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Social Capital and Physical Activity among Japanese Pregnant Women: Adjunct Study of Japan Environment and Children's Study in Miyagi Prefecture

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Adequate physical activity during pregnancy is crucial for maternal and fetal health. Although physical activity during pregnancy is restricted, social support and trust may have a favorable influence on physical activity. This study aimed to examine the association between cognitive social capital during pregnancy and prenatal physical activity among Japanese individuals. We also investigated whether social capital has an extended influence during pregnancy on physical activity 1.5 years after delivery. The cognitive social capital of 3,055 pregnant women in their second trimester was measured using nine questions on a self-administered questionnaire. Each cognitive social capital was classified into two or four groups based on their scores. Physical activity during pregnancy was measured using a validated questionnaire in the second trimester and at 1.5 years after delivery. Participants were classified as having adequate physical activity (≥ 150 min/week) or inadequate physical activity (< 150 min/week) based on the physical activity guidelines during pregnancy. After adjusting for confounders, emotional support was positively associated with the prevalence of adequate prenatal physical activity (P for trend = 0.002). Moreover, there was a positive association between emotional support during pregnancy and the prevalence of adequate physical activity 1.5 years after delivery. Among Japanese women, emotional support during pregnancy was associated with a higher prevalence of adequate prenatal physical activity during pregnancy and at 1.5 years after delivery.

Keywords: emotional support; physical inactivity; pregnancy; social support; social trust
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Introduction

Maternal lifestyle is important for both maternal and fetal health. Tobacco and alcohol use during pregnancy are well-known lifestyle-related risk factors (England et al. 2004; Kyrklund-Blomberg et al. 2005; Patra et al. 2011). Although the proportion of pregnant women with these risk factors is decreasing owing to public health efforts (Bhuvaneswar et al. 2007; Child Trends Data Bank 2016), adverse maternal and fetal health outcomes are increasing rather than diminishing (Cho et al. 2015; Betran et al. 2016). Therefore, it is essential to identify other lifestyle

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risk factors and find ways to modify them to ensure maternal and fetal health.

Adequate amounts of physical activity during pregnancy are associated with a reduced risk of preeclampsia (Aune et al. 2014), gestational diabetes mellitus (Aune et al. 2016), and preterm birth (Aune et al. 2017). Regardless of these benefits (Aune et al. 2014, 2016; Owe et al. 2016), previous studies have reported that only 2.4-47.0% of pregnant women met the levels of physical activity recommended by the current physical activity guidelines: at least 150 min of moderate-intensity aerobic activity per week during pregnancy (Evenson et al. 2014; Lee et al. 2021). In other words, 53.0-97.6% of pregnant women are physically inactive (Evenson and Wen 2010; Smith and Campbell 2013; Coll et al. 2017). Given that this proportion of physical inactivity is considerably higher than that of pregnant smokers (8.4%) (Child Trends Data Bank 2016) and drinkers (9.8%) (Popova et al. 2017), identification of factors associated maternal physical activity is necessary to ensure both maternal and fetal health.

Personal relationships with family members, friends, neighbors, and colleagues may influence maternal behavior. This relationship can be identified using a recently proposed social capital concept. Social capital is identified as a social-environmental determinant of physical activity among adults (McNeill et al. 2006); it is a multidimensional concept and is usually defined as a characteristic of social mechanisms, such as trust, norms, and networks, that can improve social efficiency by facilitating cooperative behavior (Kawachi et al. 2008). Social capital is classified into cognitive and structural dimensions. The cognitive dimension of social capital is subjective and is generally indicated by social support and interpersonal trust in people. A previous study showed that cognitive social capital, but not structural social capital, was positively associated with physical activity (Ueshima et al. 2010). Previous studies have demonstrated that emotional support, generalized trust, neighborhood trust, and perceived safety, which are major aspects of cognitive social capital, are positively associated with physical activity among adults (Ueshima et al. 2010; Kouvonen et al. 2012; Rees-Punia et al. 2018). These positive associations have been confirmed even when limited to women (Ball et al. 2010; Lindstrom 2011). Although physical activity among women is generally restricted during pregnancy (Pereira et al. 2007) because of anatomical and physiological changes and fetal requirements (Lee et al. 2021), the level of physical activity during pregnancy may be influenced by various human relationships, as integrated into the social capital concept as cognitive support and interpersonal trust. Although the mechanisms underlying the association between social capital and physical activity remain unclear, several plausible connections have been hypothesized. For example, social support from family and friends offering encouragement and connections helps pregnant women improve adherence to various health behaviors (Beets et al. 2010; Molloy et al. 2010). Pregnant women with more support from their family and friend may have a wider community and thus, more opportunities to socialize with them. Moreover, generalized or neighborhood trust as well as perceived safety may offer feelings of security in the neighborhood, which would also increase a chance of pregnant women to go out.

Thus, this study aimed to examine the association between cognitive social capital during pregnancy and prenatal physical activity in Japanese women. We hypothesized that cognitive social capital during pregnancy is positively associated with the prevalence of pregnant women who had adequate levels of prenatal physical activity, meeting the current guidelines. Moreover, although the social environment may change after delivery, along with the child's growth and development, it is unclear whether social capital during pregnancy affects the level of physical activity after delivery. Thus, we also performed an exploratory analysis of the association between cognitive social capital during pregnancy and the prevalence of adequate physical activity 1.5 years after delivery.

