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Longitudinal study of physical activity using an accelerometer in Japanese pregnant women

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Abstract

Aim: To describe the characteristics of objectively measured physical activity (PA) during the 2nd and 3rd trimesters of pregnancy using a accelerometer.

Methods: This was a longitudinal observational study wherein PA in pregnant women in the 2nd and 3rd trimesters was measured for seven consecutive days using a accelerometer (Silmee W10, TDK, Japan).

Results: A total of 34 primiparous women were examined. There was no statistically significant difference in the amount of PA during the 2nd and 3rd trimesters of pregnancy. Sub-group analysis demonstrated that PA in the full-time housewife group increased significantly from the 2nd to the 3rd trimester, while total PA and moderate and vigorous PA of the stopped-working group, decreased significantly over that time. There was no difference in the PA of the currently working group between trimesters. In the full-time housewife group, the amount of PA for each hour significantly increased at 12:00, 18:00, and 22:00 hr. In the currently working group, the amount of PA for each hour significantly increased at 9:00, 10:00, and 16:00 hr. In the stopped-working group, the amount of PA for each hour significantly decreased at 7:00, 8:00, and 18:00 hr.

Conclusion: Objective measurements using an accelerometer did not identify any significant changes in PA during the different trimesters of pregnancy. Sub-group analysis revealed clear patterns in PA change correlating with different lifestyles during pregnancy. Future research may enable the development of personalized health guidance by identifying the relationship between PA and pregnancy outcomes.

KEYWORDS

accelerometer, lifestyle, physical activity, pregnancy

1 | INTRODUCTION

Physical activity (PA) during pregnancy has beneficial effects on physical and mental health. Maintaining regular PA during pregnancy is associated with physical benefits to the mother (increased control of gestational weight gain and lower risk of gestational diabetes) (Dye, Knox, Artal, Aubry, & Wojtowycz, 1997; Solomon et al., 1997), psychological benefits to the mother (decreased symptoms of depression and anxiety) (Poudevigne & O'Connor, 2006), and potential protection from adverse obstetric and fetal outcomes (fewer large- and small-for-gestational age infants, and shorter length of labor) (Mudd et al., 2012). Furthermore, PA during pregnancy may prevent mood disturbances

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and weight retention in the postpartum period (Carter, Baker, & Brownell, 2000).

Previous studies consistently demonstrated that PA, both leisure-time and work-related, is reduced during pregnancy (Borodulin, Evenson, & Herring, 2009; Chasan-Taber et al., 2004; Nascimento, Surita, Godoy, Kasawara, & Morais, 2015; Palmer, Bonzine, Harris, Linaker, & Bonde, 2013; Santos et al., 2016). These were retrospective studies that used self-administered questionnaires. In Japan, research on pregnant women has generally been conducted using step counts (Arii & Natori, 2007; Suzuki, Ono, & Taniguchi, 2007). Questionnaires are inexpensive, can easily be used for large-scale surveys, and have the advantage of enabling evaluation of the purpose (domain) of activities, but have the disadvantage of bias. Pedometers are familiar and have easy-to-understand indicators, but cannot measure nonambulatory movements, such as sedentary behavior or light intensity PA.

Recently, accelerometers have been adopted in studies of PA during pregnancy (Evenson & Wen, 2011; Gradmark, Pomeroy, Renstrom, et al., 2011). However, there are few longitudinal accelerometer studies. In Japan, there is only one report of a longitudinal study using accelerometers, which showed that while the light intensity PA time, Moderate intensity PA time, and vigorous intensity PA time decreased during the 3rd trimester in pregnancy compared with the 2nd trimester, there was no significant difference (Watanabe, Motooka, Furukawa, et al., 2013). Pregnancy is a period of physical and social change, and a longitudinal study is required to accurately characterize PA during pregnancy.

Therefore, there is a need for a well-designed longitudinal study with objective measures to gain a better understanding of pregnancy-related changes due to PA. We aimed to objectively describe the characteristics of PA during pregnancy using an easily available triaxial accelerometer.

2 | METHODS

2.1 | Study design

This was a longitudinal observational study that was conducted between March and July 2016. Study approval was obtained from Institutional Review Board.

