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## REVIEW

# Exercise interventions for weight management during pregnancy and up to 1 year postpartum among normal weight women and women with overweight and obesity: An updated systematic review

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**Abstract**

**Background:** Given the increased occurrence of pre-gravid obesity in recent years, and the implications of maternal obesity for maternal and offspring health, it is evident that there is a continued need to investigate antenatal and postnatal weight management strategies and to provide evidence-based advice for exercise-based interventions. Given the small number of studies ( $n = 5$ ) included in an original systematic review by our group in 2015, it was important to add to the dataset by assessing data published since 2015, in order to provide a more in-depth view of current knowledge.

**Objective:** To provide an updated systematic review on studies employing exercise interventions for weight management in pregnant and postpartum women.

**Methods:** A systematic review of randomised controlled trials evaluating the effects of an exercise intervention on gestational weight gain and postpartum weight management in normal weight women, and women with overweight and obesity was conducted. PubMed, Scopus, Central Register of Controlled Trials and Web of Science were searched for studies published between September 2013 and June 2021. No restrictions were set on type, intensity, duration, or frequency of exercise intervention. Only studies that targeted body weight or mass as a primary outcome were included.

**Results:** Thirteen studies were included in this review: 11 during and two following pregnancy. Exercise significantly reduced gestational weight gain in five of the pregnancy studies and induced significant weight loss in one of the postpartum studies. Across studies, there were large disparities in exercise modality, frequency, and duration, although moderate intensity exercise was consistently employed.

**Conclusions:** Some studies showed positive effects of exercise on weight management during and following pregnancy. While there is still no consensus on effective exercise intervention approaches, it is crucial that physical activity, of any safe form, is recommended to encourage healthy weight management during this time.

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## KEYWORDS

antenatal, exercise, interventions, postnatal, weight management

## 1 | INTRODUCTION

In recent years, worldwide and maternal obesity rates have risen. In 2016, more than 1.9 billion adults were classified as overweight or obese.<sup>1</sup> The current prevalence of obesity in women is 15%, which represents a threefold increase since 1975.<sup>1</sup> Women of reproductive age represent a sub-population with one of the highest increases in obesity rates in recent years.<sup>2</sup> Public Health England<sup>3</sup> showed that, in 2017, 21.6% of women had obesity at the time of antenatal booking, which represents a 6% increase from 10 years earlier.<sup>4</sup>

The rising prevalence in pre-gravid obesity might be partially caused by inadequate guidance on appropriate GWG. At the time of publication, the GWG guidelines published in 2009 by The Institute of Medicine (IOM)<sup>5</sup> are the most up-to-date recommendations for weight gain during pregnancy. These guiding principles have, however, received criticism for being too conservative for women with overweight and obesity. Several groups<sup>6–8</sup> have suggested that less GWG, weight maintenance or even weight loss could be more appropriate for these women, and some authors<sup>9</sup> have proposed that the IOM guidelines should be modified further according to obesity class.

Recent data have shown that women with overweight or obesity are more likely to experience excessive GWG in comparison to normal weight women.<sup>10,11</sup> Excessive GWG is associated with, among other adverse outcomes, maternal hypertension and large for gestational age (LGA) offspring,<sup>12,13</sup> as well as higher postpartum weight retention.<sup>14</sup> Excessive GWG and postpartum weight retention have been shown to result in an elevated body mass index (BMI) up to 15 years following childbirth,<sup>15</sup> which is associated with adverse long-term health issues including an increased risk of breast and colon cancer, type 2 diabetes and cardiovascular disease.<sup>16</sup>

Given the dearth of knowledge in this area, the increased occurrence of pre-gravid obesity in recent years, and the implications of maternal obesity for maternal and offspring health, it is evident that there is a continued need to investigate antenatal and postnatal weight management strategies and to provide evidence-based advice for exercise-based interventions. The current review was conducted to provide an update to the systematic review published by Elliott-Sale et al.,<sup>17</sup> which aimed to determine if exercise could be used to limit excessive GWG and reduce prolonged postpartum weight retention. Results showed that exercise during pregnancy significantly reduced GWG but did not significantly enhance weight loss following childbirth. These findings led to the recommendation that further randomised controlled trials (RCTs) were necessary to establish the efficacy of exercise interventions as a weight management tool both during and following pregnancy. Given the small number of studies ( $n = 5$ ) included in the Elliott-Sale et al.<sup>17</sup> review, it was deemed important to add to the dataset by assessing the most

recent data published since 2015, in order to provide a more in-depth view of current knowledge. Therefore, a systematic literature search of RCTs published between 2013 and 2021 was performed in order to analyze the effects of an exercise intervention compared to routine care or another intervention on GWG and postpartum weight retention in normal weight women and women with overweight and obesity.

## 2 | METHODS

This review conforms to PRISMA guidelines<sup>18</sup> and follows the search and selection methods outlined in Elliott-Sale et al.<sup>17</sup> An abridged version of the methodology is described below for convenience.

### 2.1 | Search strategy

The following databases were searched: PubMed, Scopus, CENTRAL and Web of Science. A confirmatory Google search was also completed. The search was set between September 2013 and June 2021, providing an update to the Elliott-Sale et al.<sup>17</sup> publication, who performed their last search in September 2013. Search terms included: “physical activity,” “exercise,” “pregnancy,” “pregnant women,” “postpartum,” “weight,” “weight management,” “weight loss,” “overweight,” and “obesity”. The search was restricted to papers published in English, using human participants.

### 2.2 | Study selection

Three investigators (SJH, ES, KJE-S) independently screened (i) the titles and abstracts and then (ii) the full text of all potentially eligible randomised or quasi-randomised controlled studies. Any disagreements were resolved by discussion. Studies were included where the exercise intervention was compared with routine care or another intervention. Only exercise interventions that aimed to manage maternal weight during pregnancy and in the postpartum period were included. There were no restrictions set on the type, duration, frequency, intensity, setting or mode of exercise. Healthy pregnant and postpartum women, aged  $\geq 18$  years and free from medication known to influence weight or exercise performance were included. Postpartum referred to the 12 months following childbirth. Normal weight (BMI 18.5–25.0 kg/m<sup>2</sup>) women, and women with overweight (BMI >25.0 kg/m<sup>2</sup>) and obesity (BMI >30.0 kg/m<sup>2</sup>) were included. Primigravidas and multigravidas, and nulliparous, primiparas and multiparas women were included.