Materials and Methods

Study population

This study was conducted as an adjunct study to the Japan Environment and Children's Study (JECS). The JECS is a nationwide birth cohort study that aims to examine the effects of the environment on children's health and development. The study design and protocol of the JECS have been previously described in detail elsewhere (Kawamoto et al. 2014). Pregnant women were recruited from January 2011 to March 2014 from 15 regional centers in Japan, with an enrollment of 103,000 parent-child pairs in the JECS. The JECS protocol was reviewed and approved by the Ministry of the Environment's Institutional Review Board on Epidemiological Studies and the ethics committees of all participating institutions (ethical number: 100910001). Of the 15 regional centers of the JECS (Hokkaido, Fukushima, Chiba, Kanagawa, Koshin, Toyama, Aichi, Kyoto, Osaka, Hyogo, Tottori, Kochi, Fukuoka, South Kyushu/Okinawa, and Miyagi), 9,217 pregnant women were registered at the Miyagi Regional Center (Fig. 1). The Miyagi Regional Center covers 14 municipalities in the Miyagi Prefecture, including mountainous (Osaki, Wakuya, Misato, Kami, Shikama, Kurihara, and Tome) and coastal (Kesennuma, Minamisanriku, Ishinomaki, Onagawa, Iwanuma, Watari, and Yamamoto) areas and is conducting an adjunct study involving the participants of the JECS main study. Among 9,217 pregnant women, 3,793 parent-child pairs agreed to participants in the adjunct study at the Miyagi Regional Center. The adjunct study protocol was approved by the Ministry of Environment (Saito et al. 2017). We excluded multiple pregnancies (n = 32) because physical activity during pregnancy would be restricted in these pregnancies compared to a single pregnancy. Women with miscarriages were excluded from the study (n = 30). We also excluded women with a history of

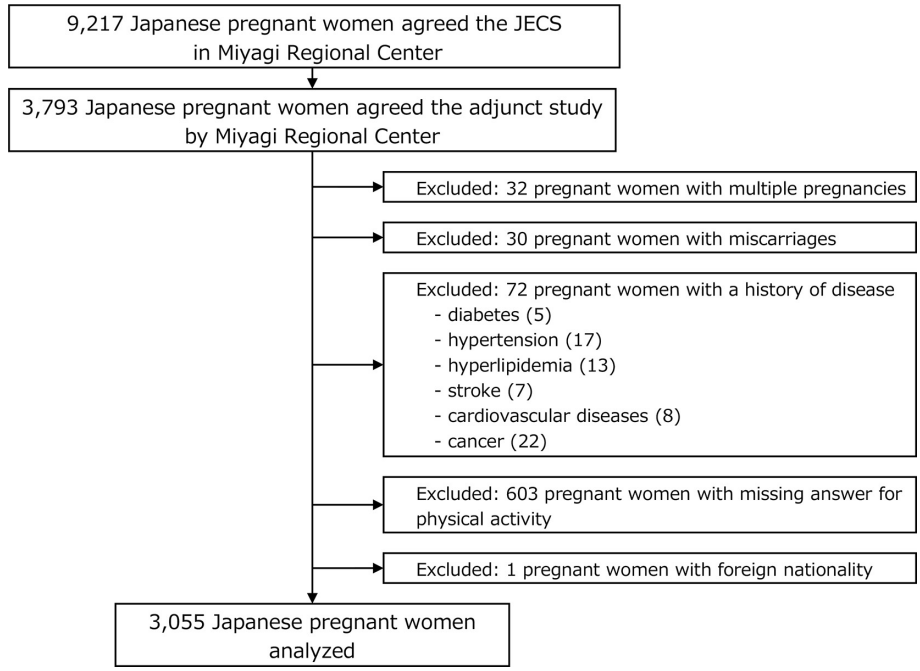

Fig. 1. Flowchart of participant selection.
JECS, Japan Environment and Children's Study.

diabetes (n = 5), hypertension (n = 17), hyperlipidemia (n = 13), stroke (n = 7), cardiovascular disease (n = 8), or cancer (n = 22) before pregnancy were excluded. Although previous studies did not consider a detailed medical history of chronic diseases (Ball et al. 2010; Ueshima et al. 2010; Lindstrom 2011; Kouvonen et al. 2012), we considered a possibility that women with these diseases have had intervened to improve their lifestyle, including physical activity, before pregnancy. No participants had a history of mental/neurological or musculoskeletal disorders. Additionally, 603 women with missing information on physical activity during pregnancy and one woman with foreign citizenship were excluded. Thus, 3,055 participants aged 17-45 years were included in the current analyses. This study was approved by the Ethics Committee of Tohoku University Graduate School of Medicine. Written informed consent was obtained from all participants.

