physical activity as overly conservative, vague, and confusing.[6,7,11,12,13,14,15,16,17,18] This is not surprising, given that providers report concern about giving appropriate physical activity guidance.[19,20]

Physical activity recommendations, therefore, provide important information to both women and healthcare providers. The recommendations should consider

> "...monitoring intensity during regular exercise consistently can help pregnant women identify when a change happens..."

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frequency, duration, type, and intensity of physical activity. In particular, intensity of physical activity has been a source of confusion to both pregnant women and their providers. Restriction of maternal heart rate during physical activity in pregnancy was first introduced with the inaugural American College of Obstetricians and Gynecologists (ACOG) guidance issued in 1985.[21] The guidance indicated that exercise target heart rate for pregnant women should be set 25–30% lower than at other times and should not exceed 140 bpm (Table 1). It is unclear how the 140 bpm value was originally derived.

The heart rate recommendation was removed in the next update from ACOG in 1994[22] and in 2002.[23] Despite the removal of heart rate recommendations, healthcare providers continued giving advice from the 1985 ACOG guidelines using the heart rate restriction of 140 bpm.[7,8,11,19,24,25,26] For example, in a small study, 67% of physicians self-reported that heart rate should stay below 140 bpm several years after the restriction was removed.[25] In the 2015 updated guidance, the use of perceived exertion was supported with moderate intensity physical activity allowed.[27]

In the 2020 ACOG recommendation,[28] 3 changes were made regarding exercise intensity during pregnancy (with quotations for the first 2 changes extracted from Table 2 for exercise in the first trimester with more than 12 weeks gestation). First, heart rate should stay "less than 60–80% of age-predicted maximum." Based on the American College of Sports Medicine (ACSM) recommendations, the flagship organization providing scientifically based exercise prescription guidance through their "Guidelines for Exercise Testing and Prescription" since 1975,[29,30] this range extends from the upper end of light intensity to the lower end of vigorous intensity (Table 3). Second, women should "usually not exceed (a heart rate of) 140 bpm." Third, the perceived exertion recommendation for moderate intensity was expanded from "somewhat hard" to include a wider range, from "fairly light to somewhat hard." The guidance indicates perceived exertion may be more effective than heart rate to monitor intensity.

Differences between guidelines can cause confusion for both healthcare providers and pregnant women. For example, the 2018 Physical Activity Guidelines for Americans[31] and the 2020 World Health Organization Guidelines on Physical Activity and Sedentary Behavior[32] do not include target heart rates for pregnant women. Moreover, the 2019 Canadian guidelines for pregnancy provide heart rate recommendations during physical activity, but they differ from those of ACOG by taking account of age and intensity.[33] This paper addresses the 2020 ACOG intensity recommendation[28] by summarizing the key scientific literature on the use of heart rate and perceived exertion to monitor exercise intensity during pregnancy. The overarching goal is to try to assist healthcare providers as they counsel women on their physical activity and exercise intensity during pregnancy.

Physical Activity Intensity

Physical activity is any bodily movement produced by skeletal muscles that results in energy expenditure.[30,31] Exercise is not synonymous with physical activity, but rather is a component of physical activity that is planned, repetitive, and structured. As stated, key components of physical activity include frequency, duration, time, type, and intensity. This paper focuses on intensity or the magnitude of effort required to perform a given physical activity, which can be expressed in either absolute or relative terms.[31] Absolute intensity is based on the work that is being performed, expressed as a metabolic equivalent (MET). It does not consider an individual's cardiorespiratory fitness, which may be higher or lower than the assigned MET value of an activity. In contrast, relative intensity, expressed as a percent of maximum aerobic capacity, accounts for cardiorespiratory fitness and is assessed based on measured oxygen uptake, heart rate, or perceived exertion. The ACSM recommends that exercise intensity is prescribed using either absolute (MET values) or relative (oxygen uptake, heart rate, and perceived exertion) values.[30] Absolute intensity can be imprecise and oxygen uptake is often not available or unfeasible to measure, which is likely why the ACOG suggests monitoring intensity based on heart rate and perceived exertion,[28] which we review here.

Relative Intensity Estimation Using Heart Rate

As background, heart rate increases linearly with oxygen uptake until near maximal effort, making it a reasonable indicator of exercise intensity.[34] In the absence of a recent maximal exercise test to provide maximal heart rate, a number of formulas can be used to estimate maximal heart rate. Several formulas are predicated on maximal heart rate declining with age in a linear fashion.[35,36] Derived in 1971, the first equation is the widely used Fox formula based on (220-age).[37] In 2001, Tanaka et al.[38] performed a meta-analysis of 351 studies and derived an alternative predictive formula for maximal heart rate: (208 – [.7 * age]). When the Fox and Tanaka formulas were rigorously evaluated among 762 sedentary adults with maximal bicycle exercise tests, maximal predicted heart rate

Table 1.

Exercise Intensity Recommendations from ACOG, 1985 to 2020.

Year, reference	Background text from ACOG guideline	ACOG recommendation
1985[21]	"During normal pregnancy, maternal blood volume increases by about 30% and sometimes more, and heart rate and cardiac output are significantly elevated at rest." (page 2)	"In general, target heart rates for pregnant and postpartum women should be set approximately 25-30% lower than would be appropriate at other times." (page 2) "Pregnant and postpartum women who exercise should be advised to measure heart rates during activity and given limits to follow." (page 2) "Pregnancy only: Maternal heart rate should not exceed 140 beats per minute." (page 4) "Heart rate should be measured at times of peak activity. Target heart rates and limits established in consultation with the physician should not be exceeded." (page 4)
1994, Technical Bulliten #189[22]	"Conflicting evidence exists concerning maternal heart rate response to steady-state aerobic exercise during pregnancy; both blunted and normal responses to weight-bearing and nonweight-bearing exercise have been reported.[68,82]" (page 65) "There are no data in humans to indicate that pregnant women should limit exercise intensity and lower target heart rates because of potential adverse effects." (page 68)	Not mentioned
2002 Committee Opinion #267[23]	Not mentioned	Not mentioned
2015 Committee Opinion #650[27]	"Blood volume, heart rate, stroke volume, and cardiac output normally increase during pregnancy, while systemic vascular resistance decreases." (page 3)	"Because blunted and normal heart-rate responses to exercise have been reported in pregnant women, the use of ratings of perceived exertion may be a more effective means to monitor exercise intensity during pregnancy than heart-rate parameters.[83] For moderate-intensity exercise, ratings of perceived exertion should be 13—14 (somewhat hard) on the 6-20 Borg scale of perceived exertion (Table 1 ACOG). Using the "talk test" is another way to measure exertion. As long as a woman can carry on a conversation while exercising, she is likely not overexerting herself.[84]" (page 4)
2020 ACOG Committee Opinion #804[28]	"Blood volume, heart rate, stroke volume, and cardiac output normally increase during pregnancy, and systemic vascular resistance decreases." (page e179) "Further research is needed on the effects of vigorous intensity exercise in the first and second trimesters and of exercise intensity exceeding 90% of maximal heart rate.[85]" (page e183)	Quote from 2015 ("because blunted….) repeated on page e182 Intensity of exercise, less than 60-80% of age predicted maximal maternal heart rate, usually not exceeding 140 beats per minute; ratings of perceived exertion 12-14 (Table 3 ACOG)

Abbreviation: ACOG, American College of Obstetricians and Gynecologists

Table 2.

