Physical fitness and maternal body composition indices during pregnancy and postpartum: the GESTAFIT project.

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1 **Title:** Physical fitness and maternal body composition indices during pregnancy and postpartum: the GESTAFIT project.

3 **Running head:** Fitness and body composition during gestation and postpartum.

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ABSTRACT

We explored the association of physical fitness (PF) during pregnancy with maternal body composition indices along pregnancy and postpartum period. The study comprised 159 pregnant women (32.9±4.7 years old). Assessments were carried out at the 16th and 34th gestational weeks (g.w.) and six weeks postpartum. Cardiorespiratory fitness (CRF), muscular strength (absolute and relative values) and flexibility were measured. Body composition indices were obtained by using dual-energy X-ray absorptiometry at postpartum. The results, after adjusting for potential covariates at the 16th g.w., indicated that greater CRF was associated with lower postpartum indices total fat mass, android and gynoid fat mass (all, $p<0.05$). Greater absolute upper-body muscular strength was associated with greater pre-pregnancy body mass index (BMI), gestational weight gain (GWG); and postpartum indices body weight, BMI, lean mass, fat free mass, fat mass, gynoid fat mass, T-score and Z-score bone mineral density (BMD) (all, $p<0.05$). Greater upper-body flexibility was associated with lower pre-pregnancy BMI; and postpartum indices body weight, BMI, lean mass, fat free mass, fat mass, android fat mass and gynoid fat mass, and with greater GWG (all, $p<0.05$). At the 34th g.w., greater CRF was additionally associated with greater postpartum T-score and Z-score BMD (both, $p<0.05$). In conclusion, this study reveals that greater PF levels, especially during early pregnancy, may promote a better body composition in the postpartum period. Therefore, clinicians and health promoters should encourage women to maintain or improve PF levels from early pregnancy.

Keywords: Cardiorespiratory fitness; strength; flexibility; bone density; gestation.

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HIGHLIGHTS

- Given that obesity is on the rise today, it is important to find strategies to cope with it, especially during pregnancy.
- The results of the present study suggest that greater physical fitness during early pregnancy is key to promoting better body composition in the postpartum period.
- It should be of clinical interest to encourage pregnant women to maintain or improve their physical fitness levels.

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INTRODUCTION

The rising prevalence of obesity, particularly among women in childbearing age, is an increasing public health concern[1]. In fact, in the European region, the current prevalence of maternal obesity ranges from 7 to 37%[2].

In this context, maternal body composition indices are correlates with maternal and foetal health. For example, excessive gestational weight gain (GWG) has been associated with adverse maternal (such as gestational diabetes, caesarean section) and foetal outcomes (small or large for gestational age and infant mortality)[1-4]. Therefore, reaching an optimal GWG during the pregnancy course is highly recommended. Furthermore, women tend to retain some of the body fat accumulated during pregnancy at the postpartum period, being heavier at 1 year postpartum compared with their pre-pregnancy body weight[2].

In addition, maintaining an adequate bone mineral density (BMD) is especially important during pregnancy and breastfeeding, since major changes occur in the maternal calcium homeostasis and bone metabolism in order to fulfil the demand of calcium and phosphorus of the placenta, foetus and breast milk[5, 6].

In this sense, adequate PF level during pregnancy, through specific physical activity or exercise recommendations[7, 8] is a modifiable factor that might be associated with a better body composition and thus, maternal and child's general health status and well-being[1, 2, 9]. Moreover, it has been suggested that greater PF levels may also have a positive impact on maternal BMD[10, 11]. Hence, the screening of PF during pregnancy could be an interesting option, especially in women at high risk of excessive GWG or low BMD.

Nevertheless, as far as we are aware, whether greater PF levels during pregnancy may influence maternal body composition has not been previously reported. Consequently, the aim of the present research was to study the association of PF during pregnancy with GWG and maternal body fat and BMD in postpartum period.

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METHODS

Study design and participants

The present cross-sectional study is part of the GESTAFIT project. The complete procedure and the inclusion-exclusion criteria (*see Supplementary Table S1*) have been published elsewhere[12]. A total of 159 Spanish pregnant women enrolled in this study in three turns (from November 2015 to April 2018), for feasibility reasons. The participants were recruited by the research team at the 12th gestational weeks (g.w.), during their first gynaecologist check up at the "San Cecilio" University Hospital (Granada, Spain). A written informed consent was signed by all interested participants after being informed about the study aims and procedures.

Procedures

After the recruitment, participants were invited to take part in the study at the Sport and Health University Research Institute (iMUDS). The assessments were carried out at the 16th (±2 g.w.) and 34th g.w. and one month after birth (postpartum period). The assessments were always conducted in 1 day in the same order: firstly, participants filled an auto-administered anamnesis form assessing their sociodemographic and clinical characteristics. Thereafter, each participant performed the PF tests (i.e., back-scratch test, handgrip test, treadmill protocol).