Social capital

A self-administered questionnaire was used to assess cognitive social capital during the second trimester of pregnancy with a median (interquartile range) of 24.0 weeks (23.0 to 25.0 weeks). The four aspects of cognitive social capital (emotional support, neighborhood trust, perceived safety, and generalized trust) were evaluated using items similar to those used in a previous study (Mizuno et al. 2016). Table 1 shows the items (Q1-Q9) of the questionnaire. The questionnaires were modified from previous studies to facilitate the understanding of study participants [Q1-Q4 (Sarason et al. 1983), Q5 and Q6 (Sampson et al. 1997; Ziersch et al. 2005), and Q8 and Q9 (Yamagishi 1986)]. Question items Q1-4 are considered "emotional support," Q5 and Q6 are considered neighborhood trust, Q7 is considered perceived safety, and Q8 and Q9 are considered "generalized trust" of social capitals.

All nine question-item scores were converted to have

Table 1. Summary of nine items of social capital questionnaire.

Items	Question	Answer
Q1	Do you have someone who shows affection and kindness?	1 = never, 2 = hardly ever, 3 = sometimes, 4 = usually, 5 = always
Q2	Do you have someone who provides support or consultations for difficult decisions?	1 = never, 2 = hardly ever, 3 = sometimes, 4 = usually, 5 = always
Q3	Do you have contact with reliable people?	1 = never, 2 = hardly ever, 3 = sometimes, 4 = usually, 5 = always
Q4	Do you have relatives and friends that you can contact readily?	1 = none, 2 = 1 or 2 person(s), 3 = 3 or more persons
Q5	Do you think people in this neighborhood can be trusted?	1 = strongly agree, 2 = agree, 3 = disagree, 4 = strongly disagree
Q6	Do you think people around here are willing to help their neighbors?	1 = strongly agree, 2 = agree, 3 = disagree, 4 = strongly disagree
Q7	Do you think your area is secure?	1 = yes, 2 = no, 3 = no idea
Q8	Do you think most people can be trusted?	1 = "can be trusted" to 9 = "better to be beware of"
Q9	Do you think most people are willing to help others?	1 = "they try to help other" to 9 = "they only help themselves"

either 0 or 1 point as follows: Q1, Q2, and Q3 were scored such that "1" to "3" was given a "0 point", and "4" and "5" were given a "1 point"; Q4 was scored such that "1" was given a "0 point", and "2" and "3" were given a "1 point"; Q5 and Q6 were scored such that "1" and "2" were given a "1 point", and "3" and "4" were given a "0 point"; Q7 was scored such that "2" and "3" were given a "0 point", and "1" was given a "1 point"; and Q8 and Q9 were scored such that "1" to "6" were given a "1 point", and "7" to "9" were given a "0 point". The total score of questions 1 to 4 was classified into four categories (0, 1, 2, 3, and 4) as scores of emotional support. Because those who scored 0 points was only 16 (0.5%), they were classified as to have scored 1 point. The total points for questions 5 and 6 were classified into three groups (0, 1, and 2) as scores for neighborhood trust. The total points of question 7 were classified into two groups (0, 1) as scores of perceived safety. The total points for questions 8 and 9 were classified into three groups (0, 1, and 2) as scores of generalized trust.

Physical activity

Physical activity was measured using the validated short version of the International Physical Activity Questionnaire (IPAQ) (Craig et al. 2003). This questionnaire is frequently used to evaluate physical activity in the population including women under parenting child and pregnant women (Craig et al. 2003; Lee et al. 2011; Sanda et al. 2017). The test-retest intraclass-correlation of different physical activity level among pregnant women ranged from 0.81 to 0.84 (Sanda et al. 2017). Moreover, the concurrent validity of the questionnaire is comparable to other pregnancy-specific physical activity questionnaires (Chasan-Taber et al. 2004; Brantsaeter et al. 2010; Haakstad et al. 2010).

In brief, the IPAQ consists of three questions regarding high-intensity physical activity, such as aerobics, moderate-intensity physical activity (e.g., leisure cycling), and light-intensity physical activity (e.g., walking), and assesses the average weekly physical activity. In addition to intensity, frequency and duration of physical activity are assessed. We estimated physical activity by multiplying the weekly frequency by the duration in days on which physical activity was performed. According to the current physical activity guidelines during pregnancy (Evenson et al. 2014; Lee et al. 2021), participants were classified as ≥ 150 min per week and < 150 min per week. Physical activity during pregnancy was measured in the second trimester, and physical activity 1.5 years after birth was also measured. Data on physical activity at 1.5 years after birth were collected by the adjunct study in Miyagi Prefecture.

Covariate

Information on pre-pregnancy height and weight was obtained through a self-administered questionnaire in the first trimester of pregnancy. Body Mass Index (BMI) [weight (kg) / height squared (m^2)] was calculated from the recalled pre-pregnant body weight (within 6 months before pregnancy) reported in the questionnaire mentioned below for pre-pregnant BMI and the weight measured in the second trimester as prenatal BMI. Depressive symptoms were assessed using the Center for Epidemiologic Studies Depression Scale (CES-D) (Radloff 1977) in the second trimester. If the CES-D score was 16 or greater, participants were defined as having depressive symptoms (Radloff 1977). Information on age, education level, parity, maternal/paternal smoking status, drinking status, marital status, family members, household income, employment, and morning sickness was obtained by conducting a self-administered questionnaire survey in the second trimester.

Statistical analyses

For descriptive statistics, continuous variables were expressed as medians (interquartile ranges), and categorical variables were expressed as percentages.