Current Recommendations from ACSM[30] and ACOG.[28].

	ACOG moderate	ACSM light	ACSM moderate	ACSM vigorous
% Heart rate maximal	Less than 60-80% of age predicted maximal heart rate usually not exceeding 140 bpm	57-63%	64-76%	77-95%
% heart rate reserve	Not applicable	30-39	40-59%	60-89%
Rating of perceived exertion on the Borg scale	12-14 Fairly light to somewhat hard	9-11 Very light to fairly light	12-13 Fairly light to somewhat hard	14-17 Somewhat hard to very hard

Abbreviations: ACOG, American College of Obstetricians and Gynecologists; ACSM, American College of Sports Medicine.
Note The Borg and Linderholm perceived exertion values above correspond as follows: 9 "very light", 10, 11 "fairly light", 12, 13 "somewhat hard", 14, 15 "hard", 16, 17 "hard".[62]

from both the Fox and Tanaka formulas correlated ~.60 with measured heart rate at maximal effort.[35] There was a larger error among Blacks and those with older age, lower cardiorespiratory fitness, and higher body mass indices. The ACOG recommendations indicate the use of "age-predicted maximum maternal heart rate" which can be derived using either the Fox or Tanaka formulas.

Calculation of exercise intensity can be performed with or without accounting for resting heart rate. The estimation formula accounting for resting heart rate before the intensity values are assigned is the Karvonen formula or heart rate reserve method.[39,40] There is discrepancy in the literature as to whether accounting for resting heart rate more closely corresponds to submaximal aerobic capacity than not accounting for it. Based on a review of studies conducted from 1966 to 2010, the Karvonen formula was recommended over other alternatives.[41] In a large study of adults, exercise intensity based on estimated heart rate reserve (i.e., difference between resting and maximal values) was compared to the use of measured heart rate at maximum effort.[42] Not surprisingly, given the prior findings on the evaluation of the Fox and Tanaka formulas,[35] large inter-individual variability was found. Based on this variability, the authors indicated that "using a standard and unique formula to predict aerobic exercise intensity can yield relatively high error in a single subject… and should raise the question of whether relying on the currently recommended equivalence between heart rate reserve and percent of oxygen uptake reserve to prescribe and monitor aerobic exercise intensity is still acceptable."[42] Nevertheless, when accounting for resting heart rate (e.g., heart rate reserve) while using the Fox or Tanaka formulas for maximal heart rate, the recommended heart rate ranges should be calculated at a lower percent range (Table 2).

The ACSM defines intensity differently depending on the use of percent of maximal heart rate or heart rate reserve (e.g., Karvonen formula) (Table 2).[30] The ACSM recommends the use of heart rate reserve over percent of maximal heart rate to calculate exercise intensity,[30] assuming that maximal heart rate was obtained from a maximal exercise test. While a maximal test is the best method for assessing maximal heart rate, this is not recommended in pregnant women.[43] Using alternative regression formulas to estimate maximal heart rate (examples provided in Ref. [30]) instead of a maximal exercise test can provide greater accuracy than relying on the Fox or Tanaka formulas. Examples of the formulas applied to a theoretical woman 30 years of age are provided in Table 3. Based on our examples, target heart rates vary slightly depending on the method used with a higher range for percent of maximal heart rate (122–144 bpm) compared to percent of heart rate reserve (118–141 bpm).

In pregnancy, studies conducted as early as 1938 found resting cardiac output (stroke volume multiplied by heart rate) to be higher in pregnant women than when not pregnant.[44,45] In 1966, a prospective study reported on cardiac output and heart rate measured up to 9 times for 30 women from 8 weeks' gestation to 17 weeks' postpartum.[45] Average resting heart rate rose from early pregnancy to delivery by 10 to 20 bpm and, following delivery, dropped to a level lower than during early in pregnancy (Figure 1). In 1985, Clapp[46] documented resting heart rate upon awakening for 10

Table 3.

Four Examples Calculating Target Heart Rate for ACSM Moderate Intensity for a Theoretical 30 Year Old Woman using the Fox and Tanaka Formulas with and without Accounting for Resting Heart Rate.

	Moderate intensity ACSM Age 30 not accounting for resting heart rate	Moderate intensity ACSM Age 30 accounting for resting heart rate 70 bpm
Fox formula		
Target heart rate with potential error of 12 bpm	122 (110 to 134) to 144 (132 to 156) bpm	118 (106 to 130) to 141 (129 to 153) bpm
Calculation using % heart rate maximal	Maximal heart rate of 190 bpm using the Fox formula (220-30) Target heart rate range from 122 (64%*190) to 144 (76%*190) bpm	Maximal heart rate of 190 bpm using the Fox formula (220-30) Heart rate reserve of 120 bpm (190-70) Target heart rate range from 118 (40%*120 + 70) to 141 (59%*120 + 70) bpm
Tanaka formula		
Target heart rate with potential error of 11 bpm	120 (109 to 131) to 142 (131 to 153) bpm	117 (106 to 128) to 140 (129 to 151) bpm
Calculation using % heart rate maximal	Maximal heart rate of 187 bpm using the Tanaka formula ([208 – .7*30]) Target heart rate in moderate intensity would range from 120 (64%*187) to 142 (76%*187) bpm	Maximal heart rate of 187 bpm using the Tanaka formula (208 – [.7*30]) Heart rate reserve of 117 bpm (187-70) Target heart rate range from 117 (40%*118 + 70) to 140 (59%*118 + 70) bpm

Abbreviations: ACSM, American College of Sports Medicine; bpm, beats per minute.
Note. Using the Karvonen method, heart rate reserve is calculated as maximal heart rate minus resting heart rate. Then heart rate reserve is multiplied by intensity values before resting heart rate is added back into the equation.
Target heart rate = ([heart rate maximum – heart rate rest] × [% heart rate maximum]) + heart rate rest.

pregnant women who ran prior to and during pregnancy. Mean resting heart rate was 7 bpm higher at 4 weeks' gestation compared to pre-pregnancy. Resting heart rate gradually increased to 32 weeks' gestation and then plateaued for the remainder of pregnancy. Overall, on average, women's resting heart rate increased 16 bpm from pre-pregnancy to delivery (Figure 2). This finding has been substantiated in other studies.[47,48]

