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Obesity Prevention/Pregnancy

Effective strategies for weight loss in post-partum women: a systematic review and meta-analysis

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Summary

Post-partum weight loss is critical to preventing and managing obesity in women, but the results from lifestyle interventions are variable and the components associated with successful outcomes are not yet clearly identified. This study aimed to identify lifestyle intervention strategies associated with weight loss in post-partum women. MEDLINE, EMBASE, PubMed, CINAHL and four other databases were searched for lifestyle intervention studies (diet or exercise or both) in post-partum women (within 12 months of delivery) published up to July 2014. The primary outcome was weight loss. Subgroup analyses were conducted for self-monitoring, individual or group setting, intervention duration, intervention types, the use of technology as a support, and home- or centre-based interventions. From 12,673 studies, 46 studies were included in systematic review and 32 randomized controlled trials were eligible for meta-analysis (1,892 women, age 24–36 years). Studies with self-monitoring had significantly greater weight lost than those without (−4.61 kg [−7.08, −2.15] vs. −1.34 kg [−1.66, −1.02], $P = 0.01$ for subgroup differences). Diet and physical activity when combined were significantly more effective on weight loss compared with physical activity alone (−3.24 kg [−4.59, −1.90] vs. −1.63 kg [−2.16, −1.10], $P < 0.001$ for subgroup differences). Lifestyle interventions that use self-monitoring and take a combined diet-and-exercise approach have significantly greater weight loss in post-partum women.

Keywords: lifestyle interventions, post-partum women, weight gain, weight loss.

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Introduction

A woman's main child-bearing years (25–34 years) hold the highest risk of weight gain compared with men or women of other age groups (1). Gestational weight gain and post-partum weight retention contribute significantly to female overweight and obesity (2) – two-thirds of women weigh more than their pre-pregnancy weight at 6 months post-partum (3). Among low-income post-partum mothers, up to 75% of women are heavier at 1 year post-partum compared with their pre-pregnancy weight (4). The average pregnancy weight retention ranges from 0.5 kg (5) to 4 kg (6,7). However, 14–25% of women who gain significant amounts of weight during pregnancy will retain more than 4.5 kg post-natally (2,7).

The short- and long-term outcomes of holding onto excess weight after pregnancy for mothers and their offspring are not without consequence. Retaining 3 or more body mass index (BMI) units during a 2-year period between consecutive births has a greater risk of adverse pregnancy outcomes in the subsequent pregnancy including stillbirth and large-for-gestational-age birth, independent of pre-pregnancy weight (8). In the longer term, inability to return to pre-pregnancy weight in the post-partum period

greatly increases the future risk of developing obesity. In the 10-year period after pregnancy, women who do not return to their pre-pregnancy weight by 6 months post-partum gained 8.4 kg compared with 2.4 kg gain in those who did (3). Longer term studies with 15 years follow-up after delivery supported this finding with only 35% of overweight women returning to within 1.5 kg of their pre-pregnancy weight compared with over 60% of normal weight women (9). This weight gain trajectory has important health implications such as increasing the risk of cardiovascular and metabolic diseases (10).

Post-partum women are ready and motivated to lose weight (11–13) with half of normal weight and around 80% of overweight and obese women planning to seek weight loss information at 4 months after delivery (14). However, challenges and barriers such as the lack of time and energy due to the demands of a newborn, the prioritization of a child's care over a mother's and the lack of social support can reduce a mother's ability to engage in lifestyle modification (11,13,15). Lifestyle interventions involving diet, exercise or both are moderately effective in producing 1.7 –2.5 kg weight loss in women up to 24 months post-partum (16–19). Nonetheless, the range of average weight loss achieved is wide, spanning from –13 kg (20) to +0.75 kg (21) and this may be due to different strategies being used to achieve lifestyle change.

Best-practice guidelines exist to support the delivery of behaviour change for the general population (22). They cover areas such as suitable theoretical approaches and practical delivery components and typically underpin weight loss interventions. In the general population, self-monitoring is an important construct built into long-term weight management (23) but its effect on post-partum weight loss has been inconsistent (20,24). Similarly, no clear consensus exists on whether individual or group interventions are more effective for these women (20,21,25,26). Providing support via phone or Internet may address a known barrier in this population (childcare availability) but its effectiveness compared with conventional methods is unclear (27–30). The lack of clarity around delivery of programmes in post-partum women means that there may be specific aspects that are critical to success in this population that are not present in the general population.

Little has been done to deconstruct lifestyle modification interventions and to identify the core components associated with greater weight loss success in post-partum women. Highly effective interventions exist and suggest that post-partum women can achieve clinically significant weight loss with the appropriate support. It is therefore important that the elements contributing to these successes are understood for wider implementation and design of effective interventions.

Accordingly, this study's objective was to determine the effect of various lifestyle intervention components (intervention type and duration, use of self-monitoring, delivery format, and delivery medium) on weight loss in post-partum women using a systematic review and meta-analysis approach.

Methods

The systematic review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement for reporting systematic reviews and meta-analyses (31).

Data sources and searches

A comprehensive search of the literature was conducted using Embase, Ovid MEDLINE, CINAHL, PsycINFO, PubMed, Cochrane Central Register of Controlled Trials and Cochrane Pregnancy and Childbirth Group Trials Register. Searches were carried out in July 2014 and were not limited by year. MeSH and free key words included post-partum period, post-partum, post-natal, lactating, diet, exercise, weight loss. An example of search strategy for MEDLINE is provided in Supporting Information Table S1. Studies were not limited to English and translations were sought, where possible. Studies were limited to peer-reviewed journals and human studies published up until 18 July 2014 across all databases.

Study selection

Intervention studies involving modification of diet or physical activity or both for women in their first year post-partum were included. Allergen avoidance studies, acute studies (e.g. post-exercise breast milk composition) and supplement trials (e.g. high protein supplements, fish oil, margarine, zinc) were excluded. Reviews, conference abstracts, letters, commentaries and case study reports were also excluded. Interventions commencing during pregnancy were excluded except for that included a post-partum group who could be independently assessed, which is consistent with our study aims. There were no limitations placed on length of intervention, maternal age, BMI or parity. Two reviewers (S.L. and H.B., S.L. and S.O'R.) independently screened and selected the articles that met the selection criteria of this review. Discrepancies were resolved by consensus.

Data extraction and quality assessment

The characteristics of the study (author, year of publication, study location, study design, sample size), participants (sampling frame, age, medical history, diet history, physical activity status, breastfeeding status), intervention (type, duration, use of self-monitoring, individual or group

setting, use of phone or Internet, location), attrition rate and outcomes (body weight, BMI, energy intake, fat intake, physical activity) were extracted from included studies. At least two attempts were made to contact the authors seeking clarification on methodology or obtaining additional outcome data in studies which otherwise fulfilled selection criteria. Two reviewers (S.L. and H.B., S.L. and S.O'R.) independently extracted the data and differences were resolved by consensus.