We used generalized linear mixed model analyses (PROC GLIMMIX) to calculate the odds ratios and adjusted odds ratios for the prevalence of meeting the recommended level of prenatal physical activity relative to each aspect of cognitive social capital during pregnancy as an independent variable. The JECS area in Miyagi Prefecture (nested within study sites) was treated as having random effects. Based on previous studies (Ball et al. 2010; Ueshima et al. 2010; Lindstrom 2011; Kouvonen et al. 2012; Takami et al. 2018; Yamada et al. 2021), we adjusted for potential confounding factors including age (continuous variable), education (< college and ≥ college), parity (0 and ≥ 1), maternal/paternal/smoking status (never smoked, ex-smokers who quit before pregnancy, ex-smokers who quit after pregnancy, and smokers), drinking status (never drank, ex-drinkers who quit before pregnancy, ex-drinkers who quit after pregnancy, and drinkers), marital status (married, unmarried, and divorced/widowed), family members [living without child(ren), living with child(ren), and living with child(ren) and parent(s)], gestational weight gain in the second trimester (continuous variable), pre-pregnancy BMI (continuous variable), household income (< 4 million Japanese Yen, 4 to < 6, and ≥ 6), morning sickness (yes or no), employment (employed and unemployed), depressive symptom (yes or no), participants who had complications during pregnancy (yes or no), and participants living in temporary housing (yes or no). Moreover, we examined cognitive social capital during pregnancy and the prevalence of the recommended level of physical activity 1.5 years after birth. To examine these associations, 1,118 participants (36.6%) were excluded because of missing values for physical activity at 1.5 years after birth (Fig. 1).

We conducted several sensitivity analyses from different perspectives. First, we excluded participants who had complications during pregnancy (n = 525) because physical activity could be increased or decreased according to the types of complications during pregnancy. Second, we excluded participants living in temporary housing (n = 114)

to eliminate the influence of the Great East Japan Earthquake. Third, we adjusted for mutual cognitive social capital during pregnancy as a continuous variable, in addition to potential confounding factors. Finally, we examined the association between emotional support and the prevalence of participants meeting the recommended level of prenatal physical activity by changing the cutoff value of question items 1 to 3 for emotional support. The questions 1, 2, and 3 were scored such that "1" and "2" were given a "0," and "3" to "1" was given a "1".

All statistical analyses were performed using Statistical Analysis System 9.4 edition (SAS Institute Inc., Cary, NC, USA). For all analyses, *P* values lower than 0.05 were considered significant in all two-sided tests.

Results

Table 2 presents the characteristics of the participants according to their emotional support scores. The proportions of maternal never-smokers ($P < 0.001$), college graduates ($P = 0.027$), and household income of over 6 million yen ($P < 0.001$) were higher in the higher emotional support groups ($P = 0.027$). The proportion of participants with depressive symptoms was lower in the higher emotional support group ($P < 0.001$). Moreover, age ($P = 0.033$), parity ($P = 0.017$), and employment ($P = 0.019$) showed intergroup differences. The characteristics of the participants according to neighborhood trust, perceived safety, and generalized trust scores are shown in Supplementary Tables S1, S2 and S3, respectively. Overall, the characteristics based on neighborhood trust, perceived safety, and generalized trust scores were similar to those of emotional support, while the proportion of temporary housing was lower in the higher perceived safety ($P < 0.001$) and generalized trust ($P = 0.026$).

Table 3 shows odds ratios and 95% confidence intervals of the prevalence of participants meeting the recommended level of prenatal physical activity, namely adequate physical activity among each cognitive social capital. The emotional support was positively associated with the prevalence of participants with adequate physical activity (*P* for trend < 0.001). This positive association remained after adjustment of confounders (*P* for trend = 0.002). By contrast, there was no association of the neighborhood trust, perceived safety, and generalized trust with adequate physical activity. Although there was no interaction of emotional support with parity on the prevalence of participants with adequate prenatal physical activity (*P* for interaction = 0.44, Table 4), the positive association between emotional support and the prevalence of participants with adequate prenatal physical activity was observed among nulliparous women (*P* for trend = 0.007). Moreover, although there was also no interaction of neighborhood trust with parity (*P* for interaction = 0.49, Table 4), the positive association between neighborhood trust and the prevalence of participants with adequate prenatal physical activity was observed among multiparous women (*P* for trend = 0.031).

To eliminate the possibility that physical activity increased or decreased depending on the type of complication during pregnancy, we performed a sensitivity analysis that excluded participants who had complications during pregnancy (Supplementary Table S4). We confirmed a positive association between emotional support and the prevalence of adequate prenatal physical activity (*P* for trend = 0.006). To eliminate the influence of the Great East Japan Earthquake, we excluded participants living in temporary housing (Supplementary Table S5). Emotional support was positively associated with the prevalence of adequate prenatal physical activity (*P* for trend = 0.001). In addition, the association between emotional support and the prevalence of adequate prenatal physical activity was confirmed when considering other types of cognitive social capital (*P* for trend = 0.003, Supplementary Table S6). Finally, even when the cutoff values of questions 1 to 3 were changed, we obtained similar results regarding the association between emotional support and the prevalence of participants with adequate prenatal physical activity (*P* for trend = 0.005, Supplementary Table S7).

