Maternal and fetal responses to acute high-intensity resistance exercise during pregnancy

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ABSTRACT

Objective To examine maternal and fetal cardiovascular responses to high-intensity resistance exercise in pregnancy.

Methods 10 healthy pregnant (26.4±3.2 weeks gestation) and 10 healthy non-pregnant individuals were recruited (34.8±6 and 33.5±2.9 years, respectively). At least 48 hours after baseline strength testing to determine 10-repetition maximum (10 RM), participants completed 10 repetitions of barbell back squat, bench press and deadlift at 70%, 80% and 90% of 10 RM with free breathing, followed by 10 repetitions at 90% 10 RM with a Valsalva manoeuvre. Maternal heart rate was monitored continuously. Fetal heart rate, umbilical systolic/diastolic (S/D) ratio, resistive index (RI) and pulsatility index (PI), as well as maternal blood pressure, glucose and lactate were assessed immediately before and after exercise.

Results The amount of weight lifted and the rate of perceived exertion by pregnant and non-pregnant participants were similar throughout each exercise. Maternal heart rate increased with the amount of weight lifted, peaking with the use of the Valsalva manoeuvre (squat: 137.3±8.4 bpm; bench press: 110.5±10.4 bpm; deadlift: 130.7±9.0 bpm). Fetal bradycardia was not observed, and fetal heart rate did not change from pre-to-post exercise (squat: p=0.639; bench press: p=0.682; deadlift: p=0.847). Umbilical blood flow metrics, such as RI, remained within normal ranges throughout each set of squats (p=0.642), bench press (p=0.287) and deadlifts (p=0.614).

Conclusion Our findings suggest that high-intensity resistance exercises are well tolerated by both mother and fetus, including while using the Valsalva manoeuvre.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Light-to-moderate intensity resistance training during pregnancy is encouraged by global physical activity guidelines to support maternal/fetal health.

⇒ High-intensity resistance exercise with and without the Valsalva manoeuvre during pregnancy is discouraged due to a lack of empirical evidence of its safety.

WHAT THIS STUDY ADDS

⇒ This study is the first to investigate the acute maternal and fetal responses to high-intensity resistance exercises (ie, barbell back squat, bench press and deadlift) using direct measures of maternal and fetal well-being.

⇒ High-intensity resistance exercise with and without Valsalva in both the supine and standing position were well tolerated by both mother and fetus.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ These data provide high-quality evidence to inform training advice for individuals who wish to continue resistance training during pregnancy using higher intensity efforts and compound, multijoint movements.

⇒ Current pregnancy guidelines suggest incorporating resistance training in general. Specific recommendations are not available due to limited empirical data. This research provides novel information on near repetition maximum lifting and acute variables, including intensity, for pregnant women engaging in resistance exercise.

INTRODUCTION

The last few decades have seen a dramatic rise in the number of female athletes participating in strength-based sports.[1 2] In turn, there is interest from these same athletes to continue resistance exercise during pregnancy. Current clinical practice guidelines recommend pregnant individuals engage in moderate-intensity aerobic and resistance exercise to promote prenatal maternal–fetal health.[3 4] High-intensity resistance training is typically discouraged due to a lack of data supporting safe participation. Pregnant individuals are also traditionally discouraged from acute and/or prolonged resistance training in the supine position because of the compression of the vena cava potentially leading to limited maternal and fetal blood flow.[5] Further, a natural 'breath-holding' response to lifting a heavy load, known as the Valsalva manoeuvre, is typically used by athletes and resistance trained individuals during near-maximal exertion. While this response is safe in healthy non-pregnant individuals, it has been hypothesised to cause transient reductions in cardiac output and fetal perfusion.[6] Two small studies published in the last 3 years investigated the use of a Valsalva manoeuvre during low to moderate intensity resistance exercise in response to bench press (maximum 50 lbs) and leg press (mean 75 lbs) and found no adverse maternal or fetal responses.[7 8] In response to the growing interest in high-intensity resistance exercise, an online survey examining the training patterns and health outcomes of 679 participants who lifted at least 80% 1-repetition maximum (RM) during pregnancy was conducted.[9] These data demonstrated that participants who maintained

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prepregnancy training levels until delivery, including continuation of supine exercise and Valsalva, had a 51% reduction in the odds of pregnancy and delivery complications compared with those following current physical activity guidelines and reduced participation in high-intensity resistance exercise.