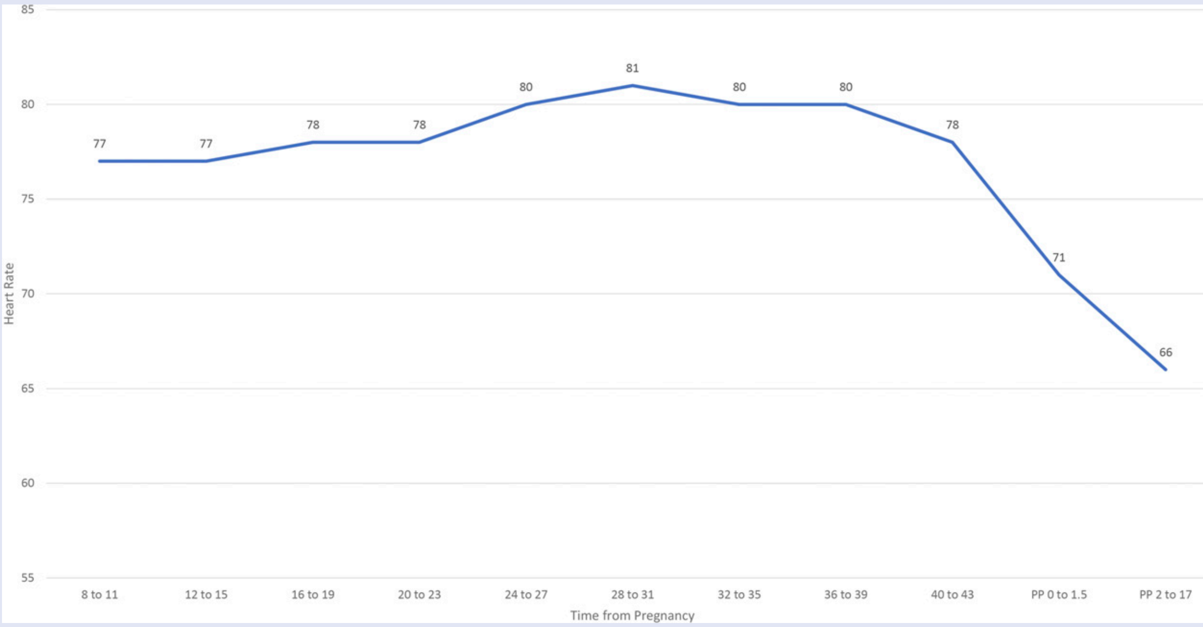
These early study findings are supported by more recent work indicating early hemodynamic changes with pregnancy, starting around 2–5 weeks' gestation.[49] During submaximal weight-bearing and non–weight-bearing exercise, measures of oxygen uptake, stroke volume, and heart rate are higher during pregnancy compared to non-pregnant states.[47,50] In a small study of active women, heart rate during the same level of submaximal exercise was on average ~8 bpm higher in third trimester pregnant women compared to non-pregnant controls, but was similar at maximal effort.[48] Others have reported that maximal effort heart rate may be reduced due to the blunted sympathetic nervous system response to exercise late in pregnancy.[51] A target heart rate range appropriate before pregnancy could meaningfully differ with the autonomic balance shift toward increased sympathetic control and away from parasympathetic control.[47,50,52]

Due to a higher resting heart rate, functional heart rate reserve at rest and submaximal exercise are reduced during pregnancy.[43] Heart rate reserve will be lower due to the higher resting heart rate and lower maximal heart rate. This results in heart rate becoming a less precise tool for monitoring intensity since it may underestimate intensity at higher work rates and overestimate intensity at lower work rates.[43] Based on the variation found in adults,[35,42] the implications for pregnant women are that exercise intensity based on heart rate estimated from age alone, or age and resting heart, is likely to have substantial error.

To demonstrate the challenges specifically with the heart rate

Figure 1.

Plot of mean heart rate (bpm) among women serially measured throughout pregnancy and postpartum (n = 18)*; Abbreviation: bpm, beats per minute; PP, postpartum. *The data were plotted using mean heart rate provided in Table 1 of the study.[45]



recommendations, Figure 3 plots target hearts rates for pregnant women 20 to 40 years of age from ACOG 2020[28] and from ACSM using heart rate maximum and heart rate reserve,[30] with resting heart rates of 60, 70, and 80 bpm. Several observations regarding target heart rate can be made. There is variation in both moderate and vigorous target heart rates across the 5 examples. Considering percent of heart rate using the Fox formula, ACOG recommends 60% while ACSM recommends 64% for the lower bound of moderate intensity. Moreover, the 140 bpm restricts heart rate moreso for younger women who generally have higher maximal heart rates than older women. The heart rate cap also restricts women with higher resting heart rate compared to a lower resting heart rate. For a younger woman with a resting heart rate of 80 bpm, she would be most limited by the ACOG heart rate cap, only reaching to around the median of the heart rate range. At 140 bpm, most pregnant women would not reach vigorous intensity unless deconditioned. In addition to these observations, it seems prudent to highlight that the heart rate recommendations should be reconsidered among women taking beta-blockers or other medication that alters heart rate. In this case, the maximal heart rate will be lower, and inappropriately calculated using the Fox or Tanaka formulas.

Measuring Heart Rate

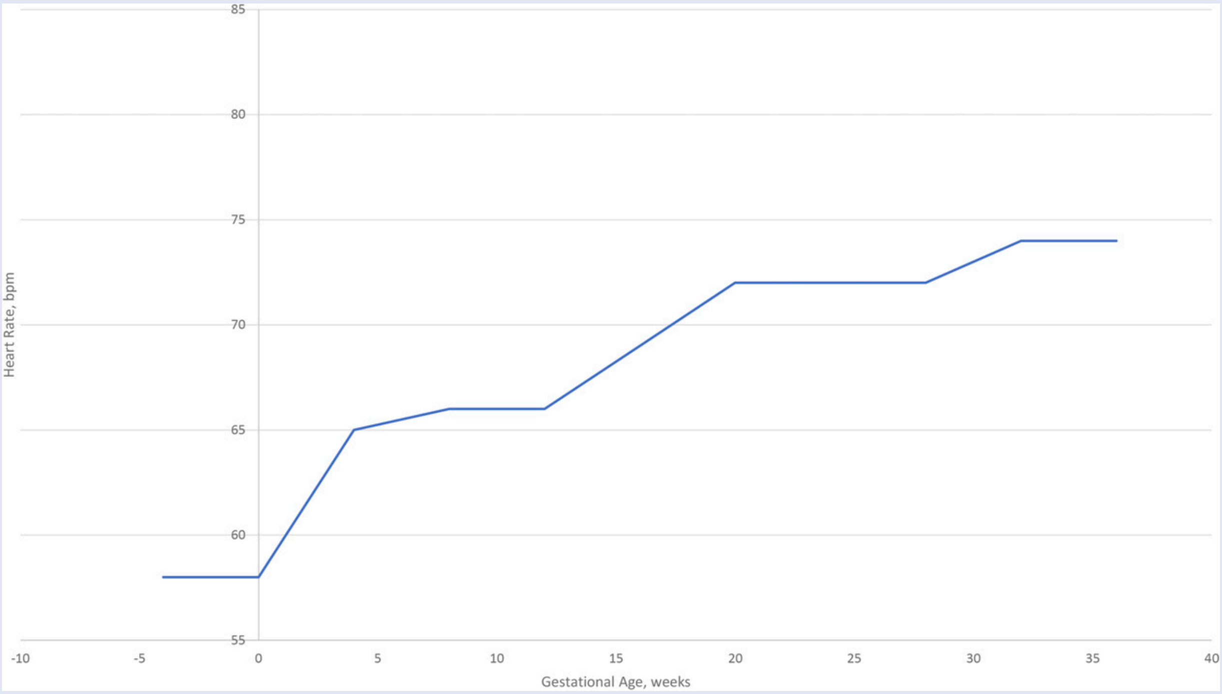
Self-assessment of heart rate is an important consideration with the ACOG heart rate recommendation.[28] The most common options a pregnant woman have for measuring heart rate include (i) palpitation, (ii) wearing a device (e.g., activity tracker, smartwatch, and pulse oximeter), or (iii) using a device (e.g., smartphone). First, palpitation is a method usually conducted at the radial artery on the wrist, rather than the carotid artery at the neck, to avoid possible syncope particularly during exercise. It can be difficult to palpitate and count heart rate for at least 10 seconds while exercising.

