Elite Athletes and Pregnancy Outcomes: A Systematic Review and Meta-analysis

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ABSTRACT

WOWDZIA, J. B., T.-L. MCHUGH, J. THORNTON, A. SIVAK, M. F. MOTTOLA, and M. H. DAVENPORT. Elite Athletes and Pregnancy Outcomes: A Systematic Review and Meta-analysis. *Med. Sci. Sports Exerc.*, Vol. 53, No. 3, pp. 534–542, 2021. **Purpose:** The purpose of this systematic review was to evaluate fetal and maternal pregnancy outcomes of elite athletes who had participated in competitive sport immediately before conception. **Methods:** Online databases were searched up to March 24, 2020. Studies of any design and language were eligible if they contained information on the relevant population (pregnant women), exposure (engaged in elite sport immediately before pregnancy), and outcomes (birth weight, low birth weight, macrosomia, preterm birth, fetal heart rate and pulse index, cesarean sections, instrumental deliveries, episiotomies, duration of labor, perineal tears, pregnancy-induced low back pain, pelvic girdle pain, urinary incontinence, miscarriages, prenatal weight gain, inadequate/excess prenatal weight gain, maternal depression or anxiety). **Results:** Eleven unique studies (n = 2256 women) were included. We identified "low" certainty evidence demonstrating lower rates of low back pain in elite athletes compared with active/sedentary controls (n = 248; odds ratio, 0.38; 95% confidence interval, 0.20–0.73; I^2 = 0%) and "very low" certainty evidence indicating an increased odds of excessive prenatal weight gain in elite athletes versus active/sedentary controls (n = 1763; odds ratio, 2.47; 95% confidence interval, 1.26–4.85; I^2 = 0%). Low certainty evidence from two studies (n = 7) indicated three episodes of fetal bradycardia after high-intensity exercise that resolved within 10 min of cessation of activity. No studies reported inadequate gestational weight gain or maternal depression or anxiety. There were no differences between elite athletes and controls for all other outcomes. **Conclusions:** There is "low" certainty of evidence that elite athletes have reduced odds of experiencing pregnancy-related low back pain and "very low"certainty of evidence that elite athletes have increased the odds of excessive weight gain compared with active/sedentary controls. More research is needed to provide strong evidence of how elite competitive sport before pregnancy affects maternal and fetal outcomes. PROSPERO Registration: CRD42020167382. **Key Words:** PRECONCEPTION, SPORT, COMPETITIVE, PRENATAL, FETUS, LOW BACK PAIN, GESTATIONAL WEIGHT GAIN, PERINEAL TEAR, CESAREAN, BIRTH WEIGHT, BRADYCARDIA, PREGNANCY

Obstetrical guidelines around the world recommend that pregnant women engage in at least 150 min of moderate-intensity physical activity each week to derive clinically meaningful health benefits (1–3). However, most evidence-based physical activity guidelines are not suitable for pregnant elite athletes. The current guidelines are limited to moderate intensities of short durations that do not account for high levels of preconception training an elite athlete may be attempting to maintain during gestation (4). There is an assumed level of risk if an athlete trains above current recommendations during pregnancy because of high intensities, volumes, durations, and specific types of exercise training, which have yet to be supported as safe practice during gestation. As a result, many elite athletes have concerns that high levels of prenatal exercise may increase their risk of having pregnancy complications (5).

The sole guidelines specific to pregnant elite athletes were developed in 2016/2017 by the International Olympic Committee Expert Group. To inform these guidelines, the authors conducted a systematic review of prenatal exercise (including both elite athletes and the general obstetric population, as well as leisure time physical activity and occupational activity). Based on the paucity of available data regarding the effect of elite sport participation

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before and during pregnancy on maternal and fetal health outcomes, the data were not synthesized as a meta-analysis or limited to elite athletes (6). Therefore, the purpose of our systematic review and meta-analysis was to evaluate fetal and maternal pregnancy outcomes (birth weight, low birth weight (LBW), macrosomia, preterm birth, fetal heart rate (FHR) and pulse index, cesarean sections, instrumental deliveries, episiotomies, duration of labor, perineal tears, pregnancy related low back pain (LBP), pelvic girdle pain, urinary incontinence, miscarriages, prenatal weight gain, inadequate/excessive prenatal weight gain, and maternal depression or anxiety) of elite athletes who had participated in competitive sport immediately before conception.

METHODS

This systematic review was completed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines including the completion of the checklist (7).

Protocol and registration. This systematic review was registered with PROSPERO, the International Prospective Register of Systematic Reviews (CRD42020167382).

Eligibility criteria. The PICOS (population, intervention, comparison, outcome and study design) framework was used to guide this review (8).

Population of interest. The population of interest was pregnant women, of any trimester, who participated in elite-level sport immediately before conception. Elite athletes (defined as training for or competing in national/international competitions or the highest division in their sport) before pregnancy were eligible for inclusion. To be as inclusive as possible, it was determined that studies that grouped elite athletes with other nonelite athletes would be accepted and labeled as a mixed group.