Yet, due to lack of high-quality data directly assessing fetal well-being, there is still fear and avoidance of higher intensity loads, use of the Valsalva manoeuvre, and prolonged lifting in the supine positions during pregnancy. Therefore, we aimed to quantify and compare maternal–fetal cardiovascular responses during high-intensity resistance exercises (up to 90% 10 RM; equivalent to >75% 1 RM) and the Valsalva manoeuvre between pregnant and non-pregnant individuals.

METHODS

This project was approved by the University of Alberta Research Ethics Board (Pro00118617). No patients were involved in the design or conduct of this study. Individuals were included if they were at least 18 years of age and pregnant (≥20 weeks' gestation) with a single fetus. All participants were required to have at least 2 years experience with resistance training, and capable of lifting more than 50 pounds in the back squat, bench press and deadlift for 10 repetitions. Non-pregnant participants were prescreened for exercise using the *Canadian Society for Exercise Physiology (CSEP) Get Active Questionnaire,* and pregnant participants using the *CSEP Get Active Questionnaire for Pregnancy*.[10] Participants were excluded if they answered yes to any question (i.e., had a potential contraindication to exercise).

Exercise testing and supervision were conducted by a clinical exercise physiologist/certified strength and conditioning specialist, and the study was supervised by a researcher with extensive experience conducting peak/maximal exercise testing with pregnant individuals. Fetal ultrasound was completed by a trained research assistant. Visits 1 and 2 were separated by 2–7 days. Participants were provided an Actigraph (Actigraph wGT3X-BT Monitor, Actigraph LLC) to wear for 7 days following visit 1 to record 24-hour physical activity and sleep/wake measurements. This information was collected to determine overall physical activity and movement behaviours. Participants were asked to fill in a log during this time indicating when the device was on, and when they were sleeping or doing activities.

Personal and family health history, as well as pregnancy, delivery and birth outcomes were recorded via an online platform (REDCap).[11] Approximately 4 weeks following the anticipated delivery date, participants were contacted via email and asked to complete an online questionnaire that requested basic descriptive information of pregnancy outcomes such as gestational age at delivery, mode of delivery (e.g., vaginal, instrumental or Caesarean, emergency, etc), development of complications (e.g., gestational hypertension, pre-eclampsia, gestational diabetes mellitus, etc) breastfeeding status and fetal outcomes (e.g., infant birth weight and length, preterm birth, complications).

Experimental overview

Visit 1: 10 RM strength testing

Participants were instructed to avoid caffeine, alcohol, over-the-counter pain medications and strenuous exercise for 12-hours prior to visit 1. On arrival, participant's height (cm; stadiometer) and body mass (kg; calibrated scale) were measured. Participants were then asked to sit for 5 min prior to taking at least three measurements of arterial blood pressure on the upper left arm using an automated cuff (BP 785, Omron Healthcare, Toronto, Canada).

Following baseline, participants completed 5 min of treadmill walking at 3 mph and standardised stretching of major muscle groups (see online supplemental material). Next, a conservative incremental loading protocol was used to determine the participant's 10 RM back squat. The protocol started with 45 lbs (20.4 kg) barbell and the participant performed 10 repetitions to at least parallel depth. The subsequent load was determined by the participant's rating of perceived exertion (RPE) following the set (see online supplemental material). Safety bars were set to the height of each participant's lowest squat position. The protocol finished when the participant reached an RPE of 9 or 10 on the 0–10 Borg Scale. A 3-min rest period was given between attempts. The process was repeated to determine the participants barbell bench press 10 RM (starting with 25 lbs/11.3 kg) and barbell deadlift (starting with 75 lbs/34.1 kg), following 10 min of rest between each exercise testing protocol. Safety bars were set up during supine bench press to ensure the bar did not make contact with the pregnant participant's abdomen. All attempts were closely supervised and spotted. The maximal load lifted for each exercise was recorded and used to determine the prescribed load for the experimental protocol during visit 2.