## 2.3 | Data extraction and risk of bias assessment

The primary outcomes were body weight and BMI (kg/m<sup>2</sup>). One reviewer (SJH) completed the data extraction, and all relevant information was extracted using a standardised data extraction form. Information on trial design (eligibility criteria (see Table 1), setting, sample size, length of follow-up), participant characteristics (i.e., age, weight status, and attrition rates), intervention type (i.e., intervention and control components, adherence, and timings) and outcomes (i.e., GWG, BMI change, and weight loss) were collected. Study authors were contacted in instances where insufficient information was obtained through identified sources. SJH assessed risk of bias using the Cochrane risk of bias tool, which evaluates data quality based off five domains: randomization, allocation concealment, double blinding, follow-up and overall bias.<sup>19</sup> Each criteria was assigned the grade A, B, C, or D; A- low risk or adequate or stated, B- moderate risk or unclear or not stated, C- high risk or not used or inadequate, D (only allocation concealment) - not used. To assess the quality of evidence, SJH and KJE-S used the criteria outlined in the Consolidated Standards of Reporting Trials (CONSORT) to assess the strength of the evidence provided.<sup>20</sup> Items 6b and 11b were removed, as they were not applicable to any of the included studies. Neither the Cochrane risk of bias tool or CONSORT criteria were employed to exclude any studies that did not meet their requirements or standards. Any differences between reviewers were resolved through discussion until a consensus was reached.

## 3 | RESULTS

### 3.1 | Description of included studies

Our search identified 919 records, and following the removal of duplicates, the titles and abstracts of 887 articles were screened. Following phase 1, 853 studies were excluded due to being retrospective, non-randomised, qualitative, duplicates or baseline studies. The eligibility of 34 full-text papers was assessed, with 21 papers excluded based on: not being conducted to specifically influence weight; having combined exercise and diet interventions; being study protocols; including participants under 18 years of age; and not being published in English. Thirteen papers were included in the review, which were published between December 2013 and October 2019. Figure 1 details the search strategy, including the study selection process and reasons for exclusion. The characteristics of the excluded studies are summarized in Table 2.

### 3.2 | Interventions

Table 3 shows the characteristics of the included studies. In brief, participants in the pregnancy studies were recruited between 5- and 19-weeks' gestation and all interventions lasted between 15 and 30 weeks. All studies included singleton pregnancies and, other than

Pelaez et al.<sup>41</sup> and Ruiz et al.<sup>42</sup> where this information was not provided, all trials included both nulliparous and multiparous women. Participants in the postpartum studies were between 6-weeks and 1-year postpartum. Between 65% and 95% of women reported exclusive or partial breastfeeding. Postpartum interventions lasted between 40 days and 18 weeks. Baseline physical activity levels ranged from "unspecified," to sedentary, to physically active.

Exercise interventions initiated during pregnancy had the following characteristics: duration 50–90 min, frequency 3–5 times per week and moderate intensity; 55%–60% maximal heart rate, <60% or <70% age predicted maximum heart rate, <80% maximal capacity, 10–12 or 12–14 on the 6–20 Borg Scale, 10,000 daily steps. Interventions were predominantly aerobic, with some additional resistance exercises (e.g., bicep curls, arm side lifts, hamstring curls, bench presses). Six of the pregnancy interventions were performed in supervised groups, three interventions were performed in both group and individual settings and two were individual focused. One postpartum study involved a progressive resistance exercise program<sup>43</sup> and the other delivered an at-home active video game intervention.<sup>44</sup>

Most studies included two comparisons: exercise versus routine care (control). Pawalia et al.<sup>45</sup> and Renault et al.<sup>46</sup> had three comparison groups (diet and exercise, exercise and control) and Simmons et al.<sup>47</sup> had four comparison groups (diet and exercise, diet, exercise and control). As the aim of the review was to investigate the effects of exercise training on weight management, only the exercise and control data were considered. Of note, LeCheminant et al.<sup>43</sup> included an active control group and compared resistance training (intervention group) to flexibility training. Brik et al.<sup>48</sup> and Pawalia et al.<sup>45</sup> conducted follow-up measures at 6 weeks and 2 months postpartum, although only the pregnancy data was considered here. Simmons et al.<sup>47</sup> assessed outcomes at both 24–28- and 35–37-weeks' gestation; only the data at 35–37 weeks was considered here. Discrete measures, such as fat and lean body mass,<sup>44</sup> waist and hip circumference<sup>44,45</sup> the number of women who exceeded the 2009 IOM weight gain guidelines,<sup>42,46,49</sup> were not included in the analysis.

### 3.3 | Methodological quality

There was considerable variability in methodological quality across the trials (Table 4). According to the criteria outlined in the Cochrane's tool for assessing risk of bias,<sup>19</sup> all trials were randomised. The method used for allocation concealment was clearly reported in eight studies.<sup>42,46,47,49–53</sup> All studies, but one,<sup>44</sup> reported attrition rates and reasons for dropouts. Three studies<sup>43,50,51</sup> lost more than 20% of participants in the follow-up period and, therefore, the reporting bias (completeness of follow-up) was classed as inadequate. Brik et al.<sup>48</sup> withdrew participants who were not attending ≥70% of exercise sessions and subsequently saw a 29.2% dropout rate; as such the reporting bias was also ranked as inadequate. One study<sup>44</sup> did not report attrition rates, therefore it was assumed that all of the participants finished the trial. Dekker Nitert et al.<sup>49</sup> and Pawalia et al.<sup>45</sup> presented the results of the first 35 and 36 women,