Sociodemographic and clinical data

Sociodemographic data, including age, number of children, marital status and educational level; and clinical data, including abortions and lactation options (exclusive breastfeeding, mixed feeding or formula feeding) were collected.

Body composition indices

Pre-pregnancy body weight was self-reported. On the first and second evaluations, body weight and height were assessed using a scale (InBody R20; Biospace, Seoul, Korea) and

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a stadiometer (Seca 22, Hamburg, Germany), respectively. Body mass index (BMI) was calculated as weight (kg) divided by squared height (m^2), including pre-pregnancy BMI. Moreover, GWG (kg) was calculated as the weight at the 34th g.w. minus weight at the 16th g.w. At the postpartum evaluation, total lean mass, fat mass, fat free mass, android and gynoid fat mass, and BMD of the whole body were measured using a dual-energy x-ray absorptiometry (DXA) device (Hologic Discovery QDR, Nasdaq: HOLX). Total body BMD was calculated (g/cm^2). Bone T-score was defined as the number of standard deviations [SDs] below the mean value of healthy young women, and the bone Z-score was defined as the number of SDs below the mean of healthy women of the same age[13].

Physical fitness tests

Cardiorespiratory fitness (CRF) was evaluated through maternal maximal oxygen intake (VO_{2max}). It was estimated with the Modified Bruce treadmill protocol[14], a submaximal, incremental, multistage and continuous treadmill test. The test incorporated progressive increments in the workload and velocity every 3 minutes to determine limits of maximal exertion. Women were asked to walk on the treadmill until the maternal heart rate reached 75% of the age-predicted maximal heart rate. If the participant requested to end the treadmill test, then the test was also stopped before reaching the heart rate value. Although submaximal treadmill testing is common and safe during pregnancy[14, 15], women were secured with a harness during the test to prevent risk of falls.

Upper-body muscular strength was evaluated by handgrip strength, used as a reference to measure global body strength, as described elsewhere[16]. A digital dynamometer (TKK 5101 Grip-D; Takey, Tokyo, Japan) was used. The participants performed the handgrip strength test twice, alternately with both hands. The best value of 2 attempts for each hand was recorded and the average of both hands was used as absolute muscular strength. Relative upper-body muscular strength was calculated as absolute handgrip strength

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divided by their body weight, measured in each assessment, and used in the analyses as recommended to address the confounding of strength by weight status[17].

Upper-body flexibility was evaluated with the back-scratch test, as a measure of overall shoulder range of motion. The distance between (or overlap of) the middle fingers behind the back was measured with a ruler[18]. The back-scratch test outcome is positive for higher flexibility (i.e. hands overlapping behind the back) and negative for lower flexibility (i.e. greater distance between middle fingers behind the back). The best score of 2 attempts for each arm was recorded, and the average of both arms was used for the analyses.

Statistical analyses

All analyses were performed using the SPSS (IBM SPSS Statistics for Windows, version 22.0, Armonk, NY) and the level of significance was set at $p<0.05$. Descriptive statistics [(mean and standard deviation (SD) for quantitative variables, and the number of women (%) for categorical variables)] were used to describe baseline characteristics of the participants. Linear regression analyses were performed to explore the independent association of CRF, muscular strength, and flexibility as predictors, with different maternal body composition outcomes (dependent variables). Each set, separately, examined the relationship between one predictor and one body composition outcome. These predictors were explored in two models based on the period evaluated: First, values of the PF tests evaluated at the 16th g.w. were introduced as predictors of maternal outcomes. Second, values of the PF tests evaluated at the 34th g.w. were introduced as predictors of maternal outcomes, when applicable. The relative upper-body muscular strength, rather than absolute strength, as previously recommended[17], was the chosen muscular strength predictor. Two models were tested. Model I was unadjusted. Model II was controlled for maternal age. Bone health outcomes were further adjusted for pre-pregnancy BMI (Model II), as a possible confounder[10]. Since in the GESTAFIT project[12]

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136 a concurrent physical exercise program was carried out until delivery, values at the 34th g.w. (Model II) were additionally adjusted for the exercise intervention (control or intervention group), in order to correct the possible effect of the exercise program on these variables.

RESULTS

The final sample size was composed of 159 Spanish pregnant women. Nonetheless, some of them did not attend the second (at the 34th g.w.) or last evaluation (postpartum) or did not return all the questionnaires duly completed, which meant a loss of data in some outcomes (Supplementary Figure S1).

The sociodemographic and clinical characteristics of the participants are shown in **Supplementary Table S2**. The mean age of the women at the recruitment was 32.9±4.6 years old. Most of them were nulliparous (61%) and opted for exclusive breastfeeding (>66%).