Visit 2: cardiovascular assessment

Participants arrived at the laboratory having been asked to refrain from caffeine, alcohol and strenuous exercise for 12 hours prior to testing. Participants were given a standard snack 15 min prior to the start of exercise. Participants rested quietly in the seated position during instrumentation. All data were collected using ADInstruments data acquisition hardware (Powerlab 16/35; ML880; Dunedin, New Zealand) at 1000 Hz using LabChart Pro (V.8.1.20. ADInstuments) and stored for offline analysis. Measures included HR (EQLM100 LifeMonitor; Equivital Limited, Cambridge, UK), skin temperature via infrared temperature sensor (Equivital Limited, Cambridge, UK) and peripheral oxygen saturation (SpO_2; Cloth Pulse Oximetry Sensor 6000C, Nonin Medical Inc, Plymouth, USA). Three measurements of arterial blood pressure were taken (as described earlier). Baseline blood lactate and glucose were taken via capillary sampling (Lactate Plus Meter; Nova Biomedial, USA; OneTouch Ultra2 meter, ONETOUCH, California, USA). Fetal HR and umbilical blood flow (UBF) were assessed using a Doppler ultrasound (Vivid Q Ultrasound, GE Healthcare, Norway) with a multifrequent curvilinear transducer (3–7 MHz; GE Healthcare, Norway). Fetal metrics were monitored in an upright seated position immediately before and after exercise. A highly trained researcher performed onsite scanning of fetal HR and UBF following a standardised protocol.[12]

After baseline, participants completed a treadmill warmup and standardised stretching as outlined in visit 1. Following the warmup, participants began with a warm up set, three sets of the barbell back squat with free breathing (70%, 80% and 90% of 10 RM), followed by a fourth set with 10 reps at 90% 10 RM with a standardised Valsalva manoeuvre during each rep (see online supplemental material). For the Valsalva manoeuvre, participants were instructed to take in a breath filling up their belly and brace while holding their breath for the duration of the repetition, releasing after the movement was completed. Immediately following the cessation of exercise, fetal HR and UBF were reassessed while the participants rested for 3 min between each bout. The four sets of exercise (70%, 80%, 90% of 10 RM with free breathing, 90% 10 RM with Valsalva) were repeated

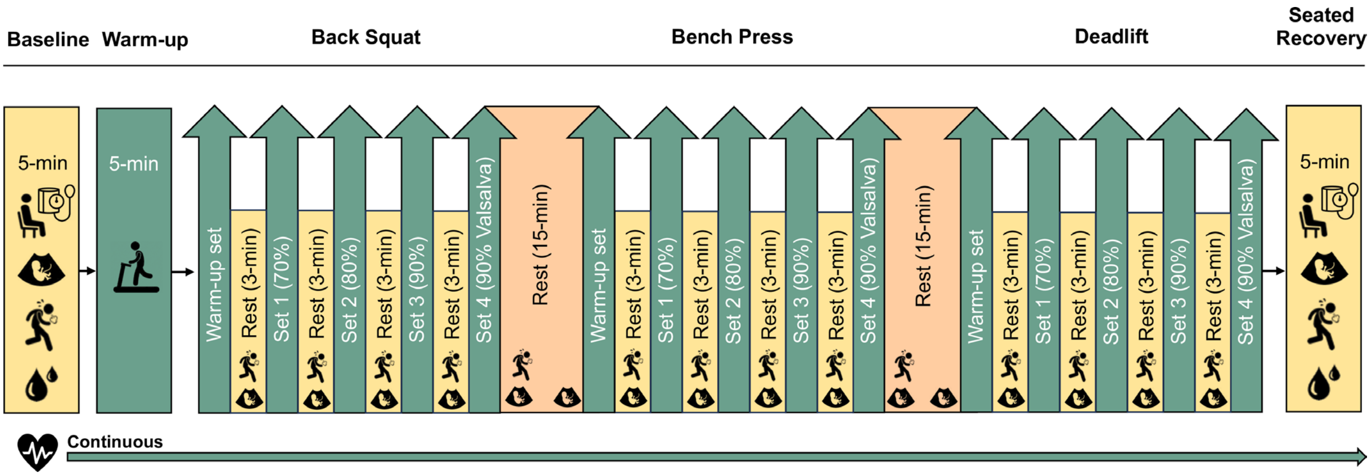

Figure 1 Visit 2 protocol. : blood pressure measurements; : capillary blood sample; : cardiovascular measurements; : fetal ultrasound; : treadmill walking; : rating of perceived exertion; : seated rest.

for bench press and deadlift, with another 15-min rest period provided between bench press and deadlift. Participants' glucose and lactate levels were measured again at the beginning of the seated recovery. Visit 2 protocols are demonstrated in figure 1.