Intervention (exposure). Studies were eligible for inclusion if they reported women competing in elite sport immediately before pregnancy.

Comparator. Eligible comparators included women who did not compete at the national/international competitions or highest division in their sport before pregnancy. This includes women who were competitive athletes at the non–elite-level, recreationally active and inactive women.

Outcome. Relevant clinical outcomes were as follows: birth weight, LBW (birth weight <2500 g or as defined by the author), macrosomia (birth weight >4000 g or as defined by the author), preterm birth (defined as birth <37 wk of gestation), fetal bradycardia (FHR <110 bpm), pulse index, cesarean section, instrumental delivery (vacuum and forceps), episiotomies, duration of labor, perineal tears, pregnancy-related LBP, pelvic girdle pain, urinary incontinence, miscarriage (or spontaneous abortion, defined as loss of a fetus before 20 wk of gestation), prenatal weight gain, inadequate/excessive prenatal weight gain (based on prepregnancy body mass index), and maternal mental health (depression and anxiety).

Study design. Primary research studies of any design were eligible, including noncomparative research designs (i.e., case studies). Narrative or systematic reviews and commentaries were excluded. Studies published in languages other than English were translated using Google Translate. If deemed as potentially relevant, native speakers were contacted for translation.

Literature sources. A structured search of electronic databases was performed by a research librarian (A.S.) using the following databases: MEDLINE, Embase, PsycINFO, Cochrane Database of Systematic Reviews, Cochrane Central Register of Controlled Trials, Scopus and Web of Science Core Collection, CINAHL, Plus with Full-text, Child Development and Adolescent Studies, ERIC, Sport Discus, ClinicalTrials.gov, and the Trip Database up to March 24, 2020 (see Appendix, Supplemental Digital Content, for complete search strategies, http://links.lww.com/MSS/C138). We manually searched the reference lists of included articles and reviews to identify potentially relevant studies. No language restrictions were applied.

Study selection and data extraction. Two independent reviewers (J.B.W. and M.H.D.) screened titles and abstracts of all retrieved articles. Abstracts that were identified to have met the initial screening criteria (i.e., PICOS) by at least one reviewer were automatically retrieved for full-text screening. Full-text articles were then independently screened by two reviewers for relevant outcomes before extraction. Relevant data from all publications were extracted for data synthesis. If two articles reported identical information and values, they were considered duplicates and only one was eligible for extraction. The following data were extracted from each publication: study characteristics (i.e., year, study design, country), population characteristics (i.e., number of participants, pregnancy complications), exposure (i.e., type of sport and competitive level, length of exposure, and quantity of prenatal physical activity) and outcomes (birth weight, LBW, macrosomia, preterm birth, FHR and pulse index, cesarean sections, instrumental deliveries, episiotomies, duration of labor, perineal tears, pregnancy-related LBP, pelvic girdle pain, urinary incontinence, miscarriages, prenatal weight gain, maternal mental health, and inadequate/excess prenatal weight gain). If data were unavailable for extractions or the number of elite athletes included in the study was unknown, authors were contacted to request additional information.

Quality assessment (risk of bias) and certainty assessment (GRADE). Two reviewers (J.B.W. and M.H.D.) independently assessed the risk of bias at the individual level. We assessed methodological quality of prospective cross-sectional, case–control, cohort, and case report studies by using the standardized critical appraisal instruments from Joanna Briggs Institute Critical Appraisal of Evidence Effectiveness Tool (9). We used Joanna Briggs Institute checklists for each study design to determine the extent to which a study has addressed the possibility of bias in its design, conduct, and analysis. Specifically, all studies were screened for potential sources of bias including inappropriate sampling, flawed measurement of exposure, flawed measurements of outcomes, selective/incomplete outcomes, unidentified confounding factors, and inappropriate statistical analysis. The differences in ratings were resolved through discussion. The overall risk of bias of a study was defined as high risk when more than one-third of the factors were marked as high risk.

The Grading of Recommendations Assessment, Development and Evaluation (GRADE) tool (10) was used to assess the certainty across studies for each maternal/fetal outcome. Evidence from observational studies began with a "low" certainty and was graded down for 1) risk of bias: risk of bias across studies was rated as "serious" when studies with the greatest influence on the pooled results (i.e., contributed to >50% of the weight of the pool estimated in the forest plots) presented "high" risk of bias; 2) inconsistency (when heterogeneity was high ($I^2 \geq 50\%$) or when only one study was assessed); and/or 3) imprecision was considered serious when the 95% confidence interval (CI) crossed the line of no effect and was wide, such that interpretation of the data would be different if the true effect were at one end of the CI or the other. When only one study was assessed, imprecision was not considered serious as inconsistency was already considered serious for this reason. No outcome had 10 or more publications; as such, publication bias was not deemed estimable and therefore rated down. The initial "low" rating was upgraded when there was evidence of a large magnitude of effect or dose–response relationship, counteracting plausible residual bias or confounders (11). The grading was completed independently by two of the reviews authors, and differences in ratings were resolved through discussion.