The maternal body composition indices and the PF tests of the participants are shown in **Table 1.** Briefly, women's BMI was 24.2 kg/m^2 during the pre-pregnancy period, and >25.0 kg/m^2 at the 16th g.w. and during the postpartum period. Women's GWG at the 34th g.w. was about 9 kg. Participants' total BMD was 1.06±0.1 g/cm^2 and their bone T-score status was -0.6±1.0 at the postpartum period. Type of lactation (breastfeeding exclusively, mixed or artificial lactation) was additionally included as a potential confounder in bone health outcomes. However, this data no longer changed these results (data not shown).

The linear regression model assessing the associations of PF tests at the 16th g.w. with maternal body composition indices is shown in **Table 2**.

In the adjusted model (Model II), greater CRF was associated with lower total fat mass, android fat mass, and gynoid fat mass at postpartum (β ranging from -0.230 to -0.311; all, $p<0.05$). Greater absolute upper-body muscular strength was associated with greater pre-

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pregnancy BMI, and postpartum body weight, BMI, lean mass, fat free mass, fat mass, gynoid fat mass, T-score and Z-score BMD (β ranging from 0.184 to 0.444; all, $p<0.05$). Greater upper-body flexibility was associated with lower pre-pregnancy BMI, and postpartum body weight, BMI, lean mass, fat free mass, fat mass, android fat mass and gynoid fat mass (β ranging from -0.246 to -0.442; all, $p<0.05$); and with greater postpartum GWG (β = 0.277, $p<0.01$). In model I, the results remain the same, except that greater upper-body flexibility was associated with lower T-score (β = -0.198, $p<0.05$) and Z-score BMD (β = 0.277, $p<0.05$) at postpartum.

The linear regression model assessing the associations of PF tests at the 34^{th} g.w. with maternal body composition indices is shown in **Table 3**.

In the adjusted model (Model II), greater CRF was associated with postpartum lower total fat mass, android fat mass and gynoid fat mass (β ranging from -0.290 to -0.294; all, $p<0.01$), and with greater T-score and Z-score BMD (β ranging from 0.228 to 0.233; all, $p<0.05$). In model I, greater CRF was additionally associated with lower BMI (β = -0.207, $p<0.05$), and T-score and Z-score BMD at postpartum were no longer significant ($p>0.05$).

Greater absolute upper-body muscular strength was associated with greater postpartum total lean mass, fat free mass, T-score and Z-score BMD (β ranging from 0.266 to 0.369; all, $p<0.01$). In model I, the results were unchanged.

Greater upper-body flexibility was associated with lower postpartum body weight, BMI, fat mass, android and gynoid fat mass (β ranging from -0.308 to -0.394; all, $p<0.01$). In model I, the results were unchanged.

The relative upper-body strength was also tested, separately, as previously recommended[17]. The linear regression model assessing the associations of the relative upper-body strength measured at the 16^{th} and 34^{th} g.w. with maternal body composition

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indices is shown in **Table 4**. At the 16th g.w. (Model II, adjusted), greater relative upper-body strength was associated with lower pre-pregnancy BMI (β = -0.639, p<0.001) and greater GWG (β = 0.271, p = 0.003); at the 16th and 34th g.w., greater relative upper-body strength was associated with lower postpartum body weight, BMI, total lean mass, fat free mass, fat mass, and android and gynoid fat mass (β ranging from -0.337 to -0.575; all, p<0.05). In model I, the results were unchanged.

DISCUSSION

Our main findings indicate that greater PF in early and late pregnancy was associated with a more adequate GWG during pregnancy, lower adiposity (i.e., total fat mass, fat free mass, lean mass and android and gynoid fat mass) and higher BMD at postpartum period. Specifically, greater relative muscular strength and flexibility during the early second trimester of gestation are strongly associated with better maternal body composition indices (except for bone health outcomes).

The recommendations of the Institute of Medicine are the most widely adopted concerning ideal GWG[19], especially for women with overweight and obesity. Pregnant women in our study had a BMI ≥25 kg/m^2 at the 16th g.w., and they were close to the 50 centiles for GWG at the 34th g.w., considering a previous study showing the recommended GWG per week[4].

A healthy lifestyle, combining diet and exercise, has been shown to prevent complications during pregnancy[2, 20], as well as to reduce the risk of excessive GWG and postpartum body weight[2, 20]. Furthermore, adequate PF levels ensure healthier outcomes in different populations[21-23], also during pregnancy, birth, and the postpartum period[7, 24-27]. In this sense, our results suggest that greater PF levels may also promote better body composition during the perinatal period.

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Since our study is the first to analyse not only maternal body weight and GWG with PF levels during pregnancy, but also a large number of body composition variables (i.e. adiposity and bone health variables) at the postpartum period, we cannot properly compare our findings with other similar studies. Nevertheless, there are some potential mechanisms that could explain the positive influence of greater PF levels on these body composition parameters.