Data analysis

All ultrasound analyses were performed to look at the change pre-exercise to postexercise for exercise type. Umbilical systolic/diastolic (S/D) ratio, resistive index and pulsatility index (PI) were calculated using 10 or more consecutive waveforms for UBF in velocimetry reports (Brachial Analyzer for Research; Medical Imaging Applications LLC, Coralville, Iowa, USA). An average of 10 consecutive fetal heartbeat intervals were analysed in ImageJ[13] and converted to beats per minute. Data from the Postpartum and Delivery Questionnaire were used to determine pregnancy and fetal outcomes. Participant values for each outcome were averaged and contributed to the group mean.

Statistical analysis

Data are presented as mean±SD. Statistical analyses were conducted using Excel 2016 (V.2405 for Windows; Microsoft, Redmond, Washington, USA). Parametric t-tests were used to determine statistical differences between pregnant and non-pregnant groups. Statistical significance was set at $p<0.05$.

Table 1 Demographics

	Participants	
	Pregnant (n=10)	Non-pregnant (n=10)
Age (years)	33.5±2.9	34.8±6.0
Ethnicity; n (%)		
White/Caucasian	10 (100%)	9 (90.0%)
Asian/Pacific Islander		1 (10.0%)
Weight at time of participation (kg)	78.0±9.0	73.0±6.7
Height (cm)	164.8±5.1	167.1±6.4
BMI	28.6±3.1	26.2±2.5
Gestational age at time of participation (weeks)	26.4±3.2	–
Primiparous; n (%)	2 (20%)	–
Resistance training experience (years)	9.8±5.1	11.2±6.6

Data are presented as mean±SD.
BMI, body mass index.

Patient and public involvement

No patients or members of the public were involved in the design, collection, analysis or interpretation of results for this study.

Equity, diversity and inclusion statement

The author team consisted of six females and one male who were primarily white (only one person of colour) representing four junior researchers, two research assistants and a senior researcher. The study population was primarily white (only one person of colour) from Edmonton, Canada. This study did not consider socioeconomic factors of the study population in its analysis.

RESULTS

Participant demographics

Ten pregnant (26.4±3.2 weeks gestation, range: 22–31 weeks) and 10 non-pregnant participants were recruited between November 2022 and November 2023 (see table 1).

Visit 2 testing

Resistance exercise testing data from visit 2 are presented in table 2. The amount of weight lifted was not different between pregnant and non-pregnant groups at each intensity. Mild symptoms were experienced, such as transient light-headedness (pregnant: 2; non-pregnant: 2), mild pelvic pressure (pregnant: 2; non-pregnant: 0), sacroiliac joint discomfort (pregnant: 1; non-pregnant: 0), mild low back pain (pregnant: 1; non-pregnant: 0), nausea (pregnant: 1; non-pregnant: 1), mild dizziness (pregnant: 0; non-pregnant: 1) and fatigue (pregnant: 0; non-pregnant: 1). No symptoms were severe enough to warrant the cessation of exercise. Glucose and lactate levels from pre- to post-exercise were not different between groups.

Fetal heart rate and umbilical blood flow

There were no significant changes in fetal HR across back squat, bench press and deadlift exercises. No fetus experienced bradycardia or tachycardia at any timepoint, and UBF parameters remained within normal ranges. Fetal well-being is summarised in table 3.