TABLE 1 PICOS model of eligibility criteria

	Inclusion	Exclusion
Population	Healthy pregnant and postpartum women, free from any pregnancy-related complications or medical conditions or not currently taking any medications known to affect body weight or exercise performance Normal weight (BMI 18.50–24.99 kg/m <sup>2</sup> ) women, and women with overweight (BMI >25 kg/m <sup>2</sup> ) and obesity (BMI >30 kg/m <sup>2</sup> ). Primigravidas and multigravidas, and nulliparous, primiparas and multiparas women	Studies including women <18 years old Studies on underweight women (BMI <18.5 kg/m <sup>2</sup> ) and women at risk of giving birth to low birthweight babies (<2500 g) or insufficient gestational weight gain (<11 kg for normal weight women)
Intervention	Interventions involving exercise aimed to manage maternal weight during and following pregnancy, such as training programmes and counseling in any setting	Interventions not specifically designed to target or affect weight Interventions involving mothers of young children when the postpartum period was not specified Interventions involving a dietary component
Control	Group not receiving the intervention treatment or receiving routine antenatal or postnatal care	
Outcome	Change in body weight (kg) or change in BMI (kg/m <sup>2</sup> )	Any studies that reported outcomes other than change in body weight or BMI as a primary outcome
Study design	RCTs and quasi-randomised trials published in English using human participants	Reviews, abstracts from conference proceedings

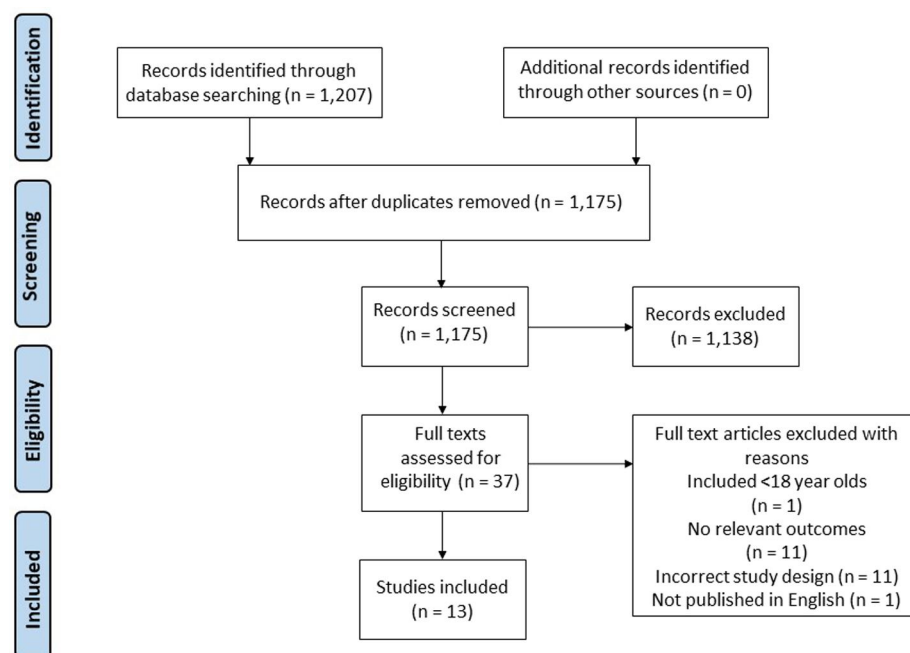


FIGURE 1 Flow of articles from identification to inclusion

respectively, who completed larger RCTs, therefore dropout rates were not calculated. Three pregnancy studies completed follow-up assessments at 6–8 weeks<sup>48,49</sup> and 2 months postpartum.<sup>45</sup> Most of the studies, except two,<sup>44,50</sup> reported full data sets. Both studies did not report maternal blood pressure data, and Tripette et al.<sup>44</sup> did not report data for glycated hemoglobin and high-density lipoprotein cholesterol.

After attrition, group sample size ranged from 35 to 962 in the pregnancy studies and 34<sup>44</sup> to 60<sup>43</sup> in the postpartum trials. All included studies performed a power calculation (accepted level of power ranged between 79% and 95%) to determine sample size. Table 5 shows the recruitment success of each study against their a

priori power calculation. Pawalia et al.<sup>45</sup> presented the results of the first 36 women that were enrolled in a larger study and Dekker Nitert et al.<sup>49</sup> presented the results of 35 women enrolled in the BAMBINO pilot RCT, therefore recruitment numbers are not presented here.

Only Garnæs et al.<sup>53</sup> reported that the CONSORT checklist had been used (Table 6). Table 6 presents information on the number of CONSORT criteria fulfilled in both the pregnancy and postpartum studies. Only one trial reported important changes to the methods after trial commencement (item 3b), presented both absolute and relative effect sizes for binary outcomes (item 17b) and presented the results of subgroup and/or adjusted analyses (item 18).<sup>31</sup> Only