Table 5 shows the OR of the prevalence of the recommended level of physical activity at 1.5 years after delivery among each cognitive social capital during pregnancy. Emotional support during pregnancy was positively associated with the prevalence of the recommended level of physical activity 1.5 years after delivery (*P* for trend < 0.001). This positive association remained after adjusting for confounders (*P* for trend < 0.001).

Discussion

In this study, we examined the association between cognitive social capital during pregnancy and prenatal physical activity in Japanese women. Our results showed that emotional support during pregnancy was positively associated with the prevalence of adequate prenatal physical activity. Stratification analysis based on parity showed that emotional support during pregnancy was positively associated with the prevalence of adequate prenatal physical activity among nulliparous women, and neighborhood trust was positively associated with the prevalence of participants with adequate prenatal physical activity among multiparous women. We also examined the association between cognitive social capital during pregnancy and the prevalence of the recommended level of physical activity 1.5 years after delivery among Japanese women. As a result, the emotional support during pregnancy was positively associated with the prevalence of recommended level of physical activity at 1.5 years after delivery.

Physical inactivity is an important modifiable risk factor for the development of complications and adverse fetal outcomes during pregnancy. Recently, social capital has been considered a social-environmental determinant of physical activity (McNeill et al. 2006). Among British adults, a previous study reported that women with high emotional support had a higher level of physical activity

Table 2. Characteristics of participants according to scores of emotional support.

	Scores of emotional support				*P*
	0 and 1 point	2 points	3 points	4 points	
n	178	216	462	2,195	
Physical activity during pregnancy, METs·hours/week	60.0 (0.0-285.0)	95.0 (0.0-360.0)	120.0 (0.0-367.5)	130.0 (0.0-450.0)	0.044
Age, years	31.0 (27.0-35.0)	30.5 (26.0-35.0)	30.0 (26.0-34.0)	31.0 (27.0-34.0)	0.033
Gestational weight gain at second-trimester, kg	5.7 (3.5-8.0)	6.3 (3.9-8.0)	5.6 (3.8-7.5)	5.6 (3.9-7.6)	0.875
Pre-pregnancy BMI, kg/m	21.1 (18.9-23.7)	21.1 (19.6-23.1)	20.8 (19.4-23.3)	20.9 (19.2-23.0)	0.430
Maternal smoking status					
Never smoked	76 (42.7)	92 (42.8)	226 (49.8)	1,142 (52.3)	< 0.001
Ex-smokers who quit before pregnancy	46 (25.8)	51 (23.7)	113 (24.9)	538 (24.6)	
Ex-smokers who quit after pregnancy	41 (23.0)	45 (20.9)	92 (20.3)	391 (17.9)	
Smokers	15 (8.4)	27 (12.6)	23 (5.1)	112 (5.1)	
Paternal smoking status					
Never smoked	43 (24.6)	41 (19.3)	91 (20.1)	442 (20.4)	0.729
Ex-smokers who quit before pregnancy	26 (14.9)	33 (15.6)	69 (15.2)	382 (17.6)	
Ex-smokers who quit after pregnancy	6 (3.4)	4 (1.9)	14 (3.1)	72 (3.3)	
Smokers	100 (57.1)	134 (63.2)	279 (61.6)	1,275 (58.7)	
Drinking status					
Never drank	69 (38.8)	66 (30.6)	147 (31.8)	727 (33.1)	0.722
Ex-drinkers who quit before pregnancy	26 (14.6)	32 (14.8)	64 (13.9)	345 (15.7)	
Ex-drinkers who quit after pregnancy	79 (44.4)	115 (53.2)	242 (52.4)	1,078 (49.1)	
Drinkers	4 (2.2)	3 (1.4)	9 (1.9)	44 (2.0)	
Education					
< college	161 (91.5)	192 (89.3)	413 (90.0)	1,887 (86.1)	0.027
≥ college	15 (8.5)	23 (10.7)	46 (10.0)	304 (13.9)	
Parity					
0	79 (44.6)	71 (33.8)	177 (38.8)	944 (43.5)	0.017
≥ 1	98 (55.4)	139 (66.2)	279 (61.2)	1,224 (56.5)	
Marital status					
Married	158 (90.3)	201 (93.1)	432 (94.3)	2,073 (94.8)	0.228
Unmarried	13 (7.4)	13 (6.0)	21 (4.6)	96 (4.4)	
Divorced/widowed	4 (2.3)	2 (0.9)	5 (1.1)	18 (0.8)	
Household income, million Japanese Yen					
< 4	86 (54.4)	117 (59.1)	204 (51.0)	857 (42.8)	< 0.001
4 to < 6	49 (31.0)	43 (21.7)	113 (28.2)	654 (32.6)	
≥ 6	23 (14.6)	38 (19.2)	83 (20.8)	493 (24.6)	
Employment					
Employed	99 (55.6)	106 (49.3)	236 (51.2)	1,256 (57.4)	0.019
unemployed	79 (44.4)	109 (50.7)	225 (48.8)	932 (42.6)	
Family members					
Living without child (ren)	78 (44.8)	77 (36.2)	178 (39.9)	929 (43.4)	0.100
Living with child (ren)	64 (36.8)	75 (35.2)	147 (33.0)	714 (33.3)	
Living with child (ren) and parent (s)	32 (18.4)	61 (28.6)	121 (27.1)	498 (23.3)	
Morning sickness					
No	41 (23.0)	45 (20.8)	83 (18.0)	370 (16.9)	0.112
Yes	137 (77.0)	171 (79.2)	377 (82.0)	1,822 (83.1)	
Depressive symptom					
No	94 (57.0)	128 (64.3)	313 (72.5)	1,640 (79.8)	< 0.001
Yes	71 (43.0)	71 (35.7)	119 (27.5)	414 (20.2)	
Pregnancy complications					
No	155 (87.1)	180 (83.3)	378 (81.8)	1,813 (82.6)	0.439
Yes	23 (12.9)	36 (16.7)	84 (18.2)	382 (17.4)	
Temporary housing					
No	169 (94.9)	206 (95.4)	444 (96.1)	2,113 (96.3)	0.777
Yes	9 (5.1)	10 (4.6)	18 (3.9)	82 (3.7)	