Table 2 Visit 2 testing data

		Pregnant	Non-pregnant	P value
Baseline physiological data				
SBP (mm Hg)		102.8±8.4	109.3±6.2	0.06
DBP (mm Hg)		65.5±9.2	75.2±6.2	**0.01***
RPE		0.0±0.0	0.1±0.2	0.15
Glucose (mmol/L)		5.9±1.1	6.1±0.9	0.69
Lactate (mmol/L)		2.4±1.3	1.9±0.4	0.25
Heart rate (bpm)		77.1±6.9	71.1±9.0	0.12
Back squat				
70% 10 RM	Absolute load (kg)	40.6±5.8	45.1±6.7	0.12
	Relative load (% body weight, kg)	23.9±4.3	28.4±6.0	0.07
	RPE	3.6±0.7	2.7±1.0	**0.04***
	Heart rate (bpm)	122.1±6.6	112.4±9.8	**0.02***
80% 10 RM	Absolute load (kg)	46.3±6.5	51.5±7.7	0.12
	Relative load (% body weight, kg)	27.2±4.8	32.4±6.8	0.07
	RPE	5.1±0.8	4.1±1.1	**0.03***
	Heart rate (bpm)	126.5±6.7	116.5±11.2	**0.03***
90% 10 RM	Absolute load (kg)	51.5±7.3	57.6±8.8	0.11
	Relative load (% body weight, kg)	30.3±5.3	36.2±7.8	0.06
	RPE	6.3±1.2	6.0±1.2	0.52
	Heart rate (bpm)	131.2±6.0	123.0±10.2	**0.04***
90% 10 RM with Valsalva	Absolute load (kg)	51.5±7.3	57.6±8.8	0.11
	Relative load (% body weight, kg)	30.3±5.3	36.2±7.8	0.06
	RPE	6.8±1.3	6.3±2.5	0.65
	Heart rate (bpm)	137.3±8.4	129.9±10.7	0.10
Bench press (supine position)				
70% 10 RM	Absolute load (kg)	26.5±4.1	25.2±4.9	0.51
	Relative load (% body weight, kg)	15.5±2.4	15.7±3.5	0.85
	RPE	3.0±1.1	3.0±1.0	1.00
	Heart rate (bpm)	102.3±5.7	97.8±11.2	0.28
80% 10 RM	Absolute load (kg)	30.2±4.1	28.3±5.2	0.40
	Relative load (% body weight, kg)	17.7±2.7	17.7±3.7	0.96
	RPE	4.7±0.9	4.1±1.5	0.34
	Heart rate (bpm)	101.4±8.5	100.2±12.9	0.81
90% 10 RM	Absolute load (kg)	34.2±4.6	32.2±5.9	0.40
	Relative load (% body weight, kg)	20.1±3.1	20.1±4.1	0.97
	RPE	5.8±1.4	5.9±1.5	0.88
	Heart rate (bpm)	107.9±9.9	104.7±15.0	0.58
90% 10 RM with Valsalva	Absolute load (kg)	34.2±4.6	32.2±5.9	0.40
	Relative load (% body weight, kg)	20.1±3.1	20.1±4.1	0.97
	RPE	6.8±1.5	6.5±1.6	0.73
	Heart rate (bpm)	110.5±10.4	103.5±13.4	0.21
Deadlift				
70% 10 RM	Absolute load (kg)	45.8±10.1	47.7±8.0	0.66
	Relative load (% body weight, kg)	27.0±6.5	30.0±6.4	0.32
	RPE	3.0±0.7	3.5±0.8	0.16
	Heart rate (bpm)	120.4±6.4	115.0±10.5	0.18
80% 10 RM	Absolute load (kg)	52.2±11.2	54.9±9.4	0.56
	Relative load (% body weight, kg)	30.8±7.6	34.6±7.7	0.29
	RPE	4.8±1.0	4.7±0.9	0.86
	Heart rate (bpm)	123.2±7.5	120.5±11.2	0.54
90% 10 RM	Absolute load (kg)	59.0±13.2	61.2±10.5	0.68
	Relative load (% body weight, kg)	34.8±8.7	38.6±8.4	0.34
	RPE	5.9±0.8	6.2±1.4	0.57
	Heart rate (bpm)	126.2±7.8	124.6±12.3	0.75

Continued

Table 2 Continued

		Pregnant	Non-pregnant	P value
90% 10 RM with Valsalva	Absolute load (kg)	59.10±13.2	61.3±10.5	0.68
	Relative load (% body weight, kg)	34.8±8.7	38.6±8.4	0.34
	RPE	7.0±1.3	7.0±1.7	p=1.00
	Heart rate (bpm)	130.7±9.0	126.0±12.9	0.36
Recovery physiological data				
SBP (mm Hg)		104.5±9.6	107.1±7.7	0.52
DBP (mm Hg)		69.5±6.5	73.4±6.6	0.20
Δ SBP		2.0±6.1	−2.2±6.1	0.16
Δ DBP		4.9±6.1	−1.8±3.4	**0.01***
RPE		0.6±0.7	0.3±0.5	0.36
Session RPE		4.3±1.5	3.8±1.2	0.40
Postexercise glucose (mmol/L)		5.2±0.7	5.2±0.8	0.93
Postexercise lactate (mmol/L)		4.7±1.2	6.0±2.1	0.12
Δ glucose		−0.8±1.1	−1.0±0.9	0.67
Δ lactate		2.3±1.6	4.2±2.2	0.05
Heart rate (bpm)		83.2±12.8	84.5±11.4	0.81

Data are presented as mean±SD or n (%).
Absolute and relative loads converted from imperial to metric measurement.
*P<0.05.
bpm, beats per minute; DBP, diastolic blood pressure; RM, repetition maximum; RPE, rating of perceived exertion; SBP, systolic blood pressure.