Gestational-related fat is predominantly accumulated centrally, combining abdominal/truncal and visceral fat, and is strongly correlated with metabolic risk factors, such as higher blood pressure, adverse plasma lipids levels and reduced insulin sensitivity[1]. As a result, decreasing the amount of accumulated android fat mass during pregnancy is mandatory to prevent these complications[1]. Conversely, the increase in total fat mass during pregnancy is inversely proportional to pregravid obesity[19]. Moreover, our results suggest that greater levels of upper-body muscular strength and flexibility were associated with greater GWG and lower total fat mass in the postpartum period. Concerning bone health, women in our study showed normal bone T-score status (-0.6±1.0) at the postpartum period, when compared with non-pregnant women[13]. Our results are consistent with this, since greater relative upper-body muscular strength was associated with greater bone scores at the postpartum period.

Calcium homeostasis is markedly altered in pregnant women[5]. Calcium is transferred to the foetus and, although the intestinal calcium absorption is increased[6], it results in a progressive bone loss from early to late pregnancy[10]. The study conducted by To and Wong[10] found that the normal physiological bone loss during pregnancy was significantly more attenuated in active pregnant women compared to their non-exercising counter-partners, supporting that exercise during pregnancy could exert a positive impact on bone metabolism[10]. Moreover, a physically active lifestyle, which is *per se* associated with

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greater bone mass, promotes a protective effect against bone loss and helps achieving higher peak bone mass[28]. Likewise, an increase in BMD content during pregnancy might prevent maternal skeleton against excessive demineralization and fragility during lactation[6]. In this regard, greater muscular strength is widely associated with greater BMD in those physiological women stages when BMC may diminish, such as the menopausal and postmenopausal period[29]. In lactating women, this relationship has been also previously shown[30].

Furthermore, evidence suggest that greater VO_{2max} and muscle power have been associated with better bone status in young females, especially in those with overweight[11]. Our results support these findings, since greater CRF (in late pregnancy) and relative upper-body muscular strength (in early second trimester and late pregnancy) were associated with greater BMD at postpartum.

Although greater PF levels, improved by practicing physical activity or exercise during pregnancy[7, 8], could be a safe alternative to control all these parameters, women typically reduce their physical activity levels during pregnancy[31]. Likewise, only a minority of pregnant women achieve the recommendations for this stage[7].

To sum up, strategies for promoting greater PF levels through exercise (focusing on resistance training) could be effective to maximize bone health during pregnancy, especially in those women with low BMD. Likewise, resistance training may have a positive effect on pregnant women with overweight, promoting better GWG and lower fat mass at postpartum.

Strengths and Limitations

Some limitations should be acknowledged. Firstly, the cross-sectional design precludes determination of causality. Secondly, since we did not measure weight at delivery, the total GWG during the whole pregnancy may be higher than reported until the 34th g.w.

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However, we based our comparisons on the reference values in GWG given by gestational weeks[4] and, therefore, our results are still valid and reliable. Moreover, we did not have the possibility of measuring pre-pregnancy BMD (due to the impossibility of knowing the intention to get pregnant), and neither BMD changes during pregnancy because of the harmful effects of radiation during pregnancy. Finally, our results should be interpreted with caution, since, although we have analysed absolute and relative muscular strength to control the interpretation of confounding parameter, such as changes in body composition during pregnancy (i.e., the higher the body mass the greater the absolute muscular strength)[17], there is a lack of reliable measures of strength in this specific population.

On the other hand, to the best of our knowledge, this is the first study documenting a strong association of PF tests with maternal GWG and body composition indices at the postpartum period. Moreover, most studies on maternal pre-pregnancy weight and GWG are based on self-reported weight, and it has been shown that there is a 1-kg difference in self-reported weight and weight registered at clinical visits[32, 33]. In this sense, although pre-pregnancy BMI was self-reported (based on self-reported weight and height), the rest of measures were assessed by validated methods, such as DXA technology at postpartum[34]. Finally, our study sample was relatively large; despite the sample loss in some outcomes, we presented a big number of body composition variables within the same report, and at different stages of pregnancy.

Interpretation

Due to the important adverse effects of non-normative body composition indices during pregnancy on maternal and foetal outcomes, as well as the burden on healthcare resources, it is imperative to support lifestyle intervention strategies, such as reaching greater PF levels. Consequently, appropriate PF levels during the gestational period will ensure a

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healthier pregnancy and might minimize the risk of suffering pregnancy complications related to excessive GWG and adiposity or BMD loss at postpartum period.

CONCLUSION

Greater PF levels have shown a strong relationship with better body composition during the perinatal period (i.e. appropriated GWG, less adiposity and greater bone mass). Further studies testing the specific influence of exercise programs based on muscular strength training (before and during pregnancy) on perinatal body composition are warranted.

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Contribution to authorship

Blinded for peer review.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Data availability statement

Data will be made available on request. Anyone interested in discussing collaborative research should contact the corresponding author.