Statistical analysis. Review Manager V.5.3. (Cochrane Collaboration, Copenhagen, Denmark) was used to conduct the statistical analyses and create the forest plots. We calculated odds ratios (OR) and 95% CI using the random-effect model with inverse variance. Statistical significance was set at a P value of <0.05. For continuous outcomes, mean differences (MD) between elite athletes and active/sedentary control groups were calculated. Due to the limited amount of literature (n = 11), all study designs were combined for analysis.

When multiple comparison groups were reported, the sample size of elite athletes was divided by the number of comparators to avoid exaggeration of sample size of athletes. If there were multiple groups of elite athletes, the single comparator was divided by the number of athlete groups. If data were unavailable for extraction (i.e., not reported), the authors were contacted to request additional information.

For outcomes where a meta-analysis was not possible, results were presented as a narrative synthesis, structured around each outcome. Unless otherwise specified, studies were not included in meta-analyses if data were reported incomplete (e.g., SD, SE, or number of cases/controls not provided), if data were adjusted for confounding factors or if the study did not include a nonelite control group. In studies where data were included in the meta-analysis but additional information that could not be meta-analyzed was available (e.g., adjusted data), the studies were included in both the meta-analysis and narrative synthesis.

RESULTS

Study Characteristics

A Preferred Reporting Items for Systematic Reviews and Meta-Analyses diagram of the study search and selection process is shown in Figure 1. Three studies were initially checked for eligibility using Google Translate (12–14); however, they were all reviews and a native translator was not required to further assess eligibility. Eleven unique studies (four cross-sectional, two case–control, one cohort, and four case reports) from six countries (Iceland, Bulgaria, Switzerland, Wales, Denmark, and Norway) were included in this review. Among the included studies, exposure to competitive sport ranged from 3 to 15 yr of experience before getting pregnant (6/11 studies did not report the number of years of competitive sport experience before pregnancy). Types of competitive sports included 400-m sprint (15), soccer (16), handball (16), marathons (17), long-distance running (18), race walking (18), duathlon (18), cross-country skiing (18,19), CrossFit (20), ballroom dancing (20), swimming (21), track and field (21), and volleyball (21). Combined, there were 2407 women included (423 elite athletes, 1984 active/sedentary controls; see Appendix, Supplemental Digital Content, Supplement Table 1, http://links.lww.com/MSS/C138). In the case of Kardel and Kase (22), only two elite athletes were confirmed in the sample of 42 women, and therefore, the study was not included because of low elite athlete representation. Two other studies (23,24) also had a mixed sample of elite and nonelite athletes. Information on the exact number of elite athletes from these studies was not able to be obtained; however, authors confirmed by e-mail that athletes competing at the national/international level were included in their sample and the studies were included in the review. The complete results for the included studies are presented hereinafter. Specifically, four case reports and three cross-sectional studies were reported narratively because of their non-comparative study design. The remaining four studies (cross-sectional (one), cohort (one), and case–controls (two)) were combined for forest plot analysis.

Certainty of Evidence

Overall, the certainty of evidence ranged from "very low" to "low" as all studies were observational in nature. The most common reasons for downgrading the quality of evidence were 1) risk of bias (one study contributed to >50% of the weight of the pooled estimate), 2) inconsistency due to high heterogeneity ($I^2 > 50\%$) or where heterogeneity was not estimable (i.e., one study in the forest plot), and 3) imprecision (wide CI). No evidence of publication bias was observed among the analysis where it was possible to systematically assess publication bias using funnel plots (Appendix, Supplemental Digital Content Supplement Tables 2–12, http://links.lww.com/MSS/C138).

Synthesis of Data

Birth weight. There was "very low" certainty evidence from five studies (n = 2146 women; downgraded for imprecision [15,16,20,24,25]) demonstrating no association between preconception elite competitive sporting exposure and birth weight (n = 2145; four studies; MD, 20.6; 95% CI, −76.1 to 117.2; I^2 = 13%; Fig. 2). One study (n = 1 woman) could not be included in the pooled estimate as a comparator was