TABLE 2 Reasons for excluding full-text studies

Study	Reason for exclusion
Aparicio et al. <sup>21</sup>	Study protocol outlining the methodology for the GESTAFIT, which aimed to assess the effects of an exercise intervention in pregnant women with overweight and obesity on maternal and fetal health markers
Barakat et al. <sup>22</sup>	The intervention did not intend to manage maternal weight gain during pregnancy or postpartum; rather to examine the impact of supervised exercise throughout pregnancy on the incidence of pregnancy-induced hypertension.
Bertz et al. <sup>23</sup>	The intervention did not intend to manage maternal weight gain during pregnancy or postpartum; rather to use data from the LEVA trial to evaluate the short- and long-term effects of the intervention on macronutrient intake and report the diet achieved with the dietary treatment in relation to the Nordic Nutrition Recommendations
Bisson et al. <sup>24</sup>	The intervention did not intend to manage maternal weight gain during pregnancy or postpartum; rather to evaluate whether a supervised exercise program during the 2 <sup>nd</sup> trimester of pregnancy results in higher physical activity levels throughout pregnancy in women with obesity
Da Silva et al. <sup>25</sup>	The intervention did not intend to manage maternal weight gain during pregnancy or postpartum; rather to evaluate the efficacy of the PAMELA RCT on preventing preterm birth and pre-eclampsia (primary outcomes) and other maternal and fetal outcomes
Daly et al. <sup>26</sup>	The intervention did not intend to manage maternal weight gain during pregnancy or postpartum; rather to evaluate whether a supervised exercise intervention for women with BMI $\geq 30$ kg/m <sup>2</sup> reduced fasting plasma glucose concentration at 24–28 weeks' gestation in the intervention group compared with women undergoing routine prenatal care
DeRosset et al. <sup>27</sup>	Combined diet and exercise intervention
Gesell et al. <sup>28</sup>	Combined diet and exercise intervention
Ghaderpanah et al. <sup>29</sup>	Not published in English
Harden et al. <sup>30</sup>	Combined diet and exercise intervention
Harrison et al. <sup>31</sup>	Combined diet and exercise intervention (HeLP-her Study)
Joshi et al. <sup>32</sup>	Combined diet and exercise intervention (RENEW Study)
Keller et al. <sup>33</sup>	Non-intervention study. The purpose of this study was to describe the correlates of overweight and obesity in postpartum Latinas in the first 6 months following childbirth
Kong et al. <sup>34</sup>	The intervention did not intend to manage maternal weight during pregnancy or postpartum; rather to increase moderate-intensity physical activity during pregnancy via a walking intervention
Nobles et al. <sup>35</sup>	The intervention did not intend to manage maternal weight during pregnancy or postpartum; rather to evaluate the impact of the B.A.B.Y. RCT on gestational diabetes risk
Rodriguez-Blanque et al. <sup>36</sup>	The intervention did not intend to manage maternal weight during pregnancy or postpartum; rather to investigate the influence of a water-based exercise program on the rate of spontaneous birth
Ronnberg et al. <sup>37</sup>	Study included under 18's
Ronnberg et al. <sup>38</sup>	Postpartum follow-up of an antenatal intervention
Seneviratne et al. <sup>39</sup>	The intervention did not intend to manage maternal weight gain during pregnancy or postpartum; rather to evaluate the effect of antenatal exercise on offspring birthweight (primary outcome) and other fetal and maternal outcomes in women with overweight and obesity
Wang et al. <sup>40</sup>	The intervention did not intend to manage maternal weight gain during pregnancy or postpartum; rather to investigate the effect of exercise on the incidence of gestational diabetes in pregnant women with overweight and obesity

Abbreviations: B.A.B.Y., Behaviors Affecting Baby and You; GESTAFIT, GESTation and FITness; HeLP- her, Healthy Lifestyle Program; LEVA, Lifestyle for Effective Weight loss during Lactation; PAMELA, Physical Activity for Mothers Enrolled in Longitudinal Analysis; RCT, randomised controlled trial; RENEW; Revolutionizing Exercise and Nutrition Everyday in Women.

TABLE 3 Characteristics of included studies (divided into pregnancy and postpartum studies)

	Study and setting	Population	Intervention	Weight change (kg) (mean $\pm$ SD)	Adherence rates (%)
Pregnancy studies	Bacchi et al. <sup>50</sup> Argentina	NW/OWI: <i>n</i> = 49C: <i>n</i> = 62	<i>Duration</i> : 85 sessions (~30 weeks) <i>Mode</i> : aquatic erobic and strengthening- exercises (SE)/ swimming <i>Frequency</i> : 55– 60 min 3 days/week <i>Intensity</i> : light-moderate intensity according to Borg rating of perceived exertion (RPE) scale <i>Delivery mode</i> : GroupC: Standard prenatal care	GWG:I: +12.7 $\pm$ 2.6C: +13.9 $\pm$ 4.3 <i>p</i> = NS	>85
	Barakat et al. <sup>51</sup> Spain	NW/OW/OBI: <i>n</i> = 107C: <i>n</i> = 93	<i>Duration</i> : ~30 weeks <i>Mode</i> : aerobic/SE <i>Frequency</i> : 55– 60 min 3 days/week <i>Intensity</i> : light-moderate intensity 55%–60% maximum heart rate (HRmax) <i>Delivery mode</i> : GroupC: Standard prenatal care, general nutrition and exercise counseling from healthcare provider, reported exercise levels once per trimester	GWG:I: +11.7 $\pm$ 4.1C: +13.7 $\pm$ 9.6 <i>p</i> = NS	>95
	Barakat et al. <sup>52</sup> Spain	NW/OWI: <i>n</i> = 234C: <i>n</i> = 222	<i>Duration</i> : 83–85 sessions (~30 weeks) <i>Mode</i> : aerobic/ SE <i>Frequency</i> : 55–60 min 3 days/week <i>Intensity</i> : light- moderate intensity <70% age predicted HRmax/RPE 12–14 <i>Delivery mode</i> : GroupC: Standard prenatal care, reported exercise levels once per trimester (by telephone)	GWG:I: +12.2 $\pm$ 3.7C: +13.3 $\pm$ 4.1 <i>p</i> = 0.005	$\geq$ 80
	Brik et al. <sup>48</sup> Spain	NW/OWI: <i>n</i> = 42C: <i>n</i> = 43	<i>Duration</i> : ~29 weeks <i>Mode</i> : aerobic/SE <i>Frequency</i> : 60 min 3 days/week <i>Intensity</i> : light- moderate intensity 55%– 60% HRmax <i>Delivery mode</i> : GroupC: Standard prenatal care, reported exercise levels (telephone interview)	GWG:I: +11.4 $\pm$ 4.2C: +11.2 $\pm$ 6.4NS	>70 (withdrawn from study if < 70)
	Dekker Nitert et al. <sup>49</sup> Australia	OBI: <i>n</i> = 19C: <i>n</i> = 16	<i>Duration</i> : ~22 weeks <i>Mode</i> : Individualized exercise plan meeting specified energy expenditure requirements based on personal preferences and ability <i>Frequency</i> : not stated <i>Intensity</i> : not stated <i>Delivery mode</i> : Group and individualC: Standard prenatal care	GWG:I: +7.87 $\pm$ 4.00C: +8.3 $\pm$ 6.1NS	NR
	Garnæs et al. <sup>53</sup> Norway	BMI >28 kg/ m <sup>2</sup> I: <i>n</i> = 38C: <i>n</i> = 36	<i>Duration</i> : ~24 weeks <i>Mode</i> : aerobic/SE <i>Frequency</i> : 60 min 3 days/week <i>Intensity</i> : <80% maximal capacity/RPE 12– 15 <i>Delivery mode</i> : Group and	GWG:I: +10.5C: +9.2NS	50