2.2 | Participants

Healthy pregnant women were recruited from the obstetric clinics and hospitals of rural Japan. Posters for recruiting research participants were posted in clinics and hospitals and flyers were given to pregnant women in prenatal health guidance classes. Inclusion criteria were: (a) age ≥20 years and (b) singleton pregnancy (c) after 24 weeks of gestation. Exclusion criteria included: (a) an obstetric or medical restriction for PA (orthopedic diseases and premature birth labor) and (b) history of hypertension and/or diabetes. All participants provided written and oral informed consent. Participants who cooperated with all processes received a reward of 3,000 yen.

In previous studies of pregnant women using accelerometers in Japan, the sample size was around 30 to 50 cases (Hayashi, Matsuzaki, Kusaka, Shiraishi, & Haruna, 2016; Watanabe et al., 2013). The number of participants in this study was set based on previous studies.

2.3 | Data collection

Participants were assessed using triaxial accelerometers (Silmee TM W10, TDK, Japan) to measure PA. Data were collected over seven consecutive days during 24–27 (2nd trimester) and 32–35 (3rd trimester) weeks of gestation. The 2nd trimester is the time when the abdomen increases and PA begins to be naturally restricted, and the 3rd trimester is the time when lifestyle may change due to antenatal leave, increasing the likelihood that PA will change. We chose these weeks as representative of the trimesters of interest. Each participant was instructed to wear the accelerometer for 7 days during each data collection period, except when showering, swimming, and sleeping. Participants were allowed to remove the device while sleeping because of the need for charging and the potential discomfort during sleep.

Self-reported questionnaires, self-administered at home, were used to collect demographic data (age, height and weight, occupation, marital status, pregnancy status, and working status) and pregnancy data (gestational weight gain and pregnancy complications, impending preterm birth, gestational hypertension syndrome, and gestational diabetes mellitus). Pregnancy data were collected in the 2nd and 3rd trimesters.

Participants who gave informed consent began wearing the accelerometer. Following the 7-day period, the accelerometer and questionnaires were returned to the investigators by mail (mail, with compensation given on delivery).

2.4 | PA assessment

PA was assessed by a triaxial accelerometer worn on the non-dominant wrist. We used multiaxial, capacitive accelerometers using microelectromechanical systems (MEMS) that can measure both static and dynamic signals; interval of measurement is 5 s. By using an accelerometer, it is possible to study in detail the intensity and duration of PA. The device measured the amount of PA, taking into account physical information such as the weight, height, and age of

participants. Although a dedicated free application (Silmee) for smartphones and tablets allows viewing the recorded PA over time, participants in this study refrained from using it to avoid behavioral changes.

Data were downloaded using the Actiband CSV converter into Excel code for every epoch length (5 min). Measured variables included walking steps, energy consumption value, and metabolic equivalent (METS) values. The device-specific algorithm automatically determines non-wearing and sleep time (Miyamoto, Hashimoto, & Suzuki, 2014). Wear time was defined as the time excluding sleep and non-wearing time, and a day was considered valid if it contained at least 8 hr of wear time. A minimum of two valid days of wear time was required for a record to be included for analysis. Studies with accelerometers often set the minimum daily wear time to 10 hr or more and the minimum number of days at 3–5 (Trost, Mclver, & Pate, 2005). However, as the number of rejected data increases, analysis data may be biased toward data obtained from participants with good compliance. The purpose of this study is to better understand general trends in PA among pregnant women, not to account for all PA, as in physiological studies. Therefore, in order to include more data and reduce the potential compliance bias, the minimum wear time was set at 8 hr, and the minimum number of days at two. Based on MET values, four activity intensity levels were recognized (Russell et al., 1995): sedentary behavior (SB, ≤1.5 METs independent of nighttime sleep); LPA (1.6–2.9 METs); MPA (3.0–5.9 METs); and VPA (≥ 6.0 METs). In the analysis, the metabolic equivalents of sleep and non-wearing time were estimated at 0.9 METs, that is, resting metabolic equivalents.

Participants' PA was described using the following indicators: (a) amount of PA (MET-hr/day), (b) cumulative time spent at each intensity of PA (min/day), and (c) amount of PA for each hour (METs). The average values of these obtained over a week were used for analysis.