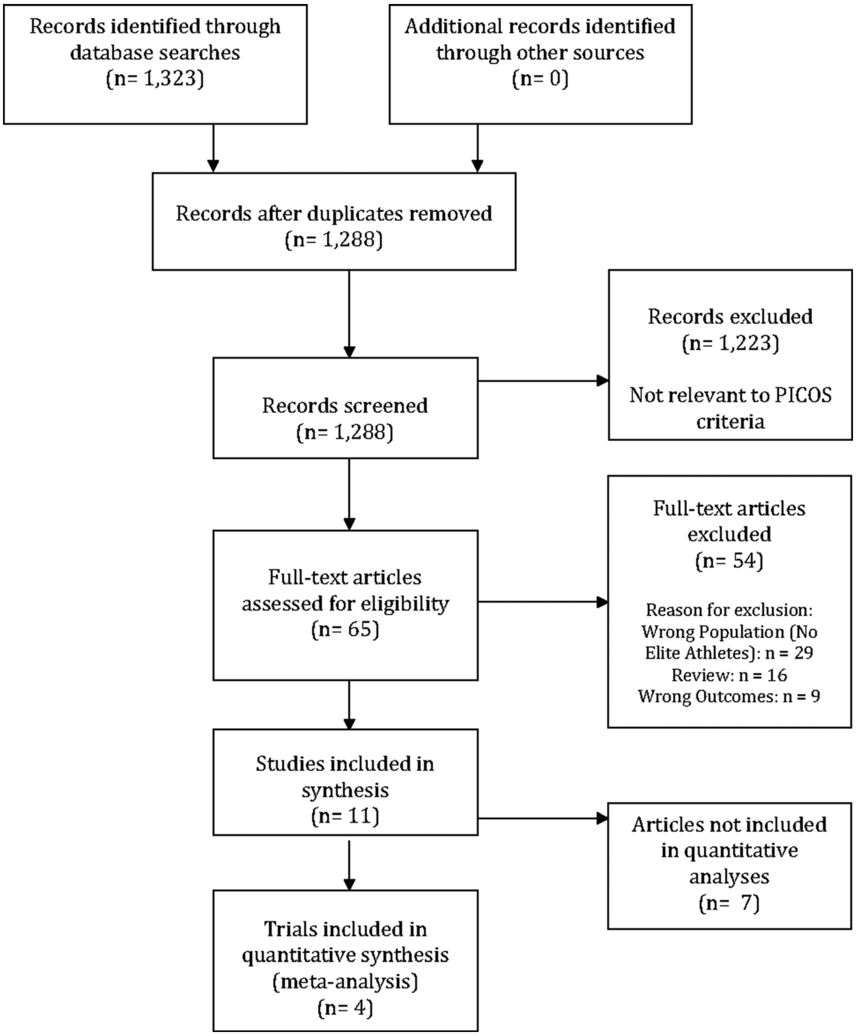

FIGURE 1—Study flow diagram.

not included (15): A single case reported a healthy birth weight of 3200 g (15).

Low birth weight (<2500 g or author defined). There was "very low" certainty evidence from five studies (*n* = 1946 women; downgraded for inconsistency and imprecision) (17,18,23,24,26) for no association between preconception competitive sporting exposure on LBW in elite athletes (*n* = 1763; 1 study; OR, 1.04; 95% CI, 0.31–3.46; I^2 = 0%; Appendix, Supplemental Digital Content, Supplement Figure 1, http://links.lww.com/MSS/C138). Four studies (*n* = 183 women) could not be included in the pooled estimates as they did not have a control group for comparison (17,18,23,26). One study reported a single case of LBW due to pregnancy complications of preeclampsia (*n* = 6 Olympic athletes) (18). No specific birth weights were listed by Beilock et al. (23); however, they did note that there were two LBWs and one "unhealthy" baby (*n* = 26). Zaharieva (26) reported that all newborns were born healthy, and there were no cases of physical or mental underdevelopment. However, Zaharieva (26) mentioned that the elite athletes (*n* = 150 women) were more likely to have LBWs compared with nonathletes. In the case study by Davies et al. (17), one athlete gave birth to healthy twins with birth weights of 2.2 and 2.3 kg, which is considered normal for twins, but overall small for gestational age.

Macrosomia (>4000 g or author defined). There was "very low" certainty evidence from one study (*n* = 1763 women; downgraded for inconsistency and imprecision [24]) for no association between preconception competitive sporting exposure and macrosomia in elite athletes (*n* = 1763; 1 study; OR, 0.76; 95% CI, 0.31–1.86; I^2 = 0%; Appendix, Supplemental Digital Content, Supplement Figure 2, http://links.lww.com/MSS/C138).

Preterm Birth

There was "very low" certainty evidence from three studies (*n* = 160 women; downgraded for risk of bias and imprecision [16,23,25]) for no association between preconception competitive sporting exposure and preterm birth in elite athletes (*n* = 134; 2 studies; OR, 0.93; 95% CI, 0.39–2.21; I^2 = 0%, Appendix, Supplemental Digital Content, Supplement Figure 3, http://links.lww.com/MSS/C138). One study (*n* = 26 women) could not be included in the pooled estimate because of a lack of

APPLIED SCIENCES

Study or Subgroup	Elite Athletes Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Bo 2007	3,291	751	31	3,466	529	46	9.2%	−175.00 [−480.38, 130.38]
Hegaard 2017 – light	3,569	426	12	3,626	491	1256	13.8%	−57.00 [−299.55, 185.55]
Hegaard 2017 – moderate	3,569	426	12	3,649	524	263	13.2%	−80.00 [−329.21, 169.21]
Hegaard 2017 – sedentary	3,569	426	12	3,632	534	208	12.9%	−63.00 [−314.72, 188.72]
Sigurdardottir 2018 – high impact elite	3,600	500	89	3,500	600	59	21.7%	100.00 [−85.01, 285.01]
Sigurdardottir 2018 – low impact elite	3,700	400	41	3,500	600	59	19.8%	200.00 [3.96, 396.04]
Sundgot-Borgen 2019	3,607	545	28	3,587	610	29	9.5%	20.00 [−280.07, 320.07]
Total (95% CI)			**225**			**1920**	**100.0%**	**20.55 [−76.11, 117.21]**