Second, wearing a device offers the option to collect and usually store heart rate over an extended period of time, both at rest and exercise. For many years, chest straps were the best option for measurement. The advantages to a chest strap included their accuracy and lower cost, but the disadvantages include slipping, discomfort over longer periods of time, and not providing a reading when not in direct contact to the body. The strap often needed water between its surface and the skin to read correctly.

An alternative to the chest strap is the wrist band. It has gained popularity in recent years since heart rate assessment is integrated into

Figure 2.

Plot of mean resting heart rate (bpm) among women runners serially measured before and during pregnancy (n = 10)*; Abbreviation: bpm, beats per minute. *The data were plotted using mean heart rate provided in Table 1 of the study.[46]



activity trackers and smartwatches.[53] The wrist bands use contact photoplethysmography (PPG) to estimate heart rate by utilizing differential reflection of light-emitting diodes in response to the pulsatile changes in blood volume near the skin surface with each heart contraction.[54,55] In a review of 5 studies documenting the validity of heart rate assessment on Garmin activity trackers, agreement with the gold standard measure was not optimal; the Garmin performed better at rest compared to higher intensity activities.[56] Other wrist-worn brands indicate similar variability when using PPG for heart rate estimation.[57,58] Emerging options for heart rate assessment creatively utilize headphones, rings, clothing, or pulse oximetry.

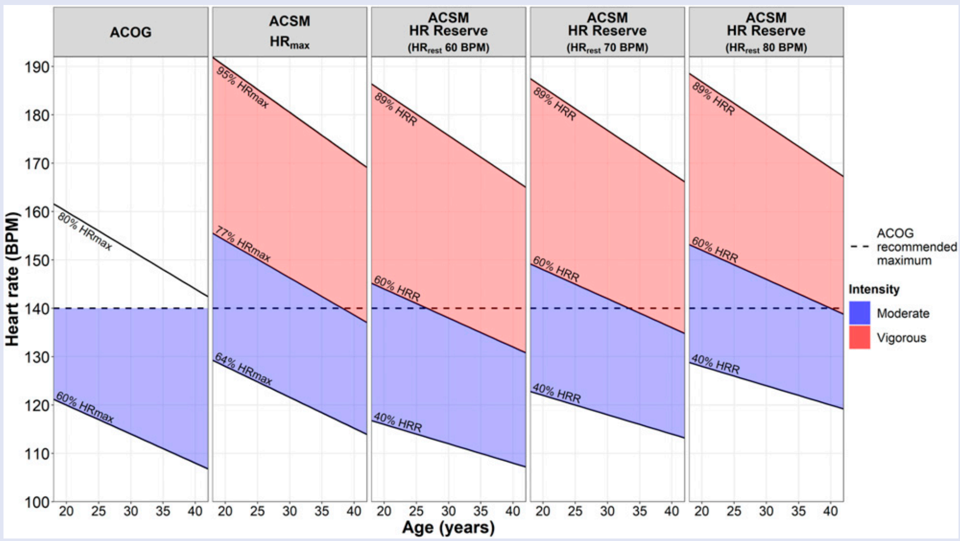
Third, consumers can use smartphone apps that measure heart rate, also assessed with PPG. In this case, the process utilizes the phone's camera and flash to detect changes in blood volume near the skin's surface. Apps that required contact (such as touching your fingers) to the phone's camera tend to be more accurate than noncontact apps that request holding the camera to your face.[59] Apps are also more accurate when the individual is in normal sinus rhythm compared to rhythms with irregular rate or tachycardia.[60] Limitations of this method include variation in heart rate assessment due to skin tone, ambient light, user movement, finger pressure, and lower than optimal sampling rate of the phone.[53] Other smartphone options include (i) mobile phone apps combined with accelerometry using the seismocardiogram and the ballistocardiogram signals[61] and (ii) mobile phones with an electrocardiogram sensor and app to assess heart rate through the handheld electrocardiogram recorder.[53]

Relative Intensity Estimation Using Perceived Exertion

The original ratings of perceived exertion scale approximates exercise heart rate from 6 (i.e., 60 bpm) to 20 (i.e., 200 bpm)[62]; predicted heart rate is in essence based on the numeric rating of perceived exertion multiplied by 10. The ACSM provides recommendations for ratings of perceived exertion using the Borg scale, summarized in Table 2.[30] Although describing exercise based on perceived exertion can be useful since it allows an approximately equivalent work-rate in individuals who have differing baseline fitness or exercise capabilities,[63] it is not without challenges.

Figure 3.

Heart rate recommendations during moderate and vigorous exercise by age from ACSM[30] for adults and ACOG[28] for pregnant women; Abbreviations: ACOG, American College of Obstetricians and Gynecologists; ACSM, American College of Sports Medicine; BPM, beats per minute; HRR, heart rate reserve using Karvonen formula; HRmax, heart rate using Fox formula (220-age).



Studies in non-pregnant populations suggest that perceived exertion may be both under- and over-estimated based on intensity level. For example, among 343 women aged 40–91 years, estimates of perceived intensity were higher for light and vigorous physical activity, but lower for moderate physical activity compared to absolute intensity based on MET values from a compendium of physical activities.[64] The mismatch was largest with vigorous physical activity. A similar mismatch was observed at higher intensities, where women and men correctly estimated light intensity effort during a treadmill walk, but underestimated walking at moderate and vigorous effort.[65] When participants were asked to walk at a pace to benefit health, about half (52%) walked at light intensity, with fewer walking at moderate or vigorous intensity. Results did not differ by sex, ethnicity, or body mass index, but younger adults (<30 years old) underestimated moderate and vigorous intensity to a greater extent than middle-aged adults (≥30 years old). Another study indicated that mismatches between perceived and measured intensities may differ by level of training; at 50–80% of maximal oxygen consumption, trained runners on average exhibited a lower level of perceived exertion compared to untrained runners.[66]

Perceived exertion is one way in which pregnant women are now recommended to monitor their physical activity intensity during pregnancy. However, the range of intensity that ACOG[28] recommends for moderate intensity (RPE 12 to 14) spans moderate (RPE 12–13) to vigorous (14–17) intensity activity using the Borg scale[62] according to the ACSM guidance (Table 2).[30] The Borg scale[62] defines a RPE of 11 as “fairly light,” 13 as “somewhat hard,” and 15 as “hard.” Changes to a woman’s physiology during pregnancy, her baseline pre-pregnancy cardiorespiratory fitness, and the type of activity performed may all make it difficult for women to accurately predict both perceived and actual exertion during pregnancy.