Data are presented as median (interquartile range) or N (%).

Table 3. The association between cognitive social capital during pregnancy and adequate prenatal physical activity among Japanese pregnant women.

Category	n	Number of cases (%)	Univariate OR (95% CI)	Multivariate OR (95% CI)†
Emotional support				
0 and 1 point	178	65 (36.5)	reference	reference
2 points	216	91 (42.1)	1.26 (0.79-1.02)	0.96 (0.56-1.66)
3 points	462	214 (46.3)	1.49 (0.99-2.26)	1.25 (0.78-2.01)
4 points	2,195	1,082 (49.3)	1.69 (1.17-2.43)	1.45 (0.95-2.22)
			P for trend < 0.001	*P* for trend = 0.002
Neighborhood trust				
0 point	1,046	491 (46.9)	reference	reference
1 point	304	136 (44.7)	0.93 (0.67-1.28)	0.92 (0.64-1.32)
2 points	1,684	814 (48.3)	1.06 (0.87-1.29)	1.17 (0.94-1.47)
			P for trend = 0.414	*P* for trend = 0.071
Perceived safety				
0 point	1,123	527 (46.9)	reference	reference
1 point	1,921	921 (47.9)	1.05 (0.82-1.33)	1.03 (0.77-1.37)
			P = 0.598	*P* = 0.771
Generalized trust				
0 point	2,037	970 (47.6)	reference	reference
1 point	516	253 (49.0)	1.07 (0.84-1.36)	1.15 (0.87-1.51)
2 points	498	228 (45.8)	0.95 (0.74-1.21)	0.99 (0.74-1.31)
			P for trend = 0.787	*P* for trend = 0.800

†Adjusted for age (continuous variable), education (< college and ≥ college), parity (0 and ≥ 1), maternal/paternal/smoking status (never smoked, ex-smokers who quit before pregnancy, ex-smokers who quit after pregnancy, and smokers), drinking status (never drank, ex-drinkers who quit before pregnancy, ex-drinkers who quit after pregnancy, and drinkers), marital status (married, unmarried, and divorced/widowed), family members [living without child(ren), living with child(ren), and living with child(ren) and parent(s)], gestational weight gain in second trimester (continuous variable), pre-pregnancy BMI (continuous variable), household income (< 4, 4 to < 6, and ≥ 6 million Japanese Yen), morning sickness (yes or no), employment (employed and unemployed), depressive symptom (yes or no), participants who had complications during pregnancy (yes or no), and participants living in temporary housing (yes or no).

than those with low emotional support among British adults (Kouvonen et al. 2012). In line with a previous study (Kouvonen et al. 2012), emotional support during pregnancy was positively associated with the prevalence of adequate prenatal physical activity. This finding suggests that, under the condition that physical activity is restricted due to physical changes during pregnancy, higher emotional support may have a favorable influence on meeting the recommended level of prenatal physical activity. On the other hand, although the interaction of emotional support and parity on the prevalence of participants with adequate prenatal physical activity was not significant, the positive association between emotional support and the prevalence of participants with adequate prenatal physical activity was observed among nulliparous women. This result suggested that even in situations of anxiety due to the first pregnancy, the behavior of pregnant women was actively transformed by emotional support.

Previous studies have reported that high neighborhood trust is associated with higher physical activity (Ueshima et al. 2010). In this study, neighborhood trust during pregnancy was not associated with the prevalence of adequate prenatal physical activity. However, although the interaction between neighborhood trust and parity on the prevalence of participants with adequate prenatal physical activity was not significant, a positive association between neighborhood trust and the prevalence of participants with adequate prenatal physical activity was observed among multiparous women. This result may be explained by the presence of children. Therefore, our results suggest that the community in the neighborhood was formed by the presence of children among multiparous women, which might have influenced their physical activity.

In contrast, in this study, there was no association between generalized trust and the prevalence of adequate prenatal physical activity. Previous studies have reported that generalized trust is positively associated with physical activity (Ball et al. 2010; Lindstrom 2011). The reason for this discrepancy may be the differences in the general level of trust between Japanese and Western people (Yamagishi and Yamagishi 1994). Compared to Japanese people, people in Western communities have more trust in people, including their neighbors, in general (Yamagishi and Yamagishi 1994). Moreover, they consider reputation to be

Table 4. The association between cognitive social capital during pregnancy and adequate prenatal physical activity stratified by parity.