Heterogeneity: $Tau^2 = 2297.03$; $Chi^2 = 6.93$, df = 6 ($P = 0.33$); $I^2 = 13\%$
Test for overall effect: $Z = 0.42$ ($P = 0.68$)

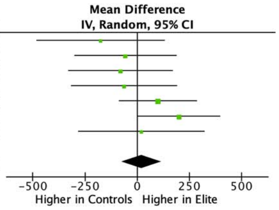

FIGURE 2—The effect of engagement in elite sports before pregnancy on birth weight in elite athletes vs controls (active/sedentary). Data reported as an MD. Analysis conducted using a random-effect model. IV, inverse variance.

control group (23). The study reported that 11.5% of their athletes delivered preterm (23).

FHR and Pulsatility Index

There was "low" certainty evidence from two studies (*n* = 7 women; (15,18), examining the effect of high-intensity prenatal exercise on FHR. In a case report of six elite athletes, two women exercising at an intensity of >90% HR_{max} experienced decelerated FHR after exercise (18). A second study (*n* = 1) reported a single fetal distress reaction in which the FHR dropped to 70 bpm and recovered within 3 min after a short burst of exercise at 87% of maternal HR_{max} (15). "Very low" certainty evidence from one study found high umbilical artery pulsatility index and decreased uterine artery blood flow within the two fetuses (pulsatility index, 1.67 and 1.65; uterine artery blood flow, 37% and 42% of initial values) after exercise (18).

Cesarean Sections

There was "very low" certainty evidence from three studies (*n* = 324 women; downgraded for imprecision [16,20,25]) for no association between preconception competitive sporting exposure and cesarean sections in elite athletes (*n* = 324; 3 studies; OR, 1.22; 95% CI, 0.58–2.60; I^2 = 0%; Appendix, Supplemental Digital Content, Supplement Figure 4, http://links.lww.com/MSS/C138).

Instrumental Deliveries

There was "very low" certainty evidence from one study (*n* = 77 women; downgraded for risk of bias, and inconsistency [16]) for no association between preconception competitive sporting exposure and instrumental delivery in elite athletes (*n* = 77; 1 study; OR, 0.71; 95% CI, 0.16–3.10; I^2 = N/A; Appendix, Supplemental Digital Content, Supplement Figure 5, http://links.lww.com/MSS/C138).

Episiotomies

There was "very low" certainty evidence from two studies (*n* = 163 women; downgraded for risk of bias [21,26]) for no association between preconception competitive sporting exposure and episiotomies. In a study of 150 elite athletes, Zaharieva (26) reported that eight had episiotomies. In a small group of 12 elite athletes who delivered vaginally, 3 indicated that they have had an episiotomy (21).

Duration of Labor: First and Second Phase

There was "very low" certainty evidence from two studies (*n* = 398 women; downgraded for risk of bias and inconsistency [20,26]) for no association between preconception competitive sporting exposure and prolonged first (*n* = 248; 1 study; MD, 2.63; 95% CI, −46.7 to 51.9]; I^2 = 0%; Online Supplement Figure 6, http://links.lww.com/MSS/C138) or second phase of labor (*n* = 248; 1 study; MD, 3.67; 95% CI, −5.1 to 12.5; I^2 = 58%; Appendix, Supplemental Digital Content, Supplement Figure 7, http://links.lww.com/MSS/C138). One study (*n* = 150) could not be included in the pooled estimate because of no control group for comparison (26). Zaharieva (26) reported no difference in duration of labor between the elite sportswomen (*n* = 150) and nonathletes (*n* = unreported). Although insignificant, elite athletes had a slightly longer first phase of labor (26). Zaharieva went on to state that the second phase was 1.5 times shorter for elite athletes, presumably because of the athletes' stronger abdominal muscles (26).

Perineal Tears

There was "very low" certainty evidence from three studies (*n* = 411 women; downgraded for risk of bias and inconsistency [20,21,26]) for no association between preconception competitive sporting exposure and intact perineum to second-degree tears (*n* = 248; 1 study; OR, 0.81; 95% CI, 0.40–1.63; I^2 = 17%; Appendix, Supplemental Digital Content, Supplement Figure 8, http://links.lww.com/MSS/C138). Similarly, there was "very low" certainty evidence from three studies (*n* = 411 women; downgraded for risk of bias and inconsistency [20,21,26]) for no association between preconception competitive sporting exposure and third- and fourth-degree perineal tears in elite athletes (*n* = 248; 1 study; OR, 0.88; 95% CI, 0.15–5.09; I^2 = 77%; Appendix, Supplemental Digital Content, Supplement Figure 9, http://links.lww.com/MSS/C138). Two studies (*n* = 162 women) could not be included in the pooled estimate for intact perineum to second-degree tears or third- and fourth-degree tears as a comparator was not included (21,26). Zaharieva (26) stated there was no substantial difference in rupturing of the perineum between athletes (*n* = 150) and nonathletes (*n* = unreported). A previous study demonstrated 46.1% of Olympic athletes who delivered vaginally experienced ruptures (*n* = 12); however, because of the small sample size, the data should be interpreted with caution (21). Neither study classified the degree/extent of the ruptures.