Studies were assessed for quality according to the Cochrane Collaboration Tool for Assessing Risk of Bias. Studies were assessed on their sequence generation, allocation concealment, blinding of participants, outcome assessments, completeness of outcome data, selective outcome reporting and other potential sources of bias. An overall risk of bias was given to the studies with the following definition: 'low risk' (four low ratings and no high ratings), 'medium risk' (less than four low ratings and one high rating) and 'high risk' (two or more high ratings). Two authors (S.L. and H.B., S.L. and S.O'R.) independently assessed the quality of the studies, and any discrepancies were resolved by consensus.

Data synthesis and analysis

The primary outcome of this review was change in body weight. Randomized controlled trial (RCT) results were combined for the meta-analysis using the inverse variance random-effects model (DerSimonian and Laird method) due to clinical and/or statistical heterogeneity (32). Outcomes were expressed as mean difference or standardized mean difference with 95% confidence interval (CI). Heterogeneity between the studies was examined by chi-square tests for significance ($P < 0.1$ was considered statistically significant). Inconsistency between the studies was quantified using I^2 tests ($I^2 < 25\%$ was considered low heterogeneity, $I^2 > 50\%$ was considered substantial heterogeneity). A sensitivity analysis was performed to exclude studies in which the control group received an exercise or dietary intervention (33–36). Subgroup analyses were conducted on the primary outcome (change in body weight) to assess heterogeneity due to intervention characteristics (type, duration, use of self-monitoring individual or group setting, use of phone or Internet, home-based intervention). A funnel plot was conducted to assess publication bias in analyses with studies of 10 or more. Data analyses were performed using RevMan 5.3 (2013) (The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark).

Results

Identification of studies

A total of 12,673 articles were identified, as shown in Fig. 1. After initial exclusion, based on titles and abstracts, 118 full texts were considered. Of these, 61 papers met the inclusion criteria for this review. Due to duplicate reporting, these papers represented 46 studies and all studies were included. Of these, 33 were RCTs and included in the meta-analysis.

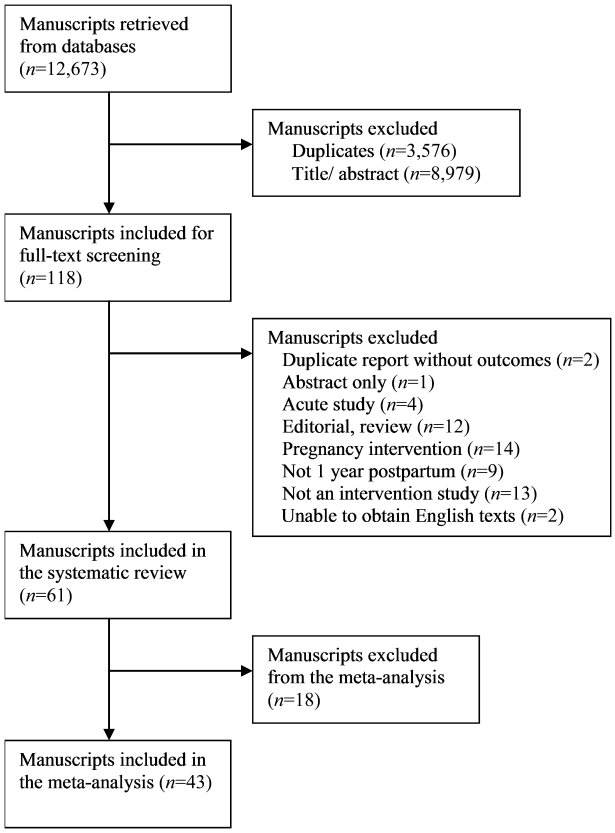

Figure 1 Flow diagram of included studies.

Study characteristics

The characteristics of the included studies are summarized in Table 1, six were single-arm interventions (37–42), seven were non-RCTs (35,43–50) and 33 were RCTs (20,21,24–30,33–36,51–83). Most studies were conducted in developed countries: Australia ($n = 6$); USA ($n = 24$); Taiwan ($n = 4$); Canada ($n = 3$); and Austria, Finland, Greece, Netherlands, Sweden, Japan and UK ($n = 1$ for each country) (Table 1). China and Thailand were the locations for the two studies conducted in developing countries. Attrition rates were reported in 37 studies, they ranged from 0% (51) to 42% (20) and the median was 17%.

Participants

Participants were recruited from clinics, hospitals, general practices, community centres or via public advertisements.

Table 1 Characteristics of included studies

Study	Study design	Recruitment, post-partum age, attrition rate (AR)	Study description	Diet, exercise and medical history	Intervention duration
Aittasalo *et al.* (43), Kinnunen *et al.* (44), Mustila *et al.* (45), Finland	Controlled trial	Maternal and child healthcare clinics; 2 months post-partum AR: 4%	Diet + physical activity counselling integrated into routine visits vs. control	Exclusion criteria: under 18 years, type 1 or 2 diabetes mellitus, twin pregnancy, otherwise problematic pregnancy, physical disability, substance abuse, treatment or clinical history of any psychiatric illness	8 months
Albright *et al.*, USA (37)	Pre-test-post-test	Non-profit organization that educates new mothers about infant care and parenting; 3–12 months post-partum	Social cognitive theory (SCT)/Transtheoretical model (TTM)-based physical activity counselling	Sedentary. Free of chronic diseases, not pregnant and free of medical conditions that would limit moderate intensity physical activity	2 months
Armstrong and Edward, Australia (51)	RCT	Gold Coast region of Queensland, by recommendations fr health professionals or from advertisement 6 weeks–12 months post-partum AR:0%	Pram pushing plus social session vs. control	Edinburgh Postnatal Depression Score (EPDS) ≥ 12; no medical condition that would prevent regular aerobic exercise, clearance on physical activity questionnaire to ensure ability to undertake exercise programme	12 weeks
Bertz *et al.* (27,52); Brekke *et al.* (25); Huseinovic *et al.* (53), Sweden	RCT	Antenatal clinics in Gothenburg 8–12 weeks post-partum, intend to breastfeed for 6 months AR: 16%	Diet vs. exercise vs. combined vs. usual care	Self-reported pre-pregnancy BMI (in kg m^{-2}) of 25–35, non-smoking, singleton term delivery, intention to breastfeed for 6 months, providing <20% of infant energy intake as complementary foods, birth weight of infant >2,500 g, and no illness in the mother or infant	12 weeks
Cahill *et al.*, USA (38)	Pre-test-post-test	Special Supplemental Nutrition Program for Women, Infants, and Children clinics, doctors' offices, and neighbourhood center. 0–4 months post-partum	SCT-based programme for low-income mothers for weight loss	BMI > 25; not participated in previous weight loss studies, absence of pregnancy and diabetes	8 weeks
Colleran *et al.*, USA (54)	RCT	Local obstetricians office <3 weeks post-partum Fully breastfeeding AR:13%	Diet + exercise programme and wait-list control	<3 days a week of structured physical activities in past 3 months; Exclusions: smoking in past 6 months, Caesarean section, medical conditions that affected hormone levels, or for whom exercise was contraindicated	16 weeks
Cramp and Brawley, Canada (33,55)	RCT	From community newspaper advertisement; 6–52 weeks post-partum AR:15%	Exercise vs. exercise + group-mediated behavioural counselling	Sedentary. Exclusion criteria: severe heart condition, other medical conditions such as chronic kidney or liver rheumatic disease, cancer, hearing or sight impairment	8 weeks
Da costa *et al.* (56), Dritsa *et al.* (57), Dritsa *et al.* (58), Canada	RCT	Obstetrician/gynaecologists offices, media advertisement, major hospitals and community health facilities; 4–38 weeks post-partum AR:33%	Home-based exercise programme vs. usual care	Sedentary. EPDS > 10; had no current alcohol or substance abuse, had no obstetrical or concomitant diseases which would have precluded participation in an exercise programme.	12 weeks
Daley *et al.*, UK (59)	RCT	General practices, local specialist mother and baby unit; <12 months post-partum AR:18%	Exercise vs. usual care	Sedentary, EPDS > 12. Excluded: severe post-natal depression that required inpatient psychiatric treatment, had psychotic symptoms, pregnancy	12 weeks