TABLE 3 (Continued)

Study and setting	Population	Intervention	Weight change (kg) (mean $\pm$ SD)	Adherence rates (%)
		individualC: Standard prenatal care		
Pelaez et al. <sup>41</sup> Spain	NW/OWI: <i>n</i> = 100C: <i>n</i> = 201	<i>Duration</i> : 70–78 sessions ( $\geq 24$ weeks) <i>Mode</i> : aerobic/SE <i>Frequency</i> : 60–65 min 3 days/week <i>Intensity</i> : 65%–70% age-predicted HRmax/RPE 12–14 <i>Delivery mode</i> : GroupC: Standard prenatal care, general nutrition and physical activity counseling from healthcare professionals	GWG:I: $+11.5 \pm 3.5$ C: $+13.7 \pm 4.1$ <i>p</i> = 0.01	96
Pawalia et al. <sup>45</sup> India	NW/OWC: <i>n</i> = 12E: <i>n</i> = 12DE: <i>n</i> = 12	<i>Duration</i> : ~24 weeks <i>Mode</i> : aerobic/SE <i>Frequency</i> : 60–90 min 2 days/week (supervised) 3 days/week (unsupervised) <i>Intensity</i> : RPE 12–14 <i>Delivery mode</i> : Group and individualC: Standard prenatal care	GWG:C: $7.58 \pm 4.29$ E: $5.75 \pm 4.35$ DE: $5.83 \pm 3.68$ NS	NR
Renault et al. <sup>46</sup> Denmark	OBC: <i>n</i> = 134E: <i>n</i> = 125DE: <i>n</i> = 130	<i>Duration</i> : ~20 weeks <i>Mode</i> : walking <i>Frequency and intensity</i> : 10,000 steps per day <i>Delivery mode</i> : IndividualC: Standard prenatal care	GWG (median/range):C: 10.9 (–4.4 to 28.7)E: 9.4 (–3.4 to 28.2)DE: 8.6 (–9.6 to 34.1) <i>p</i> = 0.024	NR
Ruiz et al. <sup>42</sup> Spain	NW/OW/OBI: <i>n</i> = 481C: <i>n</i> = 481	<i>Duration</i> : 85 sessions (~30 weeks) <i>Mode</i> : aerobic/SE <i>Frequency</i> : 50–55 min 3 days/week <i>Intensity</i> : <60% age-predicted HRmax/RPE 10–12 <i>Delivery mode</i> : GroupC: Standard prenatal care, general nutrition and physical activity counseling	GWG:I: $11.9 \pm 3.8$ C: $13.2 \pm 4.3$ <i>p</i> < 0.001	>97
Simmons et al. <sup>47</sup> United Kingdom, Ireland, Netherlands, Austria, Poland, Italy, Spain, Denmark, Belgium	OBC: <i>n</i> = 79D: <i>n</i> = 76E: <i>n</i> = 74DE: <i>n</i> = 75	<i>Duration</i> : $\geq 15$ weeks <i>Mode</i> : aerobic/SE and counseling <i>Frequency and intensity</i> : 30 min per day (progressing to 60 min if possible) moderate-vigorous activity on at least 5 days per week (preferably 7). <i>Delivery mode</i> : IndividualC: Standard prenatal care	GWG:DE: $6.5 \pm 3.8$ E: $8.5 \pm 5.0$ D: $8.0 \pm 4.7$ C: $8.8 \pm 4.7$ <i>p</i> < 0.05	NR
Postpartum studies	LeCheminant et al. <sup>43</sup> USA <i>n</i> = 30C: <i>n</i> = 30	<i>Duration</i> : 18 weeks <i>Mode</i> : resistance training <i>Frequency</i> : 2 days/week <i>Intensity</i> : progressive through 18 weeks <i>Delivery mode</i> : IndividualC: Flexibility training (active control group)	Pre- to post-intervention BMI:I: ~93 $25.0 \pm 3.4$ to $24.0 \pm 3.5$ C: $27.1 \pm 3.9$ to $26.3 \pm 4.2$ NS	

(Continues)



TABLE 3 (Continued)

Study and setting	Population	Intervention	Weight change (kg) (mean $\pm$ SD)	Adherence rates (%)
Tripette et al. <sup>44</sup> Japan	NW/OWI: <i>n</i> = 17C: <i>n</i> = 17	<i>Duration</i> : 40 days <i>Mode</i> : active video games <i>Frequency</i> : 30 min daily <i>Intensity</i> : 10 MET·hr·wk <sup>-1</sup> <i>Delivery mode</i> : IndividualC: No intervention	WL:I: $-2.2 \pm 0.9$ C: $-0.5 \pm 0.7$ <i>p</i> < 0.001	NR

Abbreviations: BMI, body mass index; C, control; D, diet; DE, diet and exercise; E, exercise; GWG, gestational weight gain; HRmax, maximum heart rate; I, intervention; NS, non-significant; NW, normal weight; NR, not reported; OB, obese; OW, overweight; RPE, rating of perceived exertion; SE, strengthening exercises; WL, weight loss.

TABLE 4 Cochrane Collaboration's tool for assessing risk of bias (adapted from Higgins and Greene<sup>64</sup>)

Study	Selection bias		Performance/detection bias	Blinding	Attrition/reporting bias				Bias quality
	Randomised	Allocation concealment			Follow-up	AR	R	DS	
Bacchi et al. <sup>50</sup>	A	A	A		C	Y	Y	F	Unclear
Barakat et al. <sup>51</sup>	A	A	B		C	Y	Y	F	High
Barakat et al. <sup>52</sup>	A	A	A		A	Y	Y	F	Unclear
Brik et al. <sup>48</sup>	A	B	B		C	Y	Y	F	High
Dekker Nitert et al. <sup>49</sup>	A	A	B		N/A	N/A	N/A	P	Unclear
Garnæs et al. <sup>53</sup>	A	A	A		A	Y	Y	F	Unclear
Pelaez et al. <sup>41</sup>	A	B	B		A	Y	Y	F	High
Pawalia et al. <sup>45</sup>	A	B	B		N/A	N/A	N/A	F	High
Renault et al. <sup>46</sup>	A	A	A		A	Y	Y	F	Unclear
Ruiz et al. <sup>42</sup>	A	A	B		A	Y	Y	F	High
Simmons et al. <sup>47</sup>	A	A	A		A	Y	Y	F	Unclear
LeCheminant et al. <sup>43</sup>	A	B	A		C	Y	Y	F	High
Tripette et al. <sup>44</sup>	A	B	B		A	N	N	P	High

Note: Overall bias quality calculated as follows; LOW- satisfies all of allocation concealment, blinding and follow-up, UNCLEAR- satisfies 2 out of 3, HIGH- satisfies 0/1 out of 3.