Postpartum and Delivery Questionnaire

All babies were born healthy and at term (39.5±1.3 weeks of gestation). All other pregnancy and delivery outcomes are summarised in table 4.

Daily physical activity

Daily physical activity levels and sedentary time between pregnant and non-pregnant participants for moderate to vigorous physical activities was not different (pregnant: 261.4±159.7 min/week, 30.0±17.8% of weekly activity; non-pregnant: 286.4±120.3 min/week, 32.3±14.1% of weekly activity).

DISCUSSION

Prenatal high-intensity resistance exercise is not recommended in current guidelines due to a lack of empirical evidence of its safety. Due to the increased participation of women in strength sports and the possible benefits of engaging in high-intensity resistance exercise during pregnancy, it is essential to determine its impacts on maternal cardiovascular response and fetal well-being. This study is the first to investigate the acute maternal and fetal responses to high-intensity resistance exercises (ie, barbell back squat, bench press and deadlift) using direct measures of maternal and fetal well-being. Fetal distress was not observed (i.e., no bradycardia and/or increases in mean UBF indices) before or after any of the attempts, including while participants performed the Valsalva manoeuvre and lifting in a supine position.

Maternal responses to resistance exercises

Pregnant and non-pregnant participants lifted similar weights for squats (90% 10 RM average: 51.5±7.3 kg; 57.6±8.8 kg, respectively), bench press (90% 10 RM average: 34.2±4.6 kg;

Table 3 Fetal haemodynamics during back squat, bench press and deadlift

	Baseline	Warm-up	70% 10 RM	80% 10 RM	90% 10 RM	90% 10 RM with Valsalva	P value (time)
Back squat							
FHR (bpm)	146.4±7.5	147.4±4.7	147.9±6.2	148.1±5.1	146.5±4.5	147.9±5.7	0.64
S/D ratio	8.80±8.22	11.25±8.01	8.35±4.48	7.93±3.26	6.78±5.01	11.77±11.45	0.61
Resistive index	0.83±0.06	0.79±0.06	0.82±4.48	0.82±0.05	0.77±0.08	0.82±0.06	0.64
Pulsatility index	1.32±0.15	1.35±0.17	1.34±0.16	1.30±0.12	1.24±0.19	1.29±0.16	0.71
Bench press (supine position)							
FHR (bpm)	149.3±6.0	146.6±7.5	149.7±4.9	149.4±5.6	153.6±6.9	147.8±8.7	0.68
S/D ratio	5.73±1.77	7.73±2.89	7.48±3.47	8.67±4.99	5.78±3.50	4.25±2.42	0.43
Resistive index	0.78±0.05	0.80±0.05	0.81±0.08	0.80±0.05	0.75±0.06	0.73±0.12	0.29
Pulsatility index	1.24±0.17	1.25±0.13	1.29±0.16	1.24±0.10	1.16±0.11	1.09±0.21	0.18
Deadlifts							
FHR (bpm)	145.0±3.2	146.6±6.1	148.0±5.6	143.8±7.3	146.9±4.7	145.5±6.6	0.85
S/D ratio	6.44±2.19	7.30±5.05	7.16±1.73	6.44±4.11	7.26±4.68	6.41±1.28	0.98
Resistive index	0.79±0.09	0.79±0.08	0.83±0.05	0.81±0.05	0.83±0.06	0.81±0.03	0.61
Pulsatility index	1.31±0.18	1.29±0.24	1.38±0.14	1.29±0.13	1.29±0.10	1.24±0.07	0.37

Data are presented as mean±SD.
FHR, fetal heart rate; S/D, ratio systolic/diastolic ratio.

Table 4 Maternal and delivery outcomes

	Delivery outcomes (n=9)
Gestational age (weeks)	39.5±1.3
Preterm birth (<37 weeks); n (%)	0 (0)
Maternal complications; n (%)	
Pelvic girdle pain	5 (56)
Pregnancy-related low-back pain	3 (33)
Urinary incontinence	1 (11)
Pre-eclampsia	0 (0)
Gestational hypertension	0 (0)
Gestational diabetes mellitus	0 (0)
Delivery method; n (%)	
Vaginal	7 (78)
Caesarean (planned)	1 (11)
Caesarean (emergency)	1 (11)
Instrumental (ie, forceps)	0 (0)
Duration of labour (hours)	21±21
Vaginal tears; n (%)	
1st Degree; n	2 (22)
2nd Degree; n	1 (11)
3rd Degree; n	2 (22)
Fetal birth weight (g)	3433±375
Microsomia (<2500 g); n (%)	0 (0)
Normal (2500–4000 g); n (%)	9 (100)
Macrosomia (>4000 g); n (%)	0 (0)
Fetal length (cm)	51±3
Fetal sex; n (%)	
Females	7 (78)
Males	2 (22)
NICU; n (%)	0 (0)

NICU, newborn intensive care unit.