Table 1 *Continued*

Study	Study design	Recruitment, post-partum age, attrition rate (AR)	Study description	Diet, exercise and medical history	Intervention duration
Davenport *et al.*, Canada (46)	Controlled trial	Physician and midwife referrals, posters and advertisements in newspapers 7–9 weeks post-partum; 85% exclusive breastfeeding AR:15%	Nutrition plus low intensity vs. moderate intensity exercise	Sedentary. Healthy, non-smoking, current BMI >25 and/or 5.0 kg from pregnancy	16 weeks
deRosset *et al.*, USA (60)	RCT	Guilford County Health Department 6 weeks post-partum 88% breastfeeding	Diet + exercise programme vs. usual medical care	Overweight or obese prior to current pregnancy. Not on other weight management programme; Excluded if they had history of heart murmur, congenital heart disease, family history of sudden death	12 weeks
Dewey *et al.* (61), Lovelady *et al.* (62), USA	RCT	Letters to new parents; women who delivered health infants; 6–8 weeks post-partum; exclusively breastfeeding AR:13%	Exercise vs. control	Sedentary. No chronic illness, used no regular medication, non-smoking	12 weeks
Ebbeling *et al.*, USA (63)	RCT	Post-partum women with an income below 185% of the poverty line and evidence of nutritional risk, community health centres in metro areas; 2–6 weeks post-partum	Diet and exercise vs. usual care	NA	12 + 6 months maintenance
Fjeldsoe *et al.*, Australia (64,65)	RCT	An existing database of post-natal women who had agreed to be re-contacted for specific health-related projects; <12 months post-partum AR: 31 %	Exercise vs. minimal contact	Sedentary. Not currently in the second or third trimesters of pregnancy.	12 weeks
Hammer *et al.*, USA (39)	Pre-test-post-test	Public advertisement; 6 weeks–1 year post-partum AR:13%	Low-fat diet and exercise in fully breastfeeding, mixed feeding and non-breastfeeding women	Not been exercising regularly or dieting to lose weight, >32% body fat, free from coronary heart disease, diabetes and hypertension	3 months
Heh *et al.*, Taiwan (47)	Controlled trial	Post-partum mother at regional hospital; 6 weeks post-partum AR:21%	Exercise vs. standard care	EPDS >10; a normal spontaneous delivery with a single full-term healthy baby. Excluded: women with post-natal obstetric complications or a previous psychiatric history.	3 months
Huang *et al.*, Taiwan (66)	RCT	Obstetrics clinic at study site (hospital); 24–48 h post-partum AR: 21%	Diet and physical activity vs. standard care	No cognitive impairment or psychiatric illness.	6 months
Kearney and Simonelli, USA (67)	RCT	2 months post-partum AR: 5%	Motivational interviewing for weight loss	Pregnancy weight gain of at least 30 lb who had delivered healthy singleton infants	6 months
Keller *et al.*, USA (68)	RCT	Community centres, medical centre, churches and Hispanic markets. 6 weeks–6 months post-partum	Weekly walking sessions vs. newsletter and phone call	Sedentary. Exclusion criteria: medical problems that would preclude physical activity, currently pregnant or planning on becoming pregnant, current use of antidepressants or high-dosed oral steroid, infectious illness, acute or chronic systemic inflammation, BMI ≤ 25 or ≥35, osteoporosis.	12 months