Abbreviations: AR, attrition rates; DS, data set; F, full; N, not reported; N/A, not applicable; P, partial; R, reasons for drop-outs; Y, reported.

	Recruitment success	% Recruited of initial prediction
Bacchi et al. <sup>50</sup>	111/94	118.1
Barakat et al. <sup>51</sup>	251/266	94.3
Barakat et al. <sup>52</sup>	520/340	152.9
Brik et al. <sup>48</sup>	120/90	133.3
Garnæs et al. <sup>53</sup>	91/150	60.7
LeCheminant et al. <sup>43</sup>	60/60	100.0
Pelaez et al. <sup>41</sup>	345/308	112.0
Renault et al. <sup>46</sup>	425/420	101.2
Ruiz et al. <sup>42</sup>	962/962	100.0
Simmons et al. <sup>47</sup>	436/440	99.1
Tripette et al. <sup>44</sup>	34/34	100.0

TABLE 5 Recruitment success of included studies

Note: Data presented as recruited/predicted based on sample size calculations.

TABLE 6 CONSORT 2010 checklist of information to include when reporting a randomised controlled trial (adapted from Schulz et al.<sup>20</sup>)

Study	1	1	2	2	3	3	4	4	4	5	6	7	7	8	8	9	10	11	12	12	13	13	14	14	15	16	17	17	18	19	20	21	22	23	24	25
	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
Bacchi et al. <sup>50</sup>	+	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Barakat et al. <sup>51</sup>	-	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	-	-	-	-	+	+	-	-	+	+	+	+	+	-	-	+	+	+	-	-
Barakat et al. <sup>52</sup>	+	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	-	-	-	+	+	+	+	+	+	+	+	+	+	-	-	+	+	+	+	-
Brik et al. <sup>48</sup>	+	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	+	+	+	+	-
Dekker Nitert et al. <sup>49</sup>	-	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	-	-	-	+	+	+	-	-	+	+	+	+	+	-	-	+	+	+	+	+
Garnæs et al. <sup>53</sup>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Pelaez et al. <sup>41</sup>	+	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Pawalia et al. <sup>45</sup>	+	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Renault et al. <sup>46</sup>	+	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Ruiz et al. <sup>42</sup>	+	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Simmons et al. <sup>47</sup>	-	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
LeCheminant et al. <sup>43</sup>	-	-	+	+	-	-	+	+	+	+	+	+	+	+	+	+	-	-	-	+	+	+	-	-	+	+	+	+	+	-	-	+	+	+	-	-
Triplette et al. <sup>44</sup>	-	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	-	-	-	+	+	-	-	+	+	+	+	+	+	-	-	+	+	+	-	+

Note: + = stated, - = not stated. NA, not applicable. Items 3b and 18 were only applicable to Garnæs. Item 7b was only applicable to Barakat et al.<sup>51</sup>.

Barakat et al.<sup>51</sup> provided an explanation of any interim analysis and stopping guidelines.

Regarding the pregnancy studies, Bacchi et al.<sup>50</sup> fulfilled 26 of 35 criteria (74%), Barakat et al.<sup>51</sup> fulfilled 19 out of 35 criteria (54%), Barakat et al.<sup>52</sup> fulfilled 24 out of 35 criteria (69%), Brik et al.<sup>48</sup> fulfilled 24 out of 35 criteria (69%) and Dekker Nitert et al.<sup>49</sup> fulfilled 16 out of 35 criteria (46%). Furthermore, Garnæs et al.<sup>53</sup> fulfilled 34 out of 34 criteria (100%; adjusted for removal of 7b- stated as N/A), Pelaez et al.<sup>41</sup> fulfilled 22 out of 35 criteria (63%), Pawalia et al.<sup>45</sup> fulfilled 18 out of 35 criteria (51%), Renault et al.<sup>46</sup> fulfilled 25 out of 35 criteria (71%), Ruiz et al.<sup>42</sup> fulfilled 22 out of 35 criteria (63%) and Simmons et al.<sup>47</sup> fulfilled 24 out of 35 criteria (69%).

In the postpartum studies, LeCheminant et al.<sup>20,43</sup> fulfilled 16 out of 35 criteria (46%) and Tripette et al.<sup>21,44</sup> fulfilled 13 out of 35 criteria (37%). Only one trial reported important changes to the methods after trial commencement (item 3b), presented both absolute and relative effect sizes for binary outcomes (item 17b) and presented the results of subgroup and/or adjusted analyses (item 18).<sup>52</sup> Only Barakat et al.<sup>51</sup> provided an explanation of any interim analysis and stopping guidelines.

## 4 | DISCUSSION

The aim of the current systematic review was to update the review published by Elliott-Sale et al.<sup>17</sup> investigating the effects of an exercise intervention compared to routine care or another intervention on GWG in normal weight women, and women with overweight and obesity. Tables 7 and 8 show a comparison between the original<sup>17</sup> and updated reviews, regarding percentage of studies that were deemed successful (i.e., significant reductions in GWG or greater postpartum weight loss when compared to a control or other intervention). There was large variation in the population characteristics and exercise modality, frequency, duration and intensity between the included studies in both reviews, which likely affected the magnitude and direction of the findings.