32.2±5.9 kg, respectively) and deadlifts (90% 10 RM average: 59.0±13.2 kg; 61.2±10.5 kg, respectively). This finding suggests that healthy pregnant women who are resistance trained can maintain training intensities well into their second/third trimester (gestational age 26.4±3.2). Maternal heart rate increased as the intensity of each exercise increased, with a peak heart rate of 137 bpm, 111 bpm and 131 bpm for squat, supine bench press and deadlift, respectively. The statistically significant difference in heart rate at 70%, 80% and 90% 10 RM during the back squat suggests a greater physiological response to incremental loading. This may be due to the greater work performed by the lower extremity and longer exercise duration during squatting compared with the deadlift and bench press. Aside from the differences in heart rate response during the back squat, there were no differences in heart rate observed between pregnant and non-pregnant women lifting similar loads with or without Valsalva manoeuvre. This is in line with other work from our lab.[7] Interestingly, we observed opposite postexercise responses blood pressure where SBP and DBP increased in the pregnant group (~4 mm Hg) and decreased in the non-pregnant group (~2 mm Hg). However, as is commonly observed maternal blood pressure was lower in the pregnant versus non-pregnant group before exercise resulting in a 'normalisation' in blood pressure between groups postexercise. Regardless of the direction of the postexercise response, all blood pressures were within normal ranges. The change in pre-exercise to postexercise lactate approached significance (pregnant 2.3±1.6, non-pregnant 4.2±2.2; p=0.05), suggesting that the non-pregnant group reached a greater intensity compared with the pregnant group. It may also indicate that there is an adapted response to lactate metabolism during high-intensity resistance exercise in healthy pregnant women lifting comparable weights to non-pregnant women. Glucose levels were not different between groups and no hypoglycaemic events were observed, demonstrating from this study that blood glucose levels are maintained during high-intensity resistance exercise. Collectively, our data demonstrate that high-intensity resistance exercise is well tolerated by the pregnant mother.

Fetal well-being

This is the first study investigating the fetal responses to high-intensity resistance exercise during pregnancy. There was no time restraint on our participants' working period, and on average each a set of 10 repetitions took under 90 s for each exercise. Resistance sets of 10 repetitions up to 90% 10 RM consists of short periods of high-intensity exertion. Maternal heart rate and RPE increased as the load increased, but fetal bradycardia was not observed and fetal heart rate did not change throughout the duration of each exercise (squat: p=0.639; bench press: p=0.682; deadlift: p=0.847). These data provide empirical evidence in support of these movements being well tolerated by healthy pregnant women and their fetuses, which is consistent with our previous research on high-intensity interval training during pregnancy.[1 12] UBF is used to assess resistance to blood flow, and subsequent oxygen delivery, between the fetus and placenta. Key metrics such as PI, remained within normal ranges before and after each set of squats (p=0.71), bench press (p=0.18) and deadlifts (p=0.37). This indicates that blood flow to the fetus was maintained as maternal weight load increased, including during supine exercise and when performing the Valsalva manoeuvre. Although previously taboo during pregnancy and exercise, we did not identify any signs of fetal distress during the Valsalva manoeuvre or bench press. Pregnancy outcomes were unremarkable with all nine babies born at term (39.5±1.3 weeks gestation, one participant was lost to follow-up) and within a normal birth weight range (average weight: 3433±375 g). These findings align with our previous work examining fetal cardiovascular responses to high-intensity interval training (HIIT) which found short bouts of exercise >90% of maximal effort are well tolerated by both mother and fetus. Future research examining the impact of longer duration high-intensity exercise is required.[12] Previous work investigating high-intensity treadmill exercise identified cases of fetal bradycardia following 5-min bouts of exercise above 90% of maximal effort.[14] Whether this divergent finding was due to the longer duration of the exercise (~1 vs 5 min), the fact the athletes were elite-level athletes, or differences in how fetal well-being was assessed (in the upright/sitting position vs semi-recumbent supine position) requires further investigation.