Category	n	Number of cases (%)	Univariate OR (95% CI)	Multivariate OR (95% CI)†
Emotional support				
P for interaction = 0.44				
Nulliparous women				
0 and 1 point	79	27 (34.2)	reference	reference
2 points	71	28 (39.4)	1.24 (0.57-2.69)	1.13 (0.47-2.71)
3 points	177	82 (46.3)	1.65 (0.87-3.12)	1.43 (0.68-3.00)
4 points	944	480 (50.8)	2.00 (1.14-3.50)	1.82 (0.96-3.47)
			P for trend < 0.001	*P* for trend = 0.007
Multiparous women				
0 and 1 point	98	38 (38.8)	reference	Reference
2 points	139	60 (43.2)	1.20 (0.65-2.20)	0.86 (0.42-1.76)
3 points	279	128 (45.9)	1.34 (0.78-2.30)	1.13 (0.60-2.15)
4 points	1,224	591 (48.3)	1.47 (0.90-2.39)	1.24 (0.70-2.21)
			P for trend = 0.041	*P* for trend = 0.094
Neighborhood trust				
P for interaction = 0.49				
Nulliparous women				
0 point	524	253 (48.3)	reference	reference
1 point	132	58 (43.9)	0.84 (0.52-1.37)	0.72 (0.42-1.23)
2 points	611	303 (49.6)	1.07 (0.80-1.44)	1.09 (0.77-1.55)
			P for trend = 0.550	*P* for trend = 0.529
Multiparous women				
0 point	511	233 (45.6)	reference	reference
1 point	168	77 (45.8)	1.01 (0.65-1.58)	1.12 (0.67-1.85)
2 points	1,049	500 (47.7)	1.08 (0.83-1.41)	1.31 (0.96-1.79)
			P for trend = 0.446	*P* for trend = 0.031
Perceived safety				
P for interaction = 0.71				
Nulliparous women				
0 point	506	236 (46.6)	reference	reference
1 point	762	379 (49.7)	1.16 (0.80-1.68)	0.99 (0.63-1.54)
			P = 0.289	*P* = 0.919
Multiparous women				
0 point	602	284 (47.2)	reference	reference
1 point	1,134	531 (46.8)	0.98 (0.71-1.36)	1.06 (0.72-1.54)
			P = 0.883	*P* = 0.682
Generalized trust				
P for interaction = 0.84				
Nulliparous women				
0 point	877	424 (48.3)	reference	reference
1 point	227	113 (49.8)	1.07 (0.74-1.55)	1.15 (0.75-1.77)
2 points	168	80 (47.6)	0.99 (0.65-1.50)	0.92 (0.56-1.50)
			P for trend = 0.909	*P* for trend = 0.935
Multiparous women				
0 point	1,141	536 (47.0)	reference	reference
1 point	278	134 (48.2)	1.06 (0.76-1.47)	1.18 (0.82-1.71)
2 points	320	146 (45.6)	0.96 (0.70-1.31)	1.01 (0.71-1.45)
			P for trend = 0.840	*P* for trend = 0.716

†Adjusted for age (continuous variable), education (< college and ≥ college), parity (0 and ≥ 1), maternal/paternal/smoking status (never smoked, ex-smokers who quit before pregnancy, ex-smokers who quit after pregnancy, and smokers), drinking status (never drank, ex-drinkers who quit before pregnancy, ex-drinkers who quit after pregnancy, and drinkers), marital status (married, unmarried, and divorced/widowed), family members [living without child(ren), living with child(ren), and living with child(ren) and parent(s)], gestational weight gain in second trimester (continuous variable), pre-pregnancy BMI (continuous variable), household income (< 4, 4 to < 6, and ≥ 6 million Japanese Yen), morning sickness (yes or no), employment (employed and unemployed), depressive symptom (yes or no), participants who had complications during pregnancy (yes or no), and participants living in temporary housing (yes or no).

Table 5. The association between social capital during pregnancy and adequate physical activity at 1.5 years after delivery among Japanese pregnant women.

Category	n	Number of cases (%)	Univariate OR (95% CI)	Multivariate OR (95% CI)†
Emotional support				
0 and 1 point	101	22 (21.8)	reference	reference
2 points	132	31 (23.5)	1.10 (0.54-2.26)	0.77 (0.35-1.71)
3 points	287	77 (26.8)	1.30 (0.70-2.43)	1.14 (0.58-2.26)
4 points	1,414	490 (34.7)	1.90 (1.09-3.33)	1.66 (0.90-3.05)
			P for trend < 0.001	*P* for trend < 0.001
Neighborhood trust				
0 point	640	202 (31.6)	reference	reference
1 point	194	58 (29.9)	0.93 (0.60-1.44)	1.07 (0.66-1.74)
2 points	1,091	357 (32.7)	1.06 (0.81-1.37)	1.15 (0.85-1.56)
			P for trend = 0.570	*P* for trend = 0.272
Perceived safety				
0 point	666	213 (32.0)	reference	reference
1 point	1,262	403 (31.9)	1.00 (0.72-1.39)	0.99 (0.67-1.45)
			P = 0.981	*P* = 0.916
Generalized trust				
0 point	1,283	414 (32.3)	reference	reference
1 point	326	112 (34.4)	1.11 (0.80-1.53)	1.17 (0.81-1.68)
2 points	325	94 (28.9)	0.87 (0.62-1.21)	0.85 (0.58-1.25)
			P for trend = 0.487	*P* for trend = 0.547