In the current review, 13 studies were identified that fulfilled the inclusion criteria over an 8-year period compared with five studies identified in the original review over a 23-year period. It is possible that, because of recent evidence showing that exercise is safe during pregnancy without compromising the health of the baby,<sup>54-56</sup> researchers have become more confident about designing and implementing exercise strategies during pregnancy. As such, it is evident that more work is now being completed that aims to understand the effects of exercise interventions on weight management during pregnancy.

The updated review results were compared to the findings from other systematic reviews with a similar research aim. Similar to the results of the current study whereby 45% of studies were successful in lowering GWG, Chan et al.<sup>57</sup> showed that five studies (36%) showed significantly lower GWG among intervention participants when compared to standard antenatal care. Muktabhant et al.<sup>58</sup> also performed an updated Cochrane Review from 2012,<sup>59</sup> and concluded

**TABLE 7** Main findings and comparisons between original and updated reviews in pregnancy studies. Data presented as *n*/total (% of total)

	Original review	Updated review
Weight status		
NW	2/3 (66.6)	7/11 (63.6)
OW	3/3 (100)	8/11 (72.7)
OB	1/3 (33.3)	6/11 (54.5)
Intervention delivery		
Group	1 (33.3)	5/11 (45.5)
Individual	0 (0.0)	2/11 (18.2)
Combined	2 (66.6)	3/11 (27.3)
Intervention success	2/3 (66.6)	5/11 (45.5)
Reported adherence	3/3 (100)	7/11 (63.6)
High attrition	1/3 (33.3)	3/9 (33.3)

Note: Intervention success was defined as "significantly less gestational weight gain in the intervention group compared to the control group". High attrition was defined as ">20% dropouts". In the updated review, attritions rates were reported as a score out of 9, rather than 11, as Dekker Nitert et al.<sup>49</sup> and Pawalia et al.<sup>45</sup> presented results of first 35 and 36 women, who completed larger RCTs.

Abbreviations: NW, normal weight; OW, overweight; OB, obese.

**TABLE 8** Main findings and comparisons between original and updated reviews in postpartum studies. Where appropriate, data presented as *n*/total

	Original review	Updated review
Weight status		
NW	1/2	2/2
OW	2/2	2/2
OB	1/2	1/2
Intervention delivery		
Group	0/2	0/2
Individual	2/2	2/2
Combined	0/2	0/2
Intervention success	0/2	1/2
Reported adherence	1/2	1/2
High attrition	0/2	1/2

Note: Intervention success regarded as significantly greater postpartum weight loss in the intervention group compared to the control group. High attrition defined as >20% dropouts. Tripette et al.<sup>44</sup> did not report attrition rates, therefore it was assumed that all of the participants finished the trial.

Abbreviations: NW, normal weight; OB, obese; OW, overweight.

that, of the exercise interventions (*n* = 20) included in their review, moderate-intensity exercise appears to be important in controlling weight during pregnancy, although most included studies were conducted in developed countries, and it is unclear if their findings were

applicable to developing countries. In the current study, the majority of included studies were also conducted in developed countries (9/11) and results concurrently showed that moderate intensity exercise was crucial in encouraging antenatal weight management. As such, investigations in developing countries are still required. Finally, Campbell et al. (n.d.)<sup>60</sup> reviewed 39 studies to determine the most effective types of lifestyle interventions for weight management during pregnancy and concluded that the available evidence was weak, with a lack of agreement between studies employing similar interventions. As such, similar to the conclusion of Elliott-Sale et al.<sup>17</sup> it is still not possible to recommend the optimal exercise intervention design to deliver during pregnancy due to large disparities in the study design and findings of previous studies exploring the effects of exercise on GWG.<sup>57-60</sup>

In the postpartum period, results from the current study showed that one of two included studies (50%) reported significant reductions in weight when compared to a usual care group. In agreement with results from the current study, only three of six studies (50%) in a previous systematic review reported a significant reduction in postpartum weight from pre- to post-intervention.<sup>61</sup> Nascimento et al.<sup>62</sup> conducted a systematic review and meta-analysis of the effect of exercise on postpartum weight and described that exercise programs including the use of objective measurements, such as heart rate monitors or pedometers, were effective in significantly reducing postpartum weight. Neither of the postpartum studies included in our review utilized objective measures of physical activity, however previous work by our group has also demonstrated that a weight loss intervention, including the use of an activity tracker, was effective in promoting post-intervention weight loss (Hanley et al., unpublished data). Collectively, from the studies included in our updated review and previous conclusions drawn by Dodd et al.<sup>61</sup> and Nascimento et al.,<sup>62</sup> there exists large heterogeneity in study designs, and future work must identify and build on the successful components of intervention strategies (e.g., inclusion of objective measures of physical activity) delivered to postpartum women.

In the studies aimed at managing GWG, there were large disparities in the exercise modality, frequency and duration, although moderate intensity exercise was consistently employed. The intensity of exercise seems crucial to encourage positive post-intervention outcomes. For example, Barakat et al.<sup>51</sup> employed a light-moderate intensity program set at 55%–60% of maximum heart rate and showed no difference in GWG between intervention and control groups following a 30-week program, but showed significant differences between groups in 2019 following an identical length program but set at  $\leq 70\%$  of maximum heart rate.<sup>52</sup> It also appears that exercise advice needs to be specific, as general advice, for example, walking for a minimum of 30 min/day on 4 days of the week did not reduce GWG compared to standard care.<sup>45</sup> Renault et al.<sup>46</sup> employed a walking program where women were set a specific target of 10,000 steps/day and experienced significantly less GWG than women in the control group. Renault et al.<sup>46</sup> delivered the shortest intervention of all included pregnancy studies, demonstrating that specific,

measurable goal orientated intervention approaches that encourage greater internal motivation may be most efficacious in delivering successful outcomes. All combined group and individual-based intervention approaches led to non-significant differences in GWG between intervention and control groups,<sup>45,49,52</sup> which could be due to the generalised, non-specific, nature of these intervention designs. For example, a group education session providing written leaflets on exercise and nutrition and the creation of exercise plans based on energy expenditure calculated from the Pregnancy Physical Activity Questionnaire (PPAQ) has demonstrated non-significant differences in post-intervention GWG outcomes between intervention and control groups.<sup>45</sup>