Table 1 *Continued*

Study	Study design	Recruitment, post-partum age, attrition rate (AR)	Study description	Diet, exercise and medical history	Intervention duration
Ko and Yang, Taiwan (48)	Controlled trial	Maternity centre; 0–1 weeks post-partum AR: 37%	Low intensity exercise vs. non-active control	Free of obstetrical complications.	3 weeks
Ko *et al.*, Taiwan (40)	Pre-test-post-test	Post-partum outpatient clinic at a medical centre in Taipei 6 weeks post-partum, half fully breastfeeding, half mixed feeding AR: 18%	Yoga and Pilates community exercise programme	No maternal and neonatal complications	12 weeks
LeCheminant *et al.*, USA (34)	RCT	The local community 6 weeks post-partum AR: 27%	Resistance training vs. flexibility training	>2.27 kg above their self-reported pre-pregnancy weight. Not engaging in resistance training 2 or more times a week in last 6 months, not in another weight management programme; non-smoking	18 weeks
Leermakers *et al.*, USA (69)	RCT	Local women's hospital; 3–12 months post-partum; non-lactating AR: 31%	Behavioural weight loss intervention vs. no-intervention control	BMI > 22; currently exceed their pre-pregnancy weight by at least 6.8 kg	6 months
Lewis *et al.*, USA (41)	Pre-test-post-test	Newspaper advertisements, health plan database; <6 months post-partum AR:19%	Exercise intervention based on TTM and SCT	Sedentary. Exclusion criteria: any medical conditions that would have impaired their abilities to exercise, those with potentially high-risk pregnancies. History coronary heart disease, miscarriage, complicated pregnancies or delivery	3 months
Lewis *et al.*, USA (70)	RCT	Targeted emails, print advertisement, online advertisement, and physician referrals 5 weeks post-partum AR: 4.6%	Home-based exercise vs. wellness support control	Exercising 90 min or less per week; not in another exercise or weight management programme; history of depression. Exclusion: current depressive episode, hypertension, diabetes, medical conditions that interfere with physical activity, medication that interferes with heart rate response to physical activity, hospitalization for psychiatric disorder in the last 6 months.	6 months
Lovelady *et al.*, USA (71–73)	RCT	4 weeks post-partum, exclusively breastfeeding AR: 17%	Weight loss vs. usual diet and physical activity	Sedentary. Free of chronic disease, non-smoking. BMI ≥ 25 and ≤30 kg m^{-1} (2) recruited.	10 weeks
Lovelady *et al.*, USA (24)	RCT	Childbirth and parenting classes offered at the local hospital, obstetricians' offices; 3 weeks post-partum, exclusively breastfeeding AR: 17%	Exercise vs. control	Sedentary. No chronic illness, non-smoking	16 weeks
McCrory *et al.*, USA (74)	RCT	Local physicians' offices, child-birth classes and letters to new parents; 8–16 weeks post-partum, exclusively breastfeeding AR: 1%	Diet vs. diet + physical activity vs. control	No chronic illnesses; were not taking medication regularly; were non-smokers; had delivered a single, healthy, term infant	11 days
McIntyre *et al.*, Australia (21)	RCT	NA 6 weeks post-partum AR: 10.7%	Individualized exercise programme vs. usual care	Women with a history of gestational diabetes	12 weeks
Mukherjea *et al.*, USA (75)	RCT	4–5 weeks post-partum, exclusively breastfeeding	Diet + physical activity vs. control	NA	10 weeks

Table 1 *Continued*

Study	Study design	Recruitment, post-partum age, attrition rate (AR)	Study description	Diet, exercise and medical history	Intervention duration
Nicklas *et al.*, USA (28)	RCT	Diabetes in Pregnancy Program at Brigham and Women's Hospital (Boston, Massachusetts) 6 weeks post-partum AR: 20%	Web-based Diabetes Prevention programme vs. control	Excluded: history of type 2 diabetes, bariatric surgery, BMI ≤ 24 or 22 for Asians, BMI > 50	12 months
Nitzsche *et al.*, Austria (42)	Pretest-post-test	Gynaecologists clinic; 2–8 weeks post-partum	Wii Fit Plus training sessions at home	No visual disabilities, second degree hypertension, diabetes mellitus, osteoporosis, BMI > 30, psychological illness, cardiovascular problems, strong abdominal pain	6 weeks
Norman *et al.*, Australia (76)	RCT	Hospital post-natal ward; 6–10 weeks post-partum AR after commencement: 19%	Mother and baby group vs. education only group	Excluded if they had a diagnosis of a psychiatric disorder.	8 week
Østbye *et al.*, USA (26,77)	RCT	Obstetrics clinics and community posters; 6 weeks post-partum AR: 6%	Diet + physical activity vs. Control	Had any health conditions that prevented them from walking a mile unassisted were excluded.	9 months
O'Toole *et al.*, USA (20)	RCT	Metropolitan St. Louis area; 6 weeks–6 months post-partum AR: 42%	Structured vs. self-directed lifestyle	Sedentary. Not on weight loss programme. Overweight, gained more than 15 kg during pregnancy, currently more than 5 kg over pre-pregnant weight, excluded those with medical contraindication to diet or exercise.	12 weeks
Reinhardt *et al.*, Australia (29)	RCT	Local area health diabetes services for gestational diabetes 6 weeks post-partum AR: 13.5%	Phone-based motivational interviewing diabetes prevention vs. usual care	History of gestational diabetes	6 months
Scholten *et al.*, The Netherlands (35)	Controlled trial	Pre-eclamptic women: Radboud University Nijmegen Medical Centre; control: community via advertisement in day care centres 6–12 months post-partum Not breastfeeding AR: 6.4%	Aerobic training in pre-eclamptic and healthy women	None had diabetes, autoimmune disease, cardiovascular disease; none smoked or used medication that affects the cardiovascular system	12 weeks
Shek *et al.*, China (78)	RCT	Prince of Wales hospital, Hong Kong 6–8 weeks post-partum AR: 25.3%	Diet and exercise vs. control	History of gestational diabetes; has IGT but otherwise in good health; excluded those needed insulin during pregnancy	36 months
Stendell *et al.*, USA (36,79)	RCT	Lactating women living in the greater Tucson, AZ area; 2 weeks–6 months post-partum AR: 21%	Mediterranean vs. MyPyramid diet	No diabetes or history of diabetes, kidney or liver disease, or cancer. Excluded: tobacco use or family history of food allergies.	4 months
Taveras *et al.*, USA (49)	Controlled trial	Paediatric and usual care primary care practices; 0–1 months post-partum AR: 5%	Mother and infant pair intervention vs. usual care	No severe health conditions	6 months
Tripette *et al.*, Japan (80)	RCT	Tokyo Metropolitan area, Japan, through advertisement in maternity and mother care magazine 3–12 months post-partum	Home-based video (Wii Fit Plus) vs. control	Not engaging in regular exercise or participated in weight loss programme; Excluded: history of cardiovascular disease and BMI ≤ 22	40 days

Table 1 *Continued*

Study	Study design	Recruitment, post-partum age, attrition rate (AR)	Study description	Diet, exercise and medical history	Intervention duration
Walker *et al.*, USA (81)	RCT	Posters in school-based clinic, private obstetric practices, radio advertisements, direct mailings from Texas Center for Health Statistics 6–12 months post-partum AR: 29.6%	Ethnic-specific weight loss programme vs. wait-list control	BMI 25 or greater, retained post-partum weight at least 5 kg, healthy single, term infant; Excluded: chronic health conditions, e.g. HIV/AIDS, heart disease, renal disease, diabetes, or taking medication for weight loss, hypertension, diabetes, thyroid conditions or depression	13 weeks
Watson *et al.*, Australia (50)	Controlled trial	Community health centres, early childhood health centres, public recruitment; average 11 weeks post-partum AR: 22%	Pram walking group vs. wait-list control	Mothers with sick infants were excluded	6 months
Wiltheiss *et al.*, USA (82)	RCT	Counties in North Carolina 2–7 months post-partum AR: 31%	Family-based preventing childhood obesity vs. control	BMI 25 or more, another child 2–5 years, no medical conditions preventing daily physical activity	10 months
Youngwanichsetha *et al.*, Thailand (30)	RCT	Unclear, from a hospital 6–12 weeks post-partum AR: 7.2%	Tai-Chi vs. control	Has type 2 diabetes, fasting glucose 110–150 mg dl^{-1} pp, HbA1c 6.5% or higher, not receiving medication for glycaemic control, not having other serious complications such as coronary heart disease, diabetic neuropathy, foot ulcers	12 weeks
Zourladani *et al.*, Greece (83)	RCT	Private obstetric clinic, gynaecological obstetric centres; 4–6 weeks post-partum AR:9%	Low impact exercise vs. control	Exclusion criteria: chronic disease, drug addiction, current alcoholism problems, mental disease requiring medication, multiple gestations, or planned caesarean delivery	12 weeks

BMI, body mass index; NA, not available; RCT, randomized controlled trial.