As with resting heart rate, the energy costs for any given physical activity are higher during later pregnancy compared to earlier in pregnancy[67] or compared to 12 weeks’ postpartum.[68] This may imply that women perceive physical activity to become more difficult as pregnancy progresses, but study findings vary as to whether this is the case. On an incremental step-test, perceived exertion for pregnant exercisers was higher compared to non-pregnant controls,[69] and another study found women perceived physical activity to be more difficult at 32 weeks’ compared to 20 weeks’ gestation relative to the energy cost.[70] In contrast, no differences in perceived exertion at either 20 or 32 weeks’ gestation were found at either moderate or vigorous intensity treadmill exercise when exercisers and sedentary women performed 5 minutes at self-selected speeds.[70] Other studies also show

Table 4.

Practical Guidance for Monitoring Physical Activity Intensity During Pregnancy.

Topic	Literature	Practical guidance for providers
Relative intensity – heart rate		
Accuracy	Overall, the standard error was 12 bpm for the Fox formula and 11 bpm for the Tanaka formula, indicating that approximately 95% of the estimated maximal heart rate values will fall within +/−24 and +/−22 bpm, respectively.[35]	There is substantial error around age predicted maximal heart rate used to calculate intensity of physical activity. This error is even larger among older ages, Blacks, those with lower cardiorespiratory fitness, and those with higher body mass indices. At the intersection of ranges between light-to-moderate or moderate-to-vigorous intensity, errors due to individual variation could place a woman in the incorrect intensity category.
Changes At rest	Resting heart rate in pregnancy is higher than prepregnancy heart rate,[45,46,47] even as early as 2-5 weeks' gestation.[49]	Target heart rate ranges for physical activity that account for resting heart rate (Karvonen) will usually be higher for a pregnant woman compared to her pre-pregnancy state starting as early as 2-5 weeks' gestation.
Submaximal effort	During submaximal weight-bearing and nonweight bearing exercise, heart rate is higher during pregnancy compared to the nonpregnancy state.[47,50]	Target heart rate ranges appropriate before pregnancy will meaningfully differ during pregnancy, since submaximal heart rates are higher with pregnancy.
Upper limit	The 140 bpm limit moreso restricts (i) younger women who generally have higher maximal heart rates than older women and (ii) women with higher resting heart rate compared to a lower resting heart rate. At 140 bpm, most pregnant women would not reach vigorous intensity unless deconditioned.	Using a single number as a heart rate cap is not a useful restriction, given the decline in maximal heart rate with age and the individual variation depending on resting heart rate.
External impacts	Heart rate is impacted by environmental factors (e.g., stress, heat, and emotions), as well as certain medications, which can obscure using heart rate to guide intensity.	Learning to use perceived intensity along with heart rate is important since heart rate can be impacted by many external factors.
Relative intensity – perceived exertion		
Differential misclassification	Perceived exertion may either under- or over-estimate measured intensity level.[64,65]	There is individual variation in perception of physical activity during pregnancy. Using perceived exertion may be better for some and heart rate may be better for others to gauge exercise intensity. A combination of both heart rate and perceived exertion may be the best way for a pregnant woman to monitor exercise intensity.
Individual variation	Changes to a woman's physiology during pregnancy, her baseline pre-pregnancy cardiorespiratory fitness, and the type of physical activity performed may all make it	There are many reasons why perception of physical activity among pregnant women may not match with intensity based on either heart rate or measured oxygen consumption.

(continued)

Table 4. (continued)

	difficult for women to accurately estimate perceived exertion during pregnancy.	Intensity could be guided by the "talk test" wherein if a woman can carry on a conversation then she should not be overexerting.
Pre-pregnancy activity levels	Physically active participants have a lower level of perceived exertion during exercise than untrained participants during the same exercise at the same level of oxygen consumption.[66,70,78]	Women who were active before pregnancy may be more likely to underestimate their actual intensity during exercise and exceed 140 bpm.
Natural changes over the course of pregnancy	Several studies, on average, indicate that women reduce the intensity of a given physical activity as pregnancy progresses.[70,73,74,75]	Pregnant women may naturally, and even unconsciously, alter the intensity of a given activity as pregnancy progresses.
Perception with activity types	The type of physical activity that women engage in (i.e., aerobic and strength) is likely to impact their perception of how hard they are working.[76,77,80,86]	Different types of physical activities may produce different perceived responses by a pregnant woman. If a woman engaged in a specific physical activity before pregnancy, then during pregnancy she may report a lower perceived intensity compared to a woman engaging in that activity during pregnancy without prior experience.

that perceived exertion remains unchanged during pregnancy for moderate intensity cycling,[69,71] and in response to a fixed load on a treadmill and cycle ergometer.[72]

It is possible that while perceptions may not change during pregnancy, women alter their physical activity intensity as pregnancy progresses either consciously or otherwise as shown by Marshall and Pivarnik.[70] In their study, women who were told to exercise at a vigorous intensity on a treadmill task did so at 20 weeks' gestation but did not at 32 weeks', with energy expenditure measurement accounting for their treadmill speed and grade. This is similar to a small sample of pregnant women who reported a change in self-paced walking over the course of pregnancy,[73] and another study showing slower walking paces in obese women combined with reductions in the metabolic cost of walking from 15 to 30 weeks' gestation.[74] Women who were 32 weeks pregnant also had lower activity energy expenditure, performed less total physical activity, and walked at a slower pace compared with non-pregnant controls.[75] It may, therefore, be inferred that earlier in pregnancy, a woman's perception of what constitutes moderate and vigorous intensity does not differ, but this changes as pregnancy progresses; pregnant women may compensate for physiological changes during gestation by decreasing walking and running speeds. More research is required to determine whether this mis-match between "perception and reality" has important physiological implications. It may however be something for providers to bear in mind when recommending activity in later gestations; women who remain active will do so at an intensity comfortable to them, with the decreased effort potentially being a natural and important mechanism for engaging in safe physical activity during pregnancy.