Low Back Pain

There was "low" certainty evidence from three studies ($n = 274$ women [16,23,25]) for an association between preconception competitive sporting exposure and decreased pregnancy-related LBP in elite athletes ($n = 248$; two studies; OR, 0.38; 95% CI, 0.20–0.73; $I^2 = 0\%$; Fig. 3). One study ($n = 26$ women) could not be included in the pooled estimate as there was no control group (23). Beilock et al. (23) reported that 15.4% of athletes perceived LBP to be a barrier to training during pregnancy.

Pelvic Girdle Pain

There was "very low" certainty evidence from two studies ($n = 248$ women; downgraded for imprecision [16,25]) for no association between preconception competitive sporting exposure and pelvic girdle pain in elite athletes ($n = 248$; 2 studies; OR, 1.00; 95% CI, 0.48–2.11; $I^2 = 0\%$; Appendix, Supplemental Digital Content, Supplement Figure 10, http://links.lww.com/MSS/C138).

Urinary Incontinence

There was "very low" quality of evidence from one study ($n = 77$ women; downgraded for risk of bias and inconsistency [16]) for no association between preconception competitive sporting exposure and urinary incontinence in elite athletes ($n = 77$; 1 study; OR, 0.93; 95% CI, 0.31–2.73; I^2 = N/A; Appendix, Supplemental Digital Content, Supplement Figure 11, http://links.lww.com/MSS/C138).

Miscarriages

There was "very low" certainty evidence from two studies ($n = 70$ women; downgraded for risk of bias and inconsistency [21,25]) for no association between preconception competitive sporting exposure and miscarriages in elite athletes ($n = 57$; 1 study; OR, 0.32; 95% CI, 0.07–1.34] I^2 = N/A; Appendix, Supplemental Digital Content, Supplement Figure 12, http://links.lww.com/MSS/C138). One study ($n = 13$ pregnant women) could not be included in the pooled estimate as a comparator was not included (21). The author stated "in no case had their sporting activities caused a spontaneous abortion" (21); however, no numerical values were stated.

Prenatal Weight Gain

There was "very low" certainty evidence from four studies ($n = 1842$ women; downgraded for inconsistency and imprecision [15,16,19,24]) for no association between preconception competitive sporting exposure and prenatal weight gain in elite athletes ($n = 1840$; two studies; MD, 0.81; 95% CI, −1.70 to 3.32; $I^2 = 62\%$; Appendix, Supplemental Digital Content, Supplement Figure 13, http://links.lww.com/MSS/C138). Two studies ($n = 2$) could not be included in the pooled estimate as a comparator was not included (15,19). A case report ($n = 1$) reported a 15-kg increase in prenatal weight gain (19). In comparison, a different case report ($n = 1$) reported a gestation weight gain of 9 kg (15).

Excessive Prenatal Weight Gain

There was "very low" evidence from one study ($n = 1763$ women; downgraded for risk of bias and inconsistency [24]) for an increased odds between preconception competitive sporting exposure and excess prenatal weight gain in elite athletes ($n = 1763$; one study; OR, 2.47; 95% CI, 1.26–4.85; $I^2 = 0\%$; Fig. 4).

Other Outcomes

No study reported on inadequate gestational weight gain or maternal depression or anxiety.

DISCUSSION

Over the last decade, mainstream media has brought attention to athletes who defy stereotypes by continuing to participate in elite sport before, during and after pregnancy. However, this remains a critically understudied population resulting in a decline in sport and exercise participation in pregnant athletes because of, at least in part, a lack of research and guidelines for these women (27,28). The current systematic review and meta-analysis of 11 studies identified "low" and "very low" evidence that elite pregnant athletes experienced a reduction in the prevalence of pregnancy-induced LBP and were at an increased odds of excessive gestational weight gain, respectively. Furthermore, two studies identified transient episodes of FHR decelerations (<110 bpm) and decreased perfusion after high-intensity exercise in three of seven elite athletes (15,18). The clinical significance of this finding is unclear as FHR returned to normal shortly (<10 min) after cessation of exercise, and the authors did not report further complications during pregnancy (15,18). All remaining reported outcomes were similar between elite athletes and active/sedentary controls.