The mean age of the participants ranged from 24 (81) to 36 years (30) (Table 1). The recruitment window for women following delivery varied: within the first 3 months ($n = 28$); within the first 6 months ($n = 5$); and within the first 12 months ($n = 13$) (Table 1). A minority of studies used selected post-natal populations – exclusive breastfeeding ($n = 7$), a history of gestational diabetes ($n = 4$) (21,28,29,78) and type 2 diabetes ($n = 1$) (30).

Interventions

The description of the interventions is as shown in Table 1. The majority of studies were combined diet and exercise ($n = 21$) or exercise-only ($n = 22$) interventions, while a single study was a diet-only intervention (Table 1). All interventions required in-person participation except for two telephone-delivered studies (41,70). A range of health professionals – nurses, dietitians, exercise physiologists, diabetes educators, research assistants, trained counsellors, health educators and fitness instructors – delivered the interventions and the intervention duration ranged from 11 days (74) to 36 months (78).

Of the RCTs, five were group interventions (20,26,69,77,81–83), six used more than three support media (e.g. in-person, phone, internet, printed materials) (26,28,54,69,77,80,82) and four were home-based interventions (26,28,29,80,82). Nine studies included telephone or mobile phone contact, text messages, website or e-mails in addition to in-person support (21,25–29,52,54,69,77,80,82).

Controls

Over half of the RCTs ($n = 18$) provided their control group with usual care, no intervention or explicit instructions to maintain their usual diet or activity patterns. In four studies, the control group had a single contact at baseline such as a lifestyle consultation or some printed resources (20,21,28,65). Seven studies maintained contact with the control group beyond baseline via emails, phone calls or mailed materials (26,54,67,68,70,76,82). Four studies compared the effects of two different interventions, in which the control group received either an exercise or dietary intervention, or both (33,34,36,46).

Quality assessment

The risk of bias assessment for all included studies is as shown in Table 2. Overall, 21 studies (47%) had high risk, 21 studies (47%) had medium risk and 3 studies (7%) had low risk of bias. Half of the controlled studies had adequate methods of generating random sequences (e.g. computer generator or random number table) and eight were inadequate (e.g. by participants' choice, alternation or non-randomized controls). Adequate allocation concealment from both investigators and participants was seen in 14 studies (e.g. sealed envelope, independent statistician), but blinding for participants and treatment provider was unlikely in all of these studies due to the nature of the interventions, which could be a source of bias in favour of the treatment group. Blinding of assessors was rarely reported but the risk of outcome bias that affected the review results was unlikely as only objective outcome endpoints were used. About half of the studies were at low risk of bias from missing outcome data and six of those conducted intention-to-treat analysis (26,28,29,65,78,80). Seven studies were at high risk of attrition bias due to unequal attrition across the intervention and control groups which could be related to the true outcome (34,40,52,61,70,71,81). All outcomes were reported as pre-specified in seven studies (21,28,35,36,43,52,82), suggesting low risk of bias from selective reporting. In nine studies, the outcomes were reported in a way that could not be included in the analyses (e.g. omission of sample size, standard error or standard deviation) (20,38,49–51,56,78,81) and expected outcomes on diet or physical activity were not reported in eight studies (39,47,48,67,69,75,83). No other potential sources of bias were identified in the included studies. The funnel plots reporting body weight were largely symmetrical, suggesting low risk of publication bias.

The effect of lifestyle intervention on post-partum women

The outcomes of the included papers are summarized in Supporting Information Table S2. Nine of the 22 studies reporting body weight had a significant decrease (20,28,46,52,54,69,71,74,80) and 7/16 reported a significant decrease in BMI (28,29,46,52,54,71,80) compared with the control group. Two of the 12 studies reported a significant decrease in total energy intake (28,54) and 2/6 found a significant decrease in fat intake in the intervention group compared with the control group (54,72). Nine of the 24 studies reported significant increases in physical activity compared with the control group (20,24,29,33,51,65,66,71,74).

The meta-analyses of RCTs showed that lifestyle interventions in post-partum women resulted in a significantly reduced body weight (mean difference –2.30 kg [95% CI: –3.22, –1.39], $P < 0.001$). There was a significant heterogeneity in this analysis with χ^2 value of 109.31 ($P < 0.001$) and I^2 of 84%. A sensitivity analysis was performed to exclude studies in which the control group received an exercise or dietary intervention (33–36) and this analysis resulted in greater effect size (body weight: –2.59 kg, 95% CI: –3.51, –1.64, $P < 0.001$). The identified studies were excluded from the subsequent subgroup analyses.