Ethical approval

Blinded for peer review.

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Table 1. Body composition indices and physical fitness levels of the participants

Maternal outcomes	**n**	**Mean±SD**
Height (cm)	157	163±6.21
Weight previous to pregnancy (Kg)	145	65.1±12.3
Pre-pregnancy body mass index (Kg/m^2)	145	24.2±4.2
Values at 16th g.w.		
Weight at 16th g. w. (Kg)	157	67.0±11.8
Body mass index at 16th g.w. (Kg/m2)	157	25.0±4.1
Values at 34th g.w.		
Weight at 34th g. w. (Kg)	123	74.6±10.8
Weight gain (16th g.w. to 34th g.w.) (Kg)	121	8.7±3.4
Weight and body composition at postpartum		
Weight at postpartum (Kg)	107	68.5±11.4
Body mass index at postpartum (Kg/m^2)	107	25.5±4.4
Total body fat free mass (Kg)	110	40.9±4.7
Total body lean mass at postpartum (Kg)	110	38.9±4.7
Total body fat mass at postpartum (Kg)	110	26.2±7.7
Total body android fat mass at postpartum (Kg)	110	18.8±0.8
Total body gynoid fat mass at postpartum (Kg)	110	52.1±1.3
Total bone mineral density (g/cm^2)		1.06±0.1
Bone mineral density T-score*		-0.6±1.0
Bone mineral density Z-score		-0.7±0.9
Physical fitness tests		**Mean±SD**
16th g. w.	157	
Cardiorespiratory fitness (75% VO_{2max})		
Upper-body absolute muscular strength; kg/weight(kg)		27.3±4.3
Upper-body relative muscular strength; kg/weight(kg)		0.4±0.1
Upper-body flexibility (cm)		4.1±6.2
34th g. w.	123	
Cardiorespiratory fitness (75% VO_{2max})		
Upper-body absolute muscular strength; kg/weight(kg)		27.2±4.5
Upper-body relative muscular strength; kg/weight(kg)		0.4±0.1
Upper-body flexibility (cm)		3.9±6.0

SD, Standard Deviation; g. w., gestational week. *Normal bone is defined as a T-score of −1.0 or higher, osteopenia is defined as between −1.0 and −2.5, osteoporosis is defined as −2.5 or lower[18].

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Table 2. Linear regression coefficients assessing the association of the physical fitness tests measured at the 16th gestational week with maternal body composition and bone health status