Elite athletes experienced a lower prevalence of pregnancy-induced LBP compared with nonelite athletes. Although it

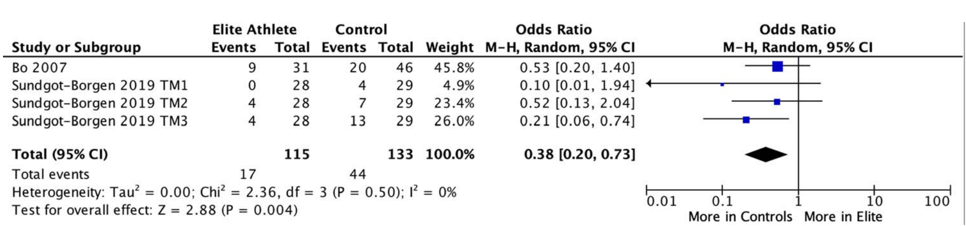

FIGURE 3—The effect of engagement in elite sports before pregnancy on LBP in elite athletes vs controls (active/sedentary). Data reported as an OR. Analysis conducted using a random-effect model. IV, inverse variance.

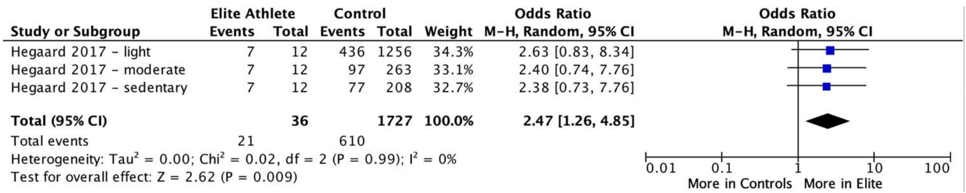

FIGURE 4—The effect of engagement in elite sports before pregnancy on excess prenatal weight gain in elite athletes vs controls (active/sedentary). Data reported as an MD. Analysis conducted using a random-effect model. IV, inverse variance.

is beyond the scope of the current review to identify the underlying cause of this reduction, previous studies demonstrate that strengthening the abdominal muscles has been linked to a reduction in pregnancy-related LBP (29), and engaging in preconception exercise can reduce the severity of LBP in the general obstetric population (30). Although a limited number of studies included in the current review reported on gestational activity levels, we found that elite athletes maintained 4–12.9 h of training per week (19,20,24) as compared with active controls at 0.2 $h \cdot wk^{-1}$ during gestation (20). This trend is supported by research that has demonstrated that women with high levels of physical activity before conception tend to maintain higher levels of prenatal physical activity than do those who were sedentary (27,31). Thus, a high level of elite training may be associated with strong abdominal musculature, which may aid in reducing the development of pregnancy-related LBP. Previous work has also demonstrated that athletes have higher pain tolerances than recreationally active controls (32); therefore, elite athletes could be less perceptive to pregnancy-related LBP than our active/sedentary controls. However, this may not be the case, as elite athletes demonstrated similar odds of PGP compared with active/sedentary controls. Thus, competing in elite sport immediately before pregnancy does not seem to have the same preventative effects for PGP as it does with pregnancy-induced LBP.

We found "very low" certainty evidence indicating that elite athletes had 247% increased odds of gaining excessive gestational weight. In the general obstetric population, gaining weight above recommendations is associated with an increased risk of delivering a large baby (>4000 g) and having a cesarean delivery (33); however, this was not observed in the current review. Similarly, we found that, although elite athletes are at higher odds of gaining excess gestational weight, they were not at increased odds of needing assisted instrumental delivery or episiotomies. Our findings are in line with a 2020 cohort study of 174,953 women where regardless of a woman's prepregnancy body mass index category, the effect of gestational weight gain on the use of instrumental delivery was small (34). Only one of our studies reported on excessive weight gain (24); therefore, our finding should be interpreted with caution ($n = 1827$). In future studies, reporting on both excessive and inadequate gestational weight gain will provide a richer understanding of health outcomes for pregnant elite athletes.

One of the primary concerns of pregnant athletes is the potential effect of training and competition on fetal health (35,36). Birth weight is an important predictor of neonatal morbidity and mortality (37). Neonates weighing less than 2500 g have an increased potential of being stillborn (38), whereas those born macrosomic (>4000 g) are more difficult to deliver (39). At both ends of the spectrum, infants born large or small are at increased risk of obesity, diabetes, and cardiovascular disease as an adult (40). Our results indicate that elite athletes had babies with similar birth weights to those of active/sedentary controls and did not have an increased risk of having a baby born <2500 or >4000 g. Regardless, there has been long-standing concern that high-intensity exercise during pregnancy could facilitate a redistribution of blood flow, and therefore nutrients, away from the fetus leading to a reduced birth weight (41). Longitudinal studies have yet to demonstrate that chronic high-intensity exercise is associated with LBW. Although a limited number of studies included in our review commented on prenatal physical activity, one study demonstrated that exercise at intensities >90% HR_{max} was associated with acute fetal bradycardia and elevated pulsatility index of the umbilical artery (potential indication of fetal distress) in two of six elite athletes (18). Each of the fetuses returned to normal resting values within 10 min of maternal recovery (18). The clinical significance of the transient bradycardia in this small sample of pregnant elite athletes is unclear; however, one elite athlete where fetal bradycardia was identified in response to high-intensity exercise later developed hemolysis-elevated liver enzyme-low platelet (HELLP) syndrome at week 35 of pregnancy delivering a baby of 2285 g (18). In comparison, the other elite athlete who experienced the fetal bradycardic episode delivered a baby weighing 3400 g at week 39 of gestation (18). Chronically, a reduction in oxygen transfer to the placenta may increase the risk for fetal growth restriction (42). However, previous studies in healthy and physically active pregnant women (nonathletes; $n = 4641$) found that, even at high intensities (>90% HR_{max}), the incidence of bradycardia and other metrics of fetal distress was low (43). Regardless, additional studies in elite athletes are critically warranted as many continue to train at high intensities during their pregnancy.