Maternal heart rate increases during exercise as pregnancy progresses at a given workload, regardless of perceived exertion.[76] However, no significant correlation between heart rate and perceived exertion in 20 pregnant women was found, where perceived exertion was higher at 15 and 30 minutes during resistance vs aerobic exercise.[77] It is likely that in those who exercise prior to pregnancy, perceived exertion is less than those who were previously sedentary.[70] Moreover, women who performed exercise training throughout gestation had a blunted perception of effort at given cycle power outputs as pregnancy progressed.[78] In trained women, perceived exertion, therefore, tends to underestimate actual heart rate during pregnancy (except for walking in the third trimester), with large underestimations in some cases putting women in higher heart rate zones than recommended by ACOG in 2020.[28] This may support findings that prior exercisers self-select exercise at intensities that are higher compared to previously sedentary women. Indeed, caloric expenditure, alveolar ventilation, and cardiac output responses appear proportionately higher in trained compared to sedentary pregnant women.[79] Trained pregnant women may therefore be at a greater risk of under estimating exercise intensity when using perceived exertion than untrained pregnant women. Others have concluded that pregnant women should not rely solely on perceived exertion when training to maintain an exercise intensity below 140 bpm,[76] the maximal heart rate recommendation from ACOG in 1985[21] and now in 2020.[28]

It is suggested that the correlation between perceived exertion and heart rate is less linear during pregnancy compared to the non-pregnant state,[76] and that this relationship may differ by activity type. One study of 124 pregnant women who were trained or sedentary in the second or third trimester showed that heart rate was not correlated with perceived exertion during walking, cycling, circuits, or aerobics.[76] Another found no significant correlation between heart rate and perceived exertion in 20 pregnant women, but that perceived exertion was higher during resistance training compared to aerobic exercise.[77] Ohtake and Wolfe[78] observed perceived exertion to be higher for pregnant women conducting step-testing at the same target heart rate compared to cycling, with women more likely to underestimate their heart rate in the cycling condition. Conversely, pregnant women were shown to work harder, both in terms of perceived exertion and heart rate, when cycling compared to walking.[80] Overall, healthy participants worked at (mean/standard deviation) 65 ± 8% and 76 ± 9% of individual age predicted heart rate maximum during treadmill tasks and static cycling, respectively, indicating the treadmill walking was perceived as "somewhat hard" and stationary cycling "hard." While no pattern is evident for which activities are likely to result in higher perceived exertion for pregnant women, it may in part depend on what women are used to and also how her body adapts to each specific pregnancy. Nevertheless, it is recommended that providers (*a*) use perceived exertion as a way of counseling women on how they can be safely active during pregnancy; (*b*) be aware that activities performed at a given perceived exertion may change depending on trimester; and (*c*) query how active a woman was, and what types of activity she engaged in, prior to pregnancy.

Practical Application and Conclusion

The earliest United States recommendations on physical activity during pregnancy date from the middle of the 20th century.[81] At that time, the guidelines had little scientific basis and encouraged housework, gardening, occasional swimming, and daily walks, while discouraging sports participation. In 1985, the ACOG provided their first prenatal exercise recommendations based on a consensus panel of obstetricians.[21] This guideline was updated in 1994,[22] 2002,[23] 2015,[27] and 2020.[28] Healthcare providers should be prepared for some confusion around the 2020 ACOG exercise intensity recommendations[28] since the heart rate restriction was included in the 1985 recommendation[21] but subsequently removed since 1994.[22]

Given the challenges and changes in ACOG recommendations to monitor exercise intensity during pregnancy, we summarize several practical recommendations in Table 4. The 2020 ACOG recommendation changed the intensity component of the exercise prescription to recommend using both heart rate and perceived exertion.[28] Our paper provided a background to the use of heart rate and perceived exertion to estimate exercise intensity for pregnant women. Among non-pregnant women, there is a linear relationship between heart rate and aerobic capacity. However, with pregnancy, resting and submaximal heart rate are elevated, while maximal heart rate is blunted. In addition, there is known error with the use of age-predicted maximal heart rate, with an 11–12 bpm standard error around the estimated value. The 2020 ACOG[28] recommendation to limit exercise beyond 140 bpm places greater restriction on younger women moreso than older women, as well as those with a higher resting heart rate.

For pregnant women, a combination of both heart rate and perceived exertion may be the current best way to monitor exercise intensity to account for their prior level of training. There are several options for women to self-monitor their heart rate during exercise. Each method has advantages and disadvantages that should be taken into consideration. However, monitoring intensity during regular exercise consistently can help pregnant women identify when a change happens and if there might be a reason to lower their intensity. More research is required to better specify guidance on physical activity intensity throughout pregnancy, considering a range of intensities, ages, cardiorespiratory fitness levels, and body sizes.

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References

1. DiPietro L, Evenson KR, Bloodgood B, et al. Benefits of physical activity during pregnancy and postpartum: An umbrella review. *Med Sci Sports Exerc*. 2019;51(6):1292-1302.
2. Artal R. Exercise during pregnancy and the postpartum period. In: Lockwood C, Fricker P, eds. *UpToDate Inc*. Waltham, MA: Walters Kluwer; 2019. https://www.uptodate.com.
3. Vladutiu CJ, Evenson KR, Marshall SW. Physical activity and injuries during pregnancy. *J Phys Activ Health*. 2010;7:761-769.
4. Hesketh K, Evenson K. Prevalence of US women meeting 2015 American College of Obstetrics and Gynecology guidelines for physical activity during pregnancy. *Am J Prev Med*. 2016;51(53):e87-e89.
5. Evenson KR, Wen F. Prevalence and correlates of objectively measured physical activity and sedentary behavior among US pregnant women. *Prev Med*. 2011;53:39-43.
6. Ferrari RM, Siega-Riz AM, Evenson KR, Moos M-K, Carrier KS. A qualitative study of women's perceptions of provider advice about diet and physical activity during pregnancy. *Patient Educ Counsel*. 2013;91(3):372-377.
7. de Jersey SJ, Nicholson JM, Callaway LK, Daniels LA. An observational study of nutrition and physical activity behaviours, knowledge, and advice in pregnancy. *BMC Pregnancy Childbirth*. 2013;13:115.
8. Stengel MR, Kraschnewski JL, Hwang SW, Kjerulff KH, Chuang CH. "What my doctor didn't tell me": Examining health care provider advice to overweight and obese pregnant women on gestational weight gain and physical activity. *Wom Health Issues*. 2012;22(6):e535-e540.
9. May LE, Suminski RR, Linklater ER, Jahnke S, Glaros AG. Exercise during pregnancy: The role of obstetric providers. *J Osteopath Med*. 2013;113(8):612-619.
10. Aittasalo M, Pasanen M, Fogelholm M, Kinnunen TI, Ojala K, Luoto R. Physical activity counseling in maternity and child health care: A controlled trial. *BMC Wom Health*. 2008;8(14):14-19.
11. Krans EE, Gearhart JG, Dubbert PM, Klar PM, Miller AL, Replogle WH. Pregnant women's beliefs and influences regarding exercise during pregnancy. *J Miss State Med Assoc*. 2005;46(3):67-73.
12. Duthie EA, Drew EM, Flynn KE. Patient-provider communication about gestational weight gain among nulliparous women: A qualitative study of the views of obstetricians and first-time pregnant women. *BMC Pregnancy Childbirth*. 2013;13:231.
13. Clarke PE, Gross H. Women's behaviour, beliefs and information sources about physical exercise in pregnancy. *Midwifery*. 2004;20:133-141.
14. Doran F, O'Brien AP. A brief report of attitudes towards physical activity during pregnancy. *Health Promot J Aust*. 2007;18(2):155-158.
15. Evenson KR, Bradley CB. Beliefs about exercise and physical activity among pregnant women. *Patient Educ Counsel*. 2010;79:124-129.
16. Liu J, Whitaker KM, Yu SM, Chao SM, Lu MC. Association of provider advice and pregnancy weight gain in a predominantly Hispanic population. *Wom Health Issues*. 2016;26(3):321-328.
17. Hayman M, Reaburn P, Alley S, Cannon S, Short C. What exercise advice are women receiving from their healthcare practitioners during pregnancy? *Women Birth*. 2020;33(4):e357-e362.
18. Findley A, Smith DM, Hesketh K, Keyworth C. Exploring womens' experiences and decision making about physical activity during pregnancy and following birth: A qualitative study. *BMC Pregnancy Childbirth*. 2020;20(1):54.
19. Whitaker KM, Wilcox S, Liu J, Blair SN, Pate RR. Patient and provider perceptions of weight gain, physical activity, and nutrition counseling during pregnancy: A qualitative study. *Wom Health Issues*. 2016;26(1):116-122.
20. Chang T, Llanes M, Gold KJ, Fetters MD. Perspectives about and approaches to weight gain in pregnancy: A qualitative study of physicians and nurse midwives. *BMC Pregnancy Childbirth*. 2013;13:47.
21. ACOG. *During Pregnancy and the Postnatal Period*. Washington DC: American College of Obstetricians and Gynecologists; 1985.
22. ACOG. Exercise during pregnancy and the postpartum period. ACOG Technical Bulletin Number 189–February 1994. *Int J Gynaecol Obstet*. 1994;45(1):65-70.
23. ACOG. ACOG Committee opinion. Number 267, January 2002: Exercise during pregnancy and the postpartum period. *Obstet Gynecol*. 2002;99(1):171-173.
24. Entin PL, Munhall KM. Recommendations regarding exercise during pregnancy made by private/small group practice obstetricians in the USA. *J Sports Sci Med*. 2006;5:449-458.
25. Bauer PW, Broman CL, Pivarnik JM. Exercise and pregnancy knowledge among healthcare providers. *J Wom Health*. 2010;19(2):335-341.
26. Evenson KR, Pompeii LA. Obstetrician practice patterns and recommendations for physical activity during pregnancy. *J Wom Health*. 2010;19(9):1733-1740.
27. ACOG. ACOG committee opinion No. 650: Physical activity and exercise during pregnancy and the postpartum period. *Obstet Gynecol*. 2015;126(6):e135-e142
28. ACOG. Physical activity and exercise during pregnancy and the postpartum period: ACOG committee opinion, Number 804. *Obstet Gynecol*. 2020;135(4):e178-e188.
29. American College of Sports Medicine. *Guidelines for Exercise Testing and Exercise Prescription*. Philadelphia: Lea & Febiger; 1975.
30. Garber CE, Blissmer B, Deschenes MR, et al. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults. *Med Sci Sports Exerc*. 2011;43(7):1334-1359.