Maternal and delivery outcomes

Our study suggests that exceeding the current recommended guidelines for resistance exercise in pregnancy does not contribute to adverse maternal or delivery outcomes. All babies were born to term (39.5±1.3 weeks), were of normal birth weight (2500–4000 g) and no babies were admitted to the newborn intensive care unit. There were no reports of pregnancy-related complications including pre-eclampsia, gestational hypertension or gestational diabetes, which is corroborated by a previous cross-sectional survey examining the impact of heavy weightlifting during pregnancy on maternal and fetal health outcomes.[9] Despite commonly held beliefs that resistance exercise during pregnancy may exacerbate pelvic floor dysfunction, only one participant experienced urinary incontinence. Overall, engaging in high-intensity resistance training did not appear to have adverse effects on maternal or delivery outcomes, but rather positive health benefits. It is possible that continuing to engage in high-intensity resistance exercise may help to limit deconditioning by maintaining or enhancing muscle strength and bone health, setting a better foundation for postpartum recovery and optimising long-term health.

Implications

Global physical activity guidelines for pregnancy encourage participation in light-to-moderate intensity resistance training (e.g., light dumbbells, resistance bands).[15–19] However, high-intensity resistance training is commonly discouraged based on expert opinion out of concern for fetal health. Our data provide the first direct assessment of fetal well-being during high-intensity resistance exercise in healthy, pregnant women with resistance training experience. Previous studies of resistance exercise typically use light loads (ie, 1–20 lbs) or resistance bands,[15 16 20–22] and few have conducted research with participants performing compound, multijoint movements including barbell back squats, bench press and deadlift.[7 23] These findings provide a foundation for evidence-based recommendations that can inform training advice for recreational and elite athletes who wish to continue resistance training during pregnancy with higher efforts and compound exercises. The data are also critical for informing general pregnant populations about activities that are well tolerated during pregnancy to help meet weekly exercise guidelines. Prospective studies of high-intensity resistance exercise are urgently needed to extend the findings of the current study.

Strengths and limitations

To our knowledge, this is the first direct assessment of maternal and fetal responses to an acute bout of high-intensity resistance exercise involving compound, mutijoint movements in a healthy pregnant population. Our study provides a broader understanding of the physiological tolerance to heavy resistance exercise in various postures, including standing and supine for both mother and fetus. Furthermore, we directly compared commonly used resistance training breathing techniques during each exercise type. At 90% 10 RM, free breathing and the Valsalva manoeuvre techniques did not elicit fetal distress, suggesting that these breathing techniques can be implemented while resistance training in healthy pregnant women.

This was a small study (n=10) and it is possible rare complications in pregnant patients engaged in heavier resistance training could have been missed. While larger studies are needed, this study provides foundational data and physiological measures of health in both the mother and fetus to inform safe resistance exercise during the late second and early third trimesters in otherwise healthy and previously trained women. Given that our participants were beyond 20 weeks of gestation, future studies might also investigate the effects of heavy resistance training throughout the entire gestational period to understand its impact on maternal and fetal outcomes at various stages of pregnancy. Further, all participants in the study had a background in resistance training (range of experience: 2–20 years). Selection bias may play a role in the generalisability of these results. Using these data as a foundation for resistance exercise safety in pregnancy, future directions should uncover if having multiple years of experience in resistance training is necessary to see all the benefits, or if starting resistance training while already pregnant may have differing outcomes. This may also help understand how training experience could impact the initiation of exercise during pregnancy to ensure that physical activity guidelines are being met through various means. Future investigations should further look at the maternal and fetal responses to higher loads (ie, >85% 1 RM) for individuals who wish to continue to train at these levels throughout their pregnancy.

CONCLUSION

An acute bout of near repetition max resistance exercise using compound, multijoint movements is well tolerated by mother and fetus including while using the Valsalva manoeuvre. These data provide a foundation to better inform training advice for women who wish to continue resistance training during pregnancy, as well as pave the way to future research in this under researched area.

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Contributors MHD and JBW contributed to the conception and design of the study. ANM, MKW, BAM, GB, MJG completed the acquisition of data. GB and MKW performed the data analysis. All authors assisted with the interpretation. MKW and MHD were the principal writers of the manuscript. All authors contributed to the drafting and revision of the final article. All authors approved the final submitted version of the manuscript. MHD is guarantor.

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