Miscarriages occur in approximately one in four pregnancies (44), and the occurrence of preterm birth is up to 11% of all pregnancies (45). Preterm birth has been linked to early neonatal death (46) and has been associated with increased risk of cerebral palsy (47), hearing and visual impairments (48), and learning difficulties (48). The cause of miscarriages and preterm birth is not always known. Because of this nature, the fear of miscarriages and preterm birth have been perceived as barriers to participating in physical activity (5). Current research supports that moderate-intensity physical activity in obstetric populations is not associated with miscarriages and preterm birth (3); however, the research in elite athletes is sparse (16,25). Our findings indicate that competing in elite sport before pregnancy does not seem to affect the odds of having a preterm birth or miscarriage. However, these results should be interpreted with caution because of the limited number of studies (16,25).

The effect of sport participation on the pelvic floor of female athletes has long been debated. It has been hypothesized that elite female athletes are more likely to have pelvic floor muscles which may not adapt or stretch sufficiently during vaginal delivery, thereby increasing the odds of having an instrumental delivery, prolonged labor, and perinatal tears (49). Although based on limited literature, it would seem that engaging in elite competitive sport before conception is not associated with any of the previously mentioned labor complications. Similarly, current data from the general obstetrical population (which did not include elite athletes) suggest that prenatal exercise does not adversely affect labor and delivery outcomes (50). More information on elite prenatal physical activity and sport-specific information would potentially clarify any mediators affecting the risk of labor/pregnancy complications. For example, athletes that participate in high-impact sports (i.e., gymnastics, track and field, tennis, and basketball) have a higher prevalence of urinary incontinence than those who compete in low-impact athletics (i.e., golf) (51). Urinary incontinence is highly prevalent in female athletes, with up to 80% of trampoline gymnasts experiencing involuntary bladder release (51). In the current review, only one study reporting on $n = 77$ (elite, $n = 31$; controls, $n = 46$) women found that 39% of elite athletes and 37% of controls (active/sedentary) experienced urinary incontinence (16). These data suggest that elite athletes, much like the general population, experience high rates of urinary incontinence during, before, and after pregnancy. Further investigation is warranted.

Strengths and limitations. The strengths of the current review include the use of methodological standards (GRADE) used in guiding the systematic review process. During the initial search, all study types (excluding narratives, systematic reviews, and commentaries) and articles published in languages other than English were considered for review. The process for the review was guided by content and methodological experts. A wide range of outcomes were considered to give a comprehensive review of the current knowledge surrounding maternal and fetal outcomes of elite athletes.

Our ability to draw conclusions is limited because of the lack of "moderate" or "high" certainty evidence and research investigating pregnant elite athletes. Importantly, no randomized controlled trials were available to include in the review. This may be due to the difficulty in conducting randomized controlled trials in elite populations (e.g., safety or ethical concerns; elite athletes may be less willing to participate in programs that will disrupt their current sport-specific training program). Additional high-quality studies are required to identify underlying relationships between elite athletes' exercise history and maternal/fetal outcomes. Information used to inform our review included that of only a single continent (Europe). We were only able to attain "very low" to "low" certainty of evidence for our outcomes of interest and their association to elite competitive sport exposure. Furthermore, most of our included studies have a retrospective design in which subjective bias and recall issues may decrease the validity of the results. Many of the studies included had small sample sizes allowing for greater chances of type II errors to occur. Not all studies reported prenatal physical activity or type of sport. Studies that did include measurements of prenatal physical activity reported it by different means and therefore made it difficult to compare. For the sake of this review, we were unable to analyze physical activity during pregnancy for the majority of outcomes and therefore were limited in our ability to address how prenatal physical activity levels of elite athletes differed from controls (active/sedentary) and how it may have affected certain outcomes. More studies are required to identify how elite athlete prenatal training affects fetal and maternal outcomes.

CONCLUSIONS

Engaging in elite competitive sport immediately before pregnancy is associated with "low" certainty evidence of a 62% reduction in the odds of pregnancy-related LBP and "very low" certainty evidence of 247% increased odds of gaining excessive weight. All other outcomes investigated did not differ between elite athletes and active/sedentary controls. With the exception of pregnancy-induced LBP and fetal bradycardia, all outcomes had "very low" certainty of evidence due to, in part, to the observational nature of the studies included in this review. Although the limited available data suggest that engaging in elite-level training and competition before and during pregnancy is not associated with an increased odds of adverse pregnancy outcomes, additional high-quality studies are urgently needed and long overdue to provide evidence-based guidance to our female elite athletes.

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