Only one of the two included studies was effective in reducing postpartum weight,<sup>44</sup> when comparing the intervention and control groups. Tripette et al. used a 40-day active video gaming protocol set at an intensity of  $10 \text{ MET} \cdot \text{h} \cdot \text{week}^{-1}$ , while LeCheminant et al.<sup>43</sup> used an 18-week progressive resistance training protocol. Although Tripette et al.<sup>44</sup> showed a significant reduction in postpartum weight in the intervention versus the control group over the 40-day period, the short-term nature of the intervention makes it difficult to draw conclusions on the long-term effect on weight management. In addition, the intervention involved a Nintendo Wii, meaning that women would need to purchase this equipment if they wished to continue the exercise program beyond the trial period, which has a cost implication for the participants. Furthermore, while Tripette et al.<sup>44</sup> showed positive correlations between total playing time and playing frequency with weight loss, higher injury rates in those individuals with longer playing times were also reported, which raises concerns regarding the supervision and instruction provided to participants. LeCheminant and colleagues<sup>43</sup> supervised all exercise sessions during the first month of their 4-month intervention and at least one session per week in months two, three and four. Mild injuries were shown in five participants, which did not persist for longer than one to 2 weeks. Post-intervention, there was, however, no significant difference in postpartum weight loss between the intervention and active control participants suggesting that the intervention may not have been of a sufficient frequency or intensity to elicit significant responses. LeCheminant et al.<sup>43</sup> employed an active control group to minimize study withdrawals, but still experienced an overall dropout rate of 26.7%, which was more than any of the pregnancy studies. The observed high attrition rate may be explained by the finding that postpartum women identify a multitude of barriers when attempting to engage in a healthy lifestyle, including a lack of time and childcare,<sup>63</sup> and, as such, may feel overwhelmed and unable to take part in exercise interventions during this time. The inclusion of formative work, specifically involving women in the design of exercise interventions, may allow the development of strategies to assist women in overcoming these barriers, and ultimately encourage better adherence and positive intervention outcomes. For example, Tripette et al.<sup>44</sup> employed a home-based program whereby participants could complete exercise sessions at a time suitable to them while attending to the needs and

routine of the baby. As such, flexible home-based exercise programs, with necessary support, may be more appropriate for the postpartum population.

There was considerable variability in the methodological quality of included trials. The use of the CONSORT checklist<sup>20</sup> highlighted that, in the pregnancy studies, studies ranged from reporting 16 of the 35 included criteria<sup>49</sup> to all criteria.<sup>52</sup> Garnæs et al.<sup>53</sup> were the only group to report the use of the CONSORT checklist. The postpartum studies covered 13<sup>44</sup> and 17<sup>43</sup> of the required criteria. The use of the Cochrane bias prevention framework<sup>19</sup> highlighted that seven of the 13 included studies were assessed as having a high risk of bias, six were assessed as unclear and none were assessed as low. All studies stated that trials were randomised however, only five studies described both blinding and allocation concealment strategies. As such, there still exists the need for future trials that conform to methodological quality (e.g., CONSORT) and bias prevention frameworks (e.g., Cochrane).

Our review is comprehensive in its approach, as it covers women of all BMI status (underweight, normal weight, overweight, obese), during and following pregnancy, unlike previous reviews that have focused solely on either pregnancy or the postpartum period.<sup>57,58,61,62</sup> Crucially, unlike previous reviews that presented findings on various maternal and neonatal outcomes,<sup>58,60</sup> this review focused solely on the effect of exercise interventions on weight management during and following pregnancy, and as such we are able to provide more in-depth, practical advice to healthcare professionals working to improve exercise engagement in pregnant and postpartum women. Specifically, the information presented in Table 3 provides practitioners with guidance related to the exercise type, intensity, frequency, duration, and delivery mode of interventions that were or were not successful in eliciting significant reductions in GWG and greater postpartum weight loss when compared to a control group. The conclusions of previous reviews state that, for example, moderate intensity exercise appears to be important in controlling weight<sup>59</sup> and that interventions including compulsory exercise classes are effective in controlling weight during pregnancy,<sup>58</sup> yet these conclusions are vague and it is unclear how exercise classes can ever be made compulsory. Nevertheless, while a sole focus upon the effects of exercise enables a highly stringent search and analysis strategy, it is limited to providing evidence for exercise interventions only, while some women will likely prefer to focus on both diet and physical activity to encourage weight management. Furthermore, a meta-analysis was outside the scope of the PhD work in which this review was conducted, as such it was not possible to draw comparisons with the results of the original meta-analysis.<sup>17</sup>

## 5 | CONCLUSION

Exercise during pregnancy had mixed effects on GWG, as non-significant differences were observed between the intervention and control groups in 6 of the 11 included studies. In the postpartum

period, exercise significantly enhanced weight loss in one of the two included studies. Owing to the conflicting results between the included studies, it is very difficult to conclude the most effective or appropriate exercise program during pregnancy and in the postpartum period. It appears, however, that antenatal and postnatal exercise interventions must be highly supported and deliver specific, goal-orientated advice. It is evident that attrition is an issue in postpartum studies involving exercise interventions, and, as such, future work must look to develop strategies to minimize participant withdrawal and effectively increase long-term physical activity levels. Furthermore, in line with the conclusions made by Elliott-Sale et al.,<sup>17</sup> there still exists a need for future RCTs that comply with methodological quality (e.g., CONSORT) and bias prevention frameworks (e.g., Cochrane) to accurately determine efficacious approaches when designing and delivering exercise interventions to encourage weight management in pregnant and postpartum women. The findings from this review should be incorporated into standard antenatal and postpartum care to encourage appropriate GWG and postpartum weight loss through physical activity.

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## CONFLICT OF INTEREST

The authors declared no conflict of interest.

## AUTHOR CONTRIBUTIONS

Stephanie J. Hanley, Elise Sibbick and Kirsty J. Elliott-Sale conducted the study selection search. Stephanie J. Hanley drafted the article and Kirsty J. Elliott-Sale provided substantial input. Elise Sibbick, Ian Varley and Craig Sale reviewed and edited the manuscript and all authors read and approved the final version.

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