	Model I			Model II		
	Standardized Coefficients (β)	**Confidence interval 95% (B)**	***p***	**Standardized Coefficients (β)**	**Confidence interval 95% (B)**	***p***
Cardiorespiratory fitness						
Pre-pregancy BMI (kg/m2)	-0.145	-0.112 (-0.252, -0.029)	0.119	-0.140	-0.108 (-0.249, 0.034)	0.134
GWG (kg)	0.095	0.052 (-0.059, 0.163)	0.352	0.099	0.054 (-0.056, 0.165)	0.331
Weight postpartum (kg)	-0.100	-0.183 (-0.578, 0.212)	0.359	-0.093	-0.170 (-0.563, 0.222)	0.391
BMI postpartum (kg/m2)	-0.147	-0.110 (-0.270, 0.051)	0.178	-0.141	-0.105 (-0.265, 0.055)	0.195
Total lean mass at postpartum (Kg)	0.021	0.015 (-0.143, 0.173)	0.848	0.024	0.018 (-0.139, 0.175)	0.819
Total fat free mass at postpartum (Kg)	0.016	0.012 (-0.149, 0.174)	0.881	0.020	0.015 (-0.146, 0.176)	0.853
Total fat mass at postpartum (Kg)	-0.255	-0.317 (-0.573, -0.060)	**0.016**	-0.311	-0.250 (-0.563, -0.059)	**0.016**
Total android fat mass at postpartum (Kg)	-0.234	-0.029 (-0.055, -0.003)	**0.027**	-0.230	-0.029 (-0.054, -0.003)	**0.028**
Total gynoid fat mass at postpartum (Kg)	-0.239	-0.054 (-0.100, -0.007)	**0.024**	-0.234	-0.052 (-0.098, -0.007)	**0.024**
Total BMD at postpartum (g/cm2)*	-0.070	-0.001 (-0.004, 0.002)	0.515	-0.036	-0.000 (-0.003, 0.002)	0.751
T-score BMD at postpartum*	0.045	0.007 (-0.027, 0.041)	0.674	0.095	0.016 (-0.020, 0.052)	0.388
Z-score BMD at postpartum*	0.052	0.008 (-0.024, 0.039)	0.631	0.104	0.016 (-0.017, 0.049)	0.346
Absolute upper-body strength						
Pre-pregancy BMI (kg/m2)	0.197	0.192 (0.031, 0.352)	**0.019**	0.203	0.197 (0.037, 0.357)	**0.016**
GWG (kg)	0.185	0.160 (0.005, 0.315)	**0.043**	0.184	0.159 (0.004, 0.315)	**0.044**
Weight postpartum (kg)	0.324	0.987 (0.428, 1.545)	**0.001**	0.311	0.947 (0.393, 1.501)	**0.001**
BMI postpartum (kg/m2)	0.288	0.339 (0.121, 0.557)	**0.003**	0.277	0.327 (0.109, 0.544)	**0.004**
Total lean mass at postpartum (Kg)	0.451	0.561 (0.349, 0.772)	**<0.001**	0.438	0.544 (0.334, 0.755)	**<0.001**
Total fat free mass at postpartum (Kg)	0.457	0.580 (0.364, 0.796)	**<0.001**	0.444	0.564 (0.350, 0.779)	**<0.001**
Total fat mass at postpartum (Kg)	0.216	0.446 (0.062, 0.829)	**0.023**	0.200	0.411 (0.032, 0.791)	**0.034**
Total android fat mass at postpartum (Kg)	0.160	0.034 (-0.006, 0.073)	0.095	0.146	0.031 (-0.009, 0.070)	0.126
Total gynoid fat mass at postpartum (Kg)	0.210	0.075 (0.008, 0.142)	**0.028**	0.190	0.068 (0.003, 0.133)	**0.042**
Total BMD at postpartum (g/cm2)*	0.161	0.003 (-0.001, 0.007)	0.092	0.185	0.004 (0.000, 0.008)	0.068
T-score BMD at postpartum*	0.300	0.075 (0.030, 0.121)	**0.001**	0.300	0.075 (0.027, 0.124)	**0.002**
Z-score BMD at postpartum*	0.309	0.072 (0.030, 0.114)	**0.001**	0.308	0.072 (0.027, 0.117)	**0.002**
Upper-body flexibility						
Pre-pregancy BMI (kg/m2)	-0.416	-0.287 (-0.392,-0.182)	**<0.001**	-0.414	-0.285 (-0.390,-0.180)	**<0.001**
GWG (kg)	0.274	0.153 (0.055, 0.252)	**0.003**	0.277	0.155 (0.056, 0.254)	**0.002**
Weight postpartum (kg)	-0.355	-0.644 (-0.973, -0.314)	**<0.001**	-0.352	-0.638 (-0.964, -0.313)	**<0.001**
BMI postpartum (kg/m2)	-0.444	-0.311 (-0.434, -0.189)	**<0.001**	-0.442	-0.310 (-0.431, -0.189)	**<0.001**
Total lean mass at postpartum (Kg)	-0.274	-0.202 (-0.339, -0.066)	**0.004**	-0.269	-0.199 (-0.334, -0.064)	**0.004**
Total fat free mass at postpartum (Kg)	-0.269	-0.203 (-0.342, -0.064)	**0.005**	-0.265	-0.200 (-0.338, -0.061)	**0.005**
Total fat mass at postpartum (Kg)	-0.336	-0.415 (-0.637, -0.192)	**<0.001**	-0.331	-0.408 (-0.626, -0.189)	**<0.001**
Total android fat mass at postpartum (Kg)	-0.338	-0.042 (-0.065, -0.020)	**<0.001**	-0.333	-0.042 (-0.064, -0.019)	**<0.001**
Total gynoid fat mass at postpartum (Kg)	-0.253	-0.054 (-0.094, -0.015)	**0.008**	-0.246	-0.053 (-0.091, -0.014)	**0.008**
Total BMD at postpartum (g/cm2)*	-0.043	-0.001 (-0.003, 0.002)	0.657	-0.025	-0.000 (-0.003, 0.002)	0.821
T-score BMD at postpartum*	-0.198	-0.029 (-0.057, -0.002)	**0.039**	-0.195	-0.030 (-0.062, -0.003)	0.072
Z-score BMD at postpartum*	-0.197	-0.027 (-0.053, -0.001)	**0.040**	-0.195	-0.028 (-0.058, -0.003)	0.074

BMI, body mass index; GWG, gestational weight gain; BMD, bone mineral density; β, standardized regression coefficient; B, non-standardized regression coefficient. Bold values, $p<0.05$. Model I was unadjusted. Model II was adjusted for maternal age. *Model II additionally adjusted for pre-pregnancy body mass index.