†Adjusted for age (continuous variable), education (< college and ≥ college), parity (0 and ≥ 1), maternal/paternal/smoking status (never smoked, ex-smokers who quit before pregnancy, ex-smokers who quit after pregnancy, and smokers), drinking status (never drank, ex-drinkers who quit before pregnancy, ex-drinkers who quit after pregnancy, and drinkers), marital status (married, unmarried, and divorced/widowed), family members [living without child(ren), living with child(ren), and living with child(ren) and parent(s)], gestational weight gain in second trimester (continuous variable), pre-pregnancy BMI (continuous variable), household income (< 4, 4 to < 6, and ≥ 6 million Japanese Yen), morning sickness (yes or no), employment (employed and unemployed), depressive symptom (yes or no), participants who had complications during pregnancy (yes or no), and participants living in temporary housing (yes or no).

more important and more honest and fair (Yamagishi and Yamagishi 1994). Japanese people more strongly consider how they can benefit from using personal connections in dealing with others than Western people (Yamagishi and Yamagishi 1994). Therefore, the level of generalized trust among our participants might have been insufficient to affect the level of physical activity in pregnant women.

A previous study reported that perceived safety is positively associated with physical activity (Rees-Punia et al. 2018). However, in this study, we found no association between perceived safety and the prevalence of adequate prenatal physical activity among pregnant Japanese women. The reasons for this discrepancy may be due to the fact that Japan has better security in general than other countries. According to the OECD Factbook 2009 (OECD 2009), the crime rate in Japan was 9.9%, which was ranked the second lowest among 26 countries. Therefore, because security in Japan is relatively good, the impact of perceived security on physical may have been small.

A previous study reported that changes in living environment may affect social capital (Hikichi et al. 2017). This study included people affected by the Great East Japan Earthquake and those living in temporary housing. People who lived in temporary housing were likely to have lower social capital and limited physical activity; consequently, the association between social capital and physical activity could have been overestimated. However, our results showed that emotional support and prenatal physical activity were positively associated, even after excluding people living in temporary housing.

In this study, there was a positive association between emotional support during pregnancy and the prevalence of adequate physical activity 1.5 years after birth. Our results suggest that although the social environment may change after delivery along with children's growth and development, emotional support may tend to continue after delivery, leading to a positive influence on the level of physical activity after childbirth.

According to previous studies among American and Brazilian women, 2.4-47.0% of pregnant women did meet the recommended levels of physical activity (Evenson and Wen 2010; Smith and Campbell 2013; Coll et al. 2017). In this study, 47.4% of pregnant women had achieved the recommended level based on the IPAQ. Given that the IPAQ

could not evaluate physical activity for less than 10 min, the prevalence of meeting the recommended levels of physical activity may have been underestimated. Moreover, the adequacy of the IPAQ for accelerometers in pregnant women is not high (Sanda et al. 2017). This is an important limitation of this study. Nevertheless, we prioritized the comparability of physical activity during pregnancy and 1.5 years after delivery.

In addition to the physical activity measurements, this study had several limitations. First, we focused on participants enrolled in the Miyagi Regional Center and excluded urbans areas. Because coastal areas were included, the damage caused by the Great East Japan Earthquake may have affected physical activity levels in addition to geographical and industrial characteristics. Moreover, our participants are likely to have a high awareness of their and/or children's health, since they additionally joined the adjunct study at the Miyagi Regional Center. Therefore, the generalizability of our results is limited. Second, the percentage of missing values for physical activity at 1.5 years after delivery was 36.6% (1,118 women), which was not small. This limitation also leads to selection bias. Moreover, because the cognitive social capital 1.5 years after delivery was not evaluated in this study, the change in actual emotional support may vary.

In conclusion, our findings showed that during pregnancy, emotional support was associated with a higher prevalence of meeting the recommended level of physical activity among Japanese women, especially nulliparous women. Moreover, neighborhood trust was positively associated with the prevalence of adequate prenatal physical activity among multiparous women. Finally, emotional support during pregnancy was positively associated with the prevalence of the recommended levels of physical activity at 1.5 years after delivery.

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Author Contributions

S.S. and H.M. conceived the study. S.S. and H.M. designed the study. K.N., T.A. and N.Y. did the data collection and processing. S.S., H.M. and C.H. did the statistical analysis. S.S., H.M., A.Y. and R.N. wrote the manuscript. S.S., H.M., A.Y. and R.N. contributed substantially to the interpretation of results and provided critical revisions to the manuscript. R.N. took overall responsibility for the integrity of the study. All authors read and approved the final manuscript.

Conflict of Interest

The authors declared no conflict of interest.

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Supplementary Files

Please find supplementary file(s);
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