31. US Department of Health and Human Services. *Physical Activity Guidelines for Americans*. 2nd edition. Washington, DC: US Department of Health and Human Services; 2018. Accessed at https://health.gov/paguidelines/second-edition/.
32. Bull FC, Al-Ansari SS, Biddle S, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *Br J Sports Med*. 2020;54(24):1451-1462.
33. Davenport MH, Mottola MF, Ruchat SM, et al. Author response: Comment and questions to Mottola et al (2018): 2018 Canadian guideline for physical activity throughout pregnancy. *J Obstet Gynaecol Can*. 2019;41(21):1406-1408.
34. Skinner JS, Gaskill SE, Rankinen T, et al. Heart rate versus %VO2max: Age, sex, race, initial fitness, and training response–HERITAGE. *Med Sci Sports Exerc*. 2003;35(11):1908-1913.
35. Sarzynski MA, Rankinen T, Earnest CP, et al. Measured maximal heart rates compared to commonly used age-based prediction equations in the Heritage Family Study. *Am J Hum Biol*. 2013;25(5):695-701.
36. Ozemek C, Whaley MH, Finch WH, Kaminsky LA. Maximal heart rate declines linearly with age independent of cardiorespiratory fitness levels. *Eur J Sport Sci*. 2017;17(5):563-570.
37. Fox SM, 3rd, Naughton JP, Haskell WL. Physical activity and the prevention of coronary heart disease. *Ann Clin Res*. 1971;3(6):404-432.
38. Tanaka H, Monahan KD, Seals DR. Age-predicted maximal heart rate revisited. *J Am Coll Cardiol*. 2001; 37(1):153-156.
39. Karvonen MJ, Kentala E, Mustala O. The effects of training on heart rate; a longitudinal study. *Ann Med Exp Biol Fenniae*. 1957;35:307-315.
40. Karvonen J, Vuorimaa T. Heart rate and exercise intensity during sports activities. *Sports Med*. 1988;5(5): 303-312.
41. Cunha FAd., Farinatti Pd. TV, Midgley AW. Methodological and practical application issues in exercise prescription using the heart rate reserve and oxygen uptake reserve methods. *J Sci Med Sport*. 2011;14(1): 46-57.
42. Ferri Marini C, Sisti D, Leon AS, et al. HRR and VO2R fractions are not equivalent: Is it time to rethink aerobic exercise prescription methods? *Med Sci Sports Exerc*. 2021;53:174-182.
43. Mottola M. Chapter 12: Performance in the pregnant woman: Maternal and fetal considerations. In: Taylor N, Groeller H, eds. *Physiological Bases of Human Performance During Work and Exercise*. USA: Elsevier; 2008: 225-237.
44. Burwell CS, Strayhorn W, Flickinger D, Corlette M, Bowerman E, Kennedy J. Circulation during pregnancy. *Arch Intern Med*. 1938;62:979-1003.
45. Walters WA, MacGregor WG, Hills M. Cardiac output at rest during pregnancy and the puerperium. *Clin Sci*. 1966;30(1):1-11.
46. Clapp JF, 3rd. Maternal heart rate in pregnancy. *Am J Obstet Gynecol*. 1985; 152(6 Pt 1):659-660.
47. Davenport MH, Skow RJ, Steinback CD. Maternal responses to aerobic exercise in pregnancy. *Clin Obstet Gynecol*. 2016;59(3):541-551.
48. Heenan AP, Wolfe LA, Davies GAL. Maximal exercise testing in late gestation. *Obstet Gynecol*. 2001;97(1):127-134.
49. Melzer K, Schutz Y, Boulvain M, Kayser B. Physical Activity and Pregnancy. *Sports Med*. 2010;40(6):493-507.
50. Mottola MF, Davenport MH, Brun CR, Inglis SD, Charlesworth S, Sopper MM. VO2 peak prediction and exercise prescription for pregnant women. *Med Sci Sports Exerc*. 2006;38(8):1389-1395.
51. Wolfe LA, Brenner IKM, Mottola MF. Maternal exercise, fetal weil-being and pregnancy outcome. *Exerc Sport Sci Rev*. 1994;22:145-194.
52. May LE, Knowlton J, Hanson J, et al. Effects of exercise during pregnancy on maternal heart rate and heart rate variability. *PM&R*. 2016;8(7):611-617.
53. Li KHC, White FA, Tipoe T, et al. The current state of mobile phone apps for monitoring heart rate, heart rate variability, and atrial fibrillation: Narrative review. *JMIR MHealth UHealth*. 2019;7(2):e11606.
54. Reddy RK, Pooni R, Zaharieva DP, et al. Accuracy of wrist-worn activity monitors during common daily physical activities and types of structured exercise: Evaluation study. *JMIR mHealth uHealth*. 2018;6(12): e10338.
55. Mühlen JM, Stang J, Lykke Skovgaard E, et al. Recommendations for determining the validity of consumer wearable heart rate devices: Expert statement and checklist of the INTERLIVE Network. *Br J Sports Med*. 2021:2020. doi:10.1136/bjsports-2020-103148.
56. Evenson KR, Spade CL. Review of validity and reliability of Garmin activity trackers. *J Meas Phys Behav*. 2020;3(2):170-185.
57. Wang R, Blackburn G, Desai M, et al. Accuracy of Wrist-Worn heart rate monitors. *JAMA Cardiol*. 2017;2(1): 104-106.
58. Wallen MP, Gomersall SR, Keating SE, Wisløff U, Coombes JS. Accuracy of heart rate watches: Implications for weight management. *PLoS One*. 2016; 11(5):e0154420. doi:10.1371/journal.pone.0154420.
59. Coppetti T, Brauchlin A, Müggler S, et al. Accuracy of smartphone apps for heart rate measurement. *European Journal of Preventive Cardiology*. Aug 2017;24(12):1287-1293.
60. Pipitprapat W, Harnchoowong S, Suchonwanit P, Sriphrapradang C. The validation of smartphone applications for heart rate measurement. *Ann Med*. 2018;50(8):721-727.
61. Landreani F, Caiani EG. Smartphone accelerometers for the detection of heart rate. *Expet Rev Med Dev*. Dec 2017;14(12):935-948.
62. Borg G, Linderholm H. Perceived exertion and pulse rate during graded exercise in various age groups. *Acta Med Scand*. 1974;472:194-206.
63. Mann T, Lamberts RP, Lambert MI. Methods of prescribing relative exercise intensity: Physiological and practical considerations. *Sports Med*. 2013;43(7):613-625.
64. Wilcox S, Irwin ML, Addy C, et al. Agreement between participant-rated and compendium-coded intensity of daily activities in a triethnic sample of women ages 40 years ears and older. *Ann Behav Med*. 2001;23(4):253-262.
65. Canning KL, Brown RE, Jamnik VK, Salmon A, Ardern CI, Kuk JL. Individuals underestimate moderate and vigorous intensity physical activity. *PLoS One*. 2014;9(5):e97927.
66. Demello JJ, Cureton KJ, Boineau RE, Singh MM. Ratings of perceived exertion at the lactate threshold in trained and untrained men and women. *Med Sci Sports Exerc*. 1987; 19(4):354-362.
67. van Raaij JM, Schonk CM, Vermaat-Miedema SH, Peek ME, Hautvast JG. Energy cost of walking at a fixed pace and self-paced before, during, and after pregnancy. *Am J Clin Nutr*. 1990; 51(2):158-161.