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Table 3. Linear regression coefficients assessing the association of the physical fitness tests measured at the 34th gestational week with maternal body composition and bone health status

	Model I			Model II		
	Standardized Coefficients (β)	**Confidence interval 95% (B)**	***p***	**Standardized Coefficients (β)**	**Confidence interval 95% (B)**	***p***
Cardiorespiratory fitness						
Weight postpartum (kg)	-0.152	-0.359 (-0.877, 0.160)	0.173	-0.115	-0.270 (-0.788, 0.247)	0.302
BMI postpartum (kg/m^2)	-0.207	-0.229 (-0.404, -0.011)	**0.039**	-0.194	-0.176 (-0.373, 0.021)	0.079
Total lean mass at postpartum (Kg)	0.029	0.027 (-0.173, 0.227)	0.791	0.085	0.079 (-0.120, 0.278)	0.433
Total fat free mass at postpartum (Kg)	0.033	0.032 (-0.174, 0.237)	0.761	0.088	0.083 (-0.122, 0.288)	0.422
Total fat mass at postpartum (Kg)	-0.324	-0.522 (-0.854, -0.191)	**0.002**	-0.290	-0.467 (-0.801, -0.134)	**0.007**
Total android fat mass at postpartum (Kg)	-0.329	-0.055 (-0.089, -0.021)	**0.002**	-0.293	-0.049 (-0.084, -0.015)	**0.006**
Total gynoid fat mass at postpartum (Kg)	-0.318	-0.087 (-0.143, -0.031)	**0.003**	-0.294	-0.081 (-0.138, -0.024)	**0.006**
Total BMD at postpartum (g/cm^2)*	0.127	0.002 (-0.001, 0.005)	0.244	0.207	0.003 (0.000, 0.007)	0.078
T-score BMD at postpartum*	0.141	0.027 (-0.014, 0.067)	0.196	0.233	0.045 (0.001, 0.090)	**0.047**
Z-score BMD at postpartum*	0.130	0.023 (-0.015, 0.060)	0.232	0.228	0.041 (0.000, 0.083)	**0.053**
Absolute upper-body strength						
Weight postpartum (kg)	0.184	0.487 (-0.022, 0.997)	0.061	0.184	0.489 (-0.019, 0.996)	0.059
BMI postpartum (kg/m^2)	0.122	0.125 (-0.074, 0.323)	0.215	0.121	0.124 (-0.075, 0.323)	0.221
Total lean mass at postpartum (Kg)	0.364	0.391 (0.199, 0.583)	**<0.001**	0.369	0.397 (0.206, 0.587)	**<0.001**
Total fat free mass at postpartum (Kg)	0.369	0.406 (0.210, 0.602)	**<0.001**	0.374	0.412 (0.217, 0.606)	**<0.001**
Total fat mass at postpartum (Kg)	0.075	0.134 (-0.208, 0.475)	0.440	0.069	0.123 (-0.217, 0.462)	0.476
Total android fat mass at postpartum (Kg)	0.023	0.004 (-0.031, 0.039)	0.808	0.022	0.004 (-0.031, 0.039)	0.822
Total gynoid fat mass at postpartum (Kg)	0.083	0.026 (-0.033, 0.085)	0.390	0.067	0.021 (-0.038, 0.079)	0.484
Total BMD at postpartum (g/cm^2)*	0.163	0.003 (0.000, 0.006)	0.090	0.165	0.003 (-0.001, 0.006)	0.100
T-score BMD at postpartum*	0.276	0.060 (0.020, 0.100	**0.004**	0.266	0.057 (0.016, 0.098)	**0.006**
Z-score BMD at postpartum*	0.284	0.057 (0.020, 0.095)	**0.003**	0.274	0.055 (0.017, 0.093)	**0.005**
Upper-body flexibility						
Weight postpartum (kg)	-0.309	-0.562 (-0.901, -0.223)	**0.001**	-0.308	-0.561 (-0.896, -0.225)	**0.001**
BMI postpartum (kg/m^2)	-0.394	-0.277 (-0.403, -0.151)	**<0.001**	-0.394	-0.277 (-0.403, -0.151)	**<0.001**
Total lean mass at postpartum (Kg)	-0.166	-0.125 (-0.268, 0.018)	0.085	-0.162	-0.122 (-0.264, 0.019)	0.089
Total fat free mass at postpartum (Kg)	-0.160	-0.123 (-0.270, -0.023)	0.097	-0.156	-0.121 (-0.266, -0.024)	0.101
Total fat mass at postpartum (Kg)	-0.342	-0.429 (-0.655, -0.203)	**<0.001**	-0.341	-0.428 (-0.650, -0.205)	**<0.001**
Total android fat mass at postpartum (Kg)	-0.339	-0.043 (-0.066, -0.020)	**<0.001**	-0.337	-0.043 (-0.066, -0.020)	**<0.001**
Total gynoid fat mass at postpartum (Kg)	-0.320	-0.070 (-0.109, -0.030)	**0.001**	-0.322	-0.070 (-0.109, -0.032)	**<0.001**
Total BMD at postpartum (g/cm^2)*	0.045	0.001 (-0.002, 0.003)	0.642	0.125	0.002 (-0.001, 0.004)	0.242
T-score BMD at postpartum*	-0.095	-0.015 (-0.044, -0.015)	0.326	-0.050	-0.008 (-0.042, -0.025)	0.632
Z-score BMD at postpartum*	-0.099	-0.014 (-0.041, -0.013)	0.308	-0.057	-0.009 (-0.040, -0.023)	0.590

BMI, body mass index; GWG, gestational weight gain; BMD, bone mineral density; β, standardized regression coefficient; B, non-standardized regression coefficient. Bold values, p<0.05. Model I was unadjusted. Model II was adjusted for maternal age, and exercise intervention at the 34th gestational week. *Model II additionally adjusted for pre-pregnancy body mass index.