Table 2 Risk of bias of included studies*

Author	Random sequence generation	Allocation concealment	Blinding of participants	Blinding of outcome	Incomplete outcome	Selective reporting	Other source of bias	Overall risk
Aittasalo *et al.* (43), Kinnunen *et al.* (44), Mustila *et al.* (45)	High	High	High	Low	Low	Low	Low	High
Albright *et al.* (37)†	NA	NA	NA	NA	NA	Unclear	Low	Low
Armstrong and Edward (51)	Low	Low	High	Low	Low	High	Low	High
Bertz *et al.* (27,52), Brekke *et al.* (25), Huseinovic *et al.* (53)	Low	Low	High	Low	High	Low	Low	High
Cahill *et al.* (38)†	NA	NA	NA	NA	NA	High	Low	Medium
Colleran and Lovelady (54)	Unclear	Unclear	High	Low	Low	Unclear	Low	Medium
Cramp and Brawley (33,55)†	Unclear	Unclear	High	Low	Low	Unclear	Low	Medium
Da costa *et al.* (56), Dritsa *et al.* (57), Dritsa *et al.* (58)	Low	Low	High	Low	Low	High	Low	High
Daley *et al.* (59)	Low	Low	High	Low	Low	Unclear	Low	Medium
Davenport *et al.* (46)	High	Unclear	High	Low	Unclear	Unclear	Low	High
deRosset *et al.* (60)	Unclear	Low	High	Low	Unclear	Unclear	Low	Medium
Dewey *et al.* (61), Lovelady *et al.* (62)	Unclear	Unclear	High	Low	High	Unclear	Low	High
Ebbeling *et al.* (63)	Low	Low	High	Low	Unclear	Unclear	Unclear	Medium
Fjeldsoe *et al.* (64,65)	Low	Low	High	Low	Low	Unclear	Low	Medium
Hammer *et al.* (39)†	NA	NA	NA	NA	NA	High	Low	Medium
Heh *et al.* (47)	High	Unclear	High	Low	Low	High	Low	High
Huang *et al.* (66)	Low	Unclear	High	Low	Low	Unclear	Low	Medium
Kearney and Simonelli (67)	Unclear	Unclear	Low	Low	Low	High	Low	Medium
Keller *et al.* (68)	Low	Unclear	High	Low	Unclear	Unclear	Unclear	Medium
Ko and Yang (48)	High	High	High	Low	High	High	Low	High
Ko *et al.* (40)†	NA	NA	NA	NA	NA	Unclear	Low	Low
LeCheminant *et al.* (34)	Low	Low	High	Low	High	Unclear	Low	High
Leermakers *et al.* (69)	Unclear	Unclear	High	Low	Low	High	Low	High
Lewis *et al.* (41)†	NA	NA	NA	NA	NA	Unclear	Low	Low
Lewis *et al.* (70)	Low	Low	High	Low	High	High	Low	High
Lovelady *et al.* (71–73)	Low	Unclear	High	Low	High	Unclear	Low	High
Lovelady *et al.* (24)	Unclear	Unclear	High	Low	Unclear	Unclear	Low	Medium
McCrory *et al.* (74)	Low	Unclear	High	Low	Low	Unclear	Low	Medium
McIntyre *et al.* (21)	Unclear	Unclear	High	Low	Low	Low	Low	Medium
Mukherjea *et al.* (75)	Unclear	Unclear	High	Low	Unclear	High	Low	High
Nicklas *et al.* (28)	Low	Low	High	Low	Low	Low	Low	Medium
Norman *et al.* (76)	Low	Low	High	Low	Low	Unclear	Low	Medium
Ostbye *et al.* (2009, 2012)	Low	Unclear	High	Low	Low	Unclear	Low	Medium
Otoole *et al.* (2003)	Low	Low	High	Low	Low	High	Low	High
Reinhardt *et al.* (29)	Low	High	High	Low	Low	Unclear	Low	High
Scholten *et al.* (35)	High	High	High	Low	Low	Low	Low	High
Shek *et al.* (78)	Low	Unclear	High	Low	Low	High	Low	High
Stendell *et al.* (36,79)	Low	Low	High	Low	Low	Unclear	Low	Medium
Taveras *et al.* (49)	High	High	NA	Low	Unclear	High	Low	High
Tripette *et al.* (80)	Unclear	Unclear	High	Low	Low	Unclear	Low	Medium
Walker *et al.* (81)	Unclear	Unclear	High	Low	High	High	Low	High
Watson *et al.* (50)	High	High	NA	Low	Unclear	High	Low	High
Wiltheiss *et al.* (82)	Unclear	Unclear	High	Low	Unclear	Low	Low	Medium
Youngwanichsetha *et al.* (30)	Low	Low	High	Low	Low	Unclear	Low	Medium
Zourladani *et al.* (83)	High	Unclear	High	Low	Unclear	High	Low	High

*Based on Cochrane risk of bias tool.†Uncontrolled study.NA – information not available.Overall risk – 'low' (four low ratings and no high ratings), 'medium' (less than four low ratings and one high rating), 'high' (two or more high ratings).

Intervention characteristics and weight loss in post-partum women

Combined diet and exercise interventions, interventions that include self-monitoring, and interventions lasting 6 months or less resulted in significantly greater weight loss than their comparative groups (Figs. 2 and 3; Table 3). Individual or group setting, home-based or centre-based intervention, the number of technology-based media used to provide support, and delivery medium had no significant effect on weight loss in post-partum women (Table 3). Significant statistical heterogeneity was seen in studies with diet and exercise interventions, interventions with self-monitoring, intervention duration of 6 months or less, individual-based interventions, group-based interventions, home-based interventions, interventions with only in-person support, interventions that include telephone support, interventions that included less than three support media, and interventions that used three or more support media (Table 3). No statistical heterogeneity was seen among studies with exercise-only interventions, interventions without self-monitoring, interventions with duration longer than 6 month, centre-based interventions and interventions that include telephone and web support (Table 3).

Discussion

Our systematic review and meta-analysis of post-partum women clearly demonstrates interventions that utilize a diet-and-exercise approach; use self-monitoring; and have a shorter duration (6 months or less) result in significantly greater weight loss. We found the pooled weight loss to be modest at 2.3 kg (follow-up duration ranged from 11 days to 36 months from baseline), which is consistent with the previous reports of an average weight loss of 1.93–2.5 kg (16–18) in post-partum women. A mean weight loss of 2.1 kg at 12 months follow-up in a recent meta-analysis showed improvements in diabetes and cardiovascular risk factors (84); thus, the weight loss seen in our analysis is likely to produce clinically significant benefits.

We found that the combination of diet and exercise resulted in twice as much weight loss as that achieved through exercise alone, which is consistent with other recent meta-analyses in post-partum women (16,18). Exercise, either as a stand-alone intervention or as an addition to a diet intervention, has not consistently been reported to produce clinically significant weight loss in the general population (85,86). Significant weight loss is seen at very high levels of physical activity, which is difficult to achieve and maintain for most individuals (87). This may explain the consistent reports of greater weight loss when dietary modification is part of the intervention (17,18).