68. Pivarnik JM, Lee W, Clark SL, Cotton DB, Spillman HT, Miller JF. Cardiac output responses of primigravid women during exercise determined by the direct Fick technique. *Obstet Gynecol*. 1990;75(6):954-959.
69. Williams A, Reilly T, Campbell I, Sutherst J. Investigation of changes in responses to exercise and in mood during pregnancy. *Ergonomics*. 1988; 31(11):1539-1549.
70. Marshall MR, Pivarnik JM. Perceived exertion of physical activity during pregnancy. *J Phys Activ Health*. 2015; 12(7):1039-1043.
71. Jensen D, Ofir D, O'Donnell DE. Effects of pregnancy, obesity and aging on the intensity of perceived breathlessness during exercise in healthy humans. *Respir Physiol Neurobiol*. 2009;167(1):87-100.
72. Pivarnik JM, Lee W, Miller JF. Physiological and perceptual responses to cycle and treadmill exercise during pregnancy. *Med Sci Sports Exerc*. 1991;23(4):470-475.
73. Nagy LE, King JC. Energy expenditure of pregnant women at rest or walking self-paced. *Am J Clin Nutr*. 1983;38(3): 369-376.
74. Byrne NM, Groves AM, McIntyre HD, Callaway LK. Changes in resting and walking energy expenditure and walking speed during pregnancy in obese women. *Am J Clin Nutr*. 2011; 94(3):819-830.
75. Lof M, Forsum E. Activity pattern and energy expenditure due to physical activity before and during pregnancy in healthy Swedish women. *Br J Nutr*. 2006;95(2):296-302.
76. O'Neill ME, Cooper KA, Mills CM, Boyce ES, Hunyor SN. Accuracy of Borg's ratings of perceived exertion in the prediction of heart rates during pregnancy. *Br J Sports Med*. 1992;26(2):121-124.
77. Petrov Fieril K, Glantz A, Fagevik Olsen M. Hemodynamic responses to single sessions of aerobic exercise and resistance exercise in pregnancy. *Acta Obstet Gynecol Scand*. 2016;95(9): 1042-1047.
78. Ohtake PJ, Wolfe LA. Physical conditioning attenuates respiratory responses to steady-state exercise in late gestation. *Med Sci Sports Exerc*. 1998;30(1):17-27.
79. Pivarnik JM, Ayres NA, Mauer MB, Cotton DB, Kirshon B, Dildy GA. Effects of maternal aerobic fitness on cardiorespiratory responses to exercise. *Med Sci Sports Exerc*. 1993; 25(9):993-998.
80. Halse RE, Wallman KE, Newnham JP, Guelfi KJ. Pregnant women exercise at a higher intensity during 30min of self-paced cycling compared with walking during late gestation: Implications for 2h postprandial glucose levels. *Metabolism*. 2013;62(6):801-807.
81. Downs DS, Chasan-Taber L, Evenson KR, Leiferman J, Yeo S. Physical activity and pregnancy: Past and present evidence and future recommendations. *Res Q Exerc Sport*. 2012;83(4):485-502.
82. McMurray RG, Hackney AC, Katz VL, Gall M, Watson WJ. Pregnancy-induced changes in the maximal physiological responses during swimming. *J Appl Physiol*. 1991;71(4): 1454-1459.
83. McMurray RG, Mottola MF, Wolfe LA, Artal R, Millar L, Pivarnik JM. Recent advances in understanding maternal and fetal responses to exercise. *Med Sci Sports Exerc*. 1993;25(12):1305-1321.
84. Persinger R, Foster C, Gibson M, Fater DC, Porcari JP. Consistency of the talk test for exercise prescription. *Med Sci Sports Exerc*. 2004;36(9):1632-1636.
85. Beetham KS, Giles C, Noetel M, Clifton V, Jones JC, Naughton G. The effects of vigorous intensity exercise in the third trimester of pregnancy: A systematic review and meta-analysis. *BMC Pregnancy Childbirth*. 2019;19(1):281.
86. Ohtake P, Wolfe L, Hall P, McGrath M. Physical conditioning effects on heart rate and perception of exertion in pregnancy. *Can J Sport Sci*. 1988; 13(71P-73P).