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Table 4. Linear regression coefficients assessing the association of the relative upper-body strength measured at the 16th and 34th gestational week with maternal body composition and bone health status

	Model I			Model II		
	Standardized Coefficients (β)	**Confidence interval 95% (B)**	***p***	**Standardized Coefficients (β)**	**Confidence interval 95% (B)**	***p***
Relative upper-body strength (16th gestational week)						
Pre-pregancy BMI (kg/m²)	-0.639	-32.310 (-38.840, -25.780)	**<0.001**	-0.641	-32.453 (-39.101, -25.804)	**<0.001**
GWG (kg)	0.271	12.266 (4.324, 20.208)	**0.003**	0.283	12.801 (4.793, 20.808)	**0.002**
Weight postpartum (kg)	-0.561	-89.624 (-115.483, -63.764)	**<0.001**	-0.546	-87.316 (-113.060, -61.571)	**<0.001**
BMI postpartum (kg/m²)	-0.498	-30.771 (-41.240, -20.301)	**<0.001**	-0.487	-30.074 (-40.565, -19.582)	**<0.001**
Total lean mass at postpartum (Kg)	-0.353	-22.978 (-34.688, -11.269)	**<0.001**	-0.340	-22.132 (-33.750, -10.513)	**<0.001**
Total fat free mass at postpartum (Kg)	-0.350	-23.219 (-35.198, -11.241)	**<0.001**	-0.337	-22.384 (-34.282, -10.486)	**<0.001**
Total fat mass at postpartum (Kg)	-0.575	-61.829 (-78.782, -44.876)	**<0.001**	-0.561	-60.377 (-77.089, -43.666)	**<0.001**
Total android fat mass at postpartum (Kg)	-0.553	-6.035 (-7.788, -4.283)	**<0.001**	-0.542	-5.915 (-7.656, -4.173)	**<0.001**
Total gynoid fat mass at postpartum (Kg)	-0.504	-9.375 (-12.473, -6.278)	**<0.001**	-0.487	-9.064 (-12.092, -6.037)	**<0.001**
Total BMD at postpartum (g/cm²)*	0.055	0.054 (-0.138, 0.246)	0.579	0.080	0.083 (-0.177, 0.344)	0.528
T-score BMD at postpartum*	0.011	0.138 (-2.374, 2.649)	0.914	0.153	2.033 (-1.226, 5.291)	0.219
Z-score BMD at postpartum*	0.017	0.206 (-2.127, 2.539)	0.862	0.163	2.006 (-1.029, 5.040)	0.193
Relative upper-body strength (34th gestational week)						
Weight postpartum (kg)	-0.529	-92.112 (-121.104, -63.120)	**<0.001**	-0.516	-89.762 (-118.898, -60.627)	**<0.001**
BMI postpartum (kg/m²)	-0.501	-33.649 (-45.056, -22.241)	**<0.001**	-0.493	-33.087 (-44.614, -21.560)	**<0.001**
Total lean mass at postpartum (Kg)	-0.291	-20.447 (-33.402, -7.493)	**0.002**	-0.271	-19.074 (-32.048, -6.100)	**0.004**
Total fat free mass at postpartum (Kg)	-0.286	-20.522 (-33.780, -7.264)	**0.003**	-0.267	-19.182 (-32.477, -5.887)	**0.005**
Total fat mass at postpartum (Kg)	-0.597	-69.942 (-88.045, -51.839)	**<0.001**	-0.586	-68.687 (-86.736, -50.637)	**<0.001**
Total android fat mass at postpartum (Kg)	-0.562	-6.689 (-8.583, -4.795)	**<0.001**	-0.551	-6.560 (-8.466, -4.654)	**<0.001**
Total gynoid fat mass at postpartum (Kg)	-0.553	-11.237 (-14.501, -7.974)	**<0.001**	-0.546	-11.104 (-14.309, -7.899)	**<0.001**
Total BMD at postpartum (g/cm²)*	0.058	0.065 (-0.152, 0.282)	0.554	0.139	0.155 (-0.116, 0.427)	0.260
T-score BMD at postpartum*	0.032	0.449 (-2.287, 3.186)	0.746	0.181	2.564 (-0.809, 5.937)	0.135
Z-score BMD at postpartum*	0.035	0.465 (-2.077, 3.007)	0.717	0.185	2.422 (-0.726, 5.571)	0.130

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