Self-monitoring is known for its central role in weight management (23), but its effect has never been quantified in a meta-analysis. We report lifestyle interventions that include self-monitoring resulted in weight loss three times greater than those without, which supports the findings

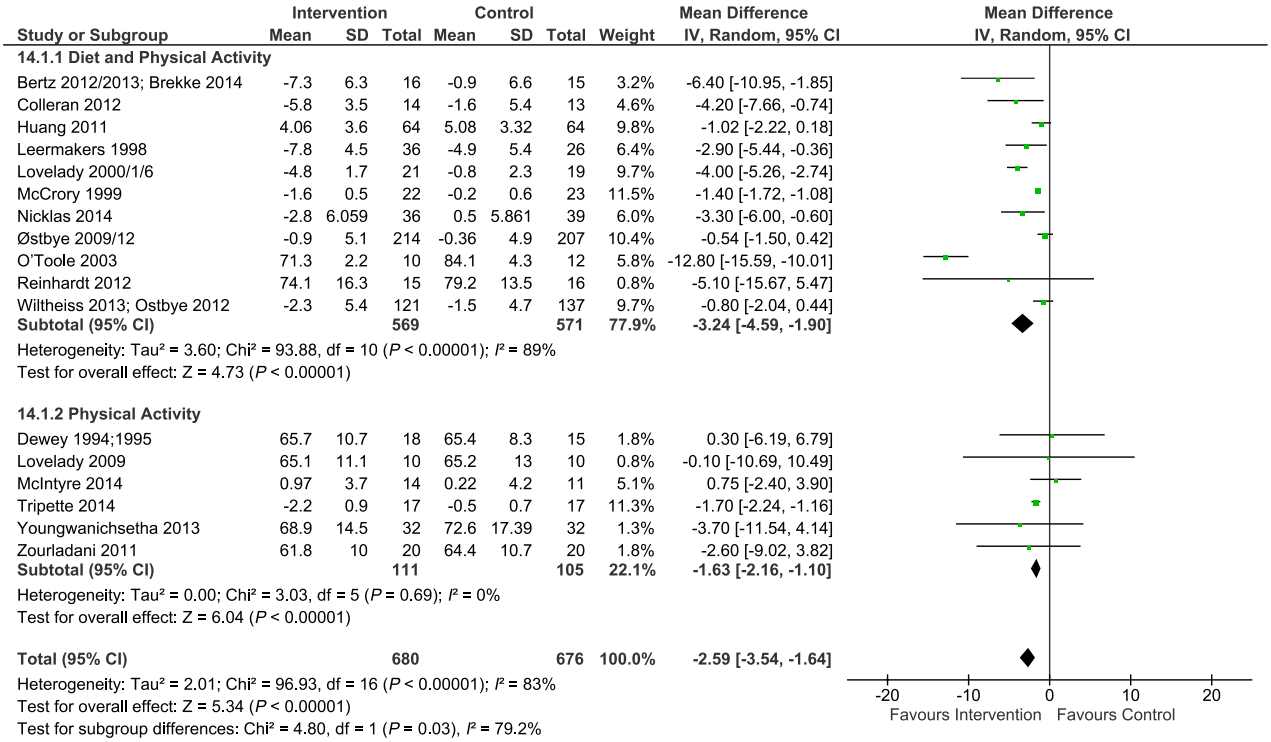

Figure 2 Forest plot of subgroup analysis of the effect of intervention type on body weight in post-partum women.

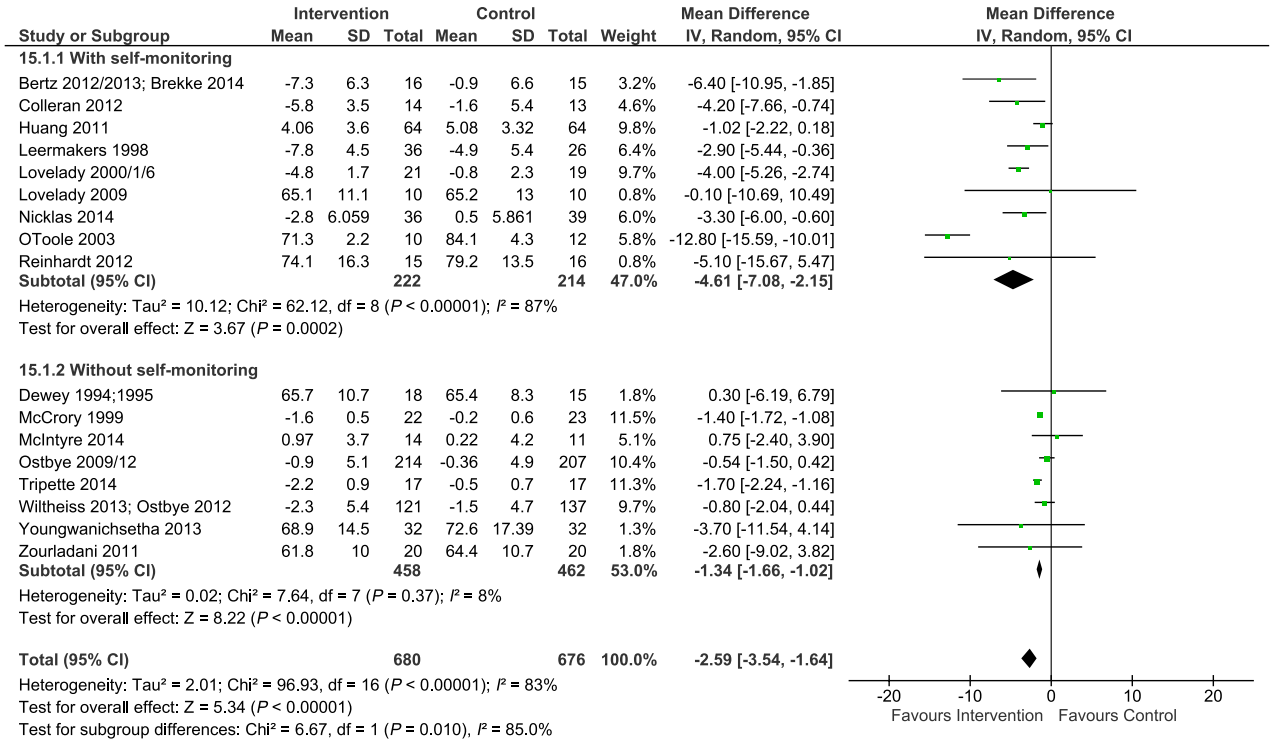

Figure 3 Forest plot of subgroup analysis of the effect of self-monitoring on body weight in post-partum women.

Table 3 Subgroup analyses of lifestyle interventions in post-partum women on body weight*

Analysis	Studies	Participants	Mean difference, kg (95% CI), *P*-value	χ^2 (*P*-value)	I^2 (%)	*P*-value for subgroup differences
Intervention duration						0.01
6 months or less	14	1,356	–3.11 (–3.54, –1.64), *P* < 0.001	88.59 (*P* < 0.001)	85	
More than 6 months	3	602	–1.01 (–2.10, 0.08), *P* = 0.01	3.57 (*P* = 0.17)	44	
Intervention setting						0.33
Individual	11	489	–2.06 (–2.83, –1.29), *P* < 0.001	27.29 (*P* = 0.002)	63	
Group	5	803	–3.86 (–7.37, –0.35), *P* < 0.001	69.37 (*P* < 0.001)	94	
Intervention location						0.08
Home-based	4	398	–3.04 (–4.48, –1.60), *P* < 0.001	93.26 (*P* < 0.001)	87	
Centre-based	13	958	–1.59 (–2.32, –0.87), *P* < 0.001	3.66 (*P* = 0.30)	18	
Use of technology as support						0.19
In-person only	8	392	–3.66 (–5.97, –1.36), *P* = 0.002	78.82 (*P* < 0.001)	91	
Phone support	6	828	–1.31 (–2.62, –0.00), *P* = 0.05	10.22 (*P* = 0.07)	51	
Phone and web support	3	136	–2.36 (–3.78, –0.94), *P* = 0.001	3.16 (*P* = 0.21)	37	
Different medium for support						0.09
Less than 3 medium	11	131	–3.44 (–5.43, –1.45), *P* < 0.001	85.65 (*P* < 0.001)	88	
3 or more medium	6	1,225	–1.57 (–2.41, –0.73), *P* < 0.001	10.81 (*P* = 0.06)	54	

*Random effects model used.CI, confidence interval.

from a meta-regression of healthy eating and physical activity interventions where self-monitoring accounted for the greatest heterogeneity between studies included (88). The self-monitoring we reported in this review was facilitated by the use of exercise logs, diaries, heart rate monitors (to determine exercise intensity) or pedometers. Newer technology such as phone apps can increase self-monitoring (89) and should be further explored in post-partum women in the future.

Extending intervention length has been proposed to improve long-term weight loss in the general population (90,91), but our findings suggest that this was not the case for post-partum women. We found that a shorter intervention duration of 6 months or less (follow-up duration

ranged from 12 days to 1 year) had significantly greater weight loss compared with an intervention duration beyond 6 months (follow-up duration ranged from 10 months to 1 year). However, this appears to be largely due to the result of one study (completers' analysis of 23 participants out of 40 at baseline) (20), which reported a mean difference of −12.8 kg between groups. When this study was removed, the difference between shorter and longer intervention duration was no longer significant in the analysis. Further research is required to confirm if shorter intervention is indeed more effective than longer intervention in post-partum women. In any case, our findings do not support the notion that longer intervention duration is more effective in long-term weight loss in post-partum women. Weight loss barriers are known to increase over time and this is seen across all barrier types (self-monitoring, social cues, holidays, physical activity and internal cues) (92). In post-partum women, the needs of their infant change significantly during the first year and this can mean barriers shift and new strategies are needed over time. Interventions in post-partum women – regardless of duration – need be dynamic and flexible to address the barriers that arise during this challenging life stage.

In this review, individual or group format did not differ significantly in its weight loss effects. The removal of a significant outlier (20) altered this picture to make individual interventions significantly more effective than group ones for weight loss. The literature does not provide a clear-cut picture either. On the one hand, previous systematic review ($n = 336$ with a predominantly female participant pool) found that group sessions resulted in greater weight loss than individual sessions (93). On the other hand, meta-regression ($n = 44{,}747$) found that delivery format had no differential effects on behavioural outcomes (88). Gender might exert an effect here with a study reporting women lost more weight with individual sessions while men did better with group ones (94). We know individual interventions provide individualized feedback and the format allows for home-based delivery, while group interventions facilitate social support. It is unclear which factors were more important in supporting weight loss in post-partum women and whether combining both interventions in a mixed delivery format will yield greater benefit. Further research is needed to determine the best delivery format for lifestyle interventions in post-partum women.

Two major barriers to participating in post-partum lifestyle interventions are lack of time and childcare demands (28,95). Home-based interventions have been proposed as a solution as they enable participation at any time without needing to leave the home. Our findings suggest that home-based interventions are as effective as conventional ones. Using newer technology (Internet, telephone or both) either as the main or adjunct support mechanism did not result in greater weight loss, which suggests that the technology is not inherently superior or inferior to in-person interventions. Other intervention characteristic such as the inclusion of self-monitoring may have greater influence on weight outcome. However, technology-based interventions may improve other outcomes such as recruitment and retention. This merits further investigation because recruitment and retention are major challenges in this population and any method that can address these will go a long way to improving clinical outcomes (95).

The demands of a newborn impact greatly on a woman's ability to participate and adhere to a lifestyle intervention (95). Attrition rates reported in post-partum lifestyle interventions vary from 0% to 42% (20,51) and those with lower rates (5% or less) integrated their interventions into routine newborn visits or provided incentives to participants (43,49,67). Once recruited, adherence is the most important determinant of effectiveness in lifestyle interventions (96). Post-partum women have low engagement rates in weight loss interventions (97) and this could result in a non-significant outcome despite the number of sessions offered (77). Unfortunately, retention and engagement strategies are rarely reported and this needs to be addressed through standardized reporting on any participant benefits received (e.g. vouchers, financial reimbursements, gym memberships). These strategies are especially important for post-partum women with whom time and energy are particularly in demand and may exert a stronger influence on outcomes.

The unique strength of our study is the inclusion of subgroup analyses on intervention characteristics, which enabled effective strategies to be identified for inclusion in future interventions. There are several limitations in this study. Firstly, the presence of significant heterogeneity in over half of the analyses should be noted as this may reflect the diversity of interventions and varying levels of participant adherence. Secondly, insufficient information existed from the reports to systematically consider the effect of staff qualifications and treatment intensity on weight loss. Thirdly, there was also a lack of process outcome reporting (such as recruitment rate, acceptability and adherence levels) which may play a role in determining the effectiveness of intervention in real-life settings and we recommend systematic reporting of these characteristics in future studies.

Lifestyle interventions in the first year post-partum can result in clinically significant weight loss but their effectiveness depends on the intervention content, which needs to be reported in greater detail so others could determine the active ingredients for future iterations or scale-up.

Conclusion

This systematic review and meta-analysis found that the most effective lifestyle intervention strategies are

self-monitoring and the combined approach of diet and exercise, both of which increase weight loss in post-partum women. Future research should focus on determining the optimum intervention duration, delivery format and the role of technology in lifestyle intervention for this group.

Conflict of interest statement

No conflict of interest was declared.

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Author contributions

S.L. extracted the data and wrote the manuscript. S.O.R. extracted the data and reviewed/edited the manuscript. H.B. extracted the data and reviewed/edited the manuscript. I.E. reviewed/edited the manuscript. T.S. contributed to discussion and reviewed/edited the manuscript. J.D contributed to discussion and reviewed/edited the manuscript.

Supporting information

Additional Supporting Information may be found in the online version of this article, http://dx.doi.org/10.1111/obr.12312

Table S1. Summarized search strategy to identify diet and/or exercise interventions in post-partum women.
Table S2. Summary of results of included studies.

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