2.5 | Statistical analysis

Demographic characteristics were reported as means and standard deviations (SD) for continuous variables (age, body mass index [BMI], and gestational weight gain) and as percentages for categorical variables (employment status and exercise intention). The amount of PA and the time spent at a specific PA intensity in the 2nd and 3rd trimesters were compared using a paired *t* test. Sub-group analysis was performed to investigate whether there was a difference in PA depending on lifestyle. Lifestyle was categorized using a self-reported employment status as: "full-time housewife" group (those who were not employed in the 2nd and 3rd trimester), "currently working" group (those who were employed in the 2nd trimester through to the 3rd trimester), and "stopped-working" group (those who were employed in the 2nd trimester but were not working in the 3rd trimester). The different groups were compared using independent *t* tests for continuous variables and Chi-square or Fisher's exact test for categorical variables. A repeated measures analysis of variance was used to investigate any change over time between the groups. All analyses were performed using JMP pro 12.1.0 with the level of significance set to <.05.

3 | RESULTS

3.1 | Participant characteristics (Table 1)

A total of 40 pregnant women at 24–27 weeks of gestation were enrolled in this prospective, longitudinal study. Forty completed the first data collection. One woman failed to follow up in the second survey. From the collected longitudinal data, data of five women who did not meet the wear time criteria were excluded. Thus, longitudinal data were analyzed from 34 primiparous women (Figure 1). The mean number of days for which data were collected and analyzed in the 2nd and 3rd trimesters was 6.9 and 6.7 days, respectively. The mean wear time was 827.5 ± 109.4 min/day in the 2nd trimester and 824.9 ± 126.6 min/day in the 3rd trimester. The mean (standard deviation) age and BMI before pregnancy were 33.4 years (4.8) and 21.6 kg/m^2 (2.9), respectively (underweight [<18.5 kg/m^2] BMI, $n = 3$; normal [18.5–24.9 kg/m^2], $n = 29$; overweight [25–29.9 kg/m^2], $n = 2$).

The mean gestational age was 177.4 ± 7.5 days in the 2nd trimester, and 238.8 ± 5.6 days in the 3rd trimester. Gestational weight gain in the 2nd and 3rd trimesters were 5.0 ± 2.2 and 7.8 ± 2.4 kg, respectively. In the 2nd trimester, 11 women (32.3%) were categorized as full-time housewives and 23 women (67.6%) as currently working. In the 3rd trimester, 13 women (41.2%) stopped working during pregnancy and 10 women (29.4%) were currently working. Among the participants, 18 had no exercise habits before pregnancy, 10 discontinued exercise during pregnancy, and six had exercise before and during pregnancy.

3.2 | Changes in PA during pregnancy (Table 2)

Total PA (MET-hr/day) and MVPA (moderate and vigorous PA; MET-hr/day) in the 3rd trimester were lower than in the 2nd trimester; however, the difference was not statistically significant. With respect to the intensity of PA, LPA time (min/day) was higher in the 3rd trimester than in the 2nd trimester, while MPA time (min/day) and VPA time (min/day) were lower. However, these differences were not statistically significant.

TABLE 1 Sociodemographic and behavioral characteristics ($n = 34$)

		Mean ± SD or *n* (%)
Age (years)		33.6 ± 4.8
Pre-pregnancy body mass index (kg/m^2)		21.6 ± 2.9
Past history	Atopic dermatitis	6 (17.6)
	Hyperthyroidism	2 (5.9)
	Asthma	1 (2.9)
	Epilepsy	1 (2.99)
Infertility treatment		7 (20.6)
Exercise habit before and during pregnancy	Yes	6 (17.6)
	Stopped	10 (29.4)
	No	18 (52.9)

		2nd trimester	3rd trimester
		Mean ± *SD* or *n* (%)	Mean ± *SD* or *n* (%)
Gestational age (days)		177.4 ± 7.5	238.8 ± 5.6
Gestational weight gain (kg)		5.0 ± 2.2	7.8 ± 2.4
Pregnancy complication	Threatened premature delivery	2 (5.9)	3 (8.8)
	Pregnancy anemia	2 (5.9)	14 (41.1)
	Other	1 (2.9)	2 (5.9)
Employment status	Unemployed	11 (32.3)	24 (70.6)
	Employed	23 (67.6)	10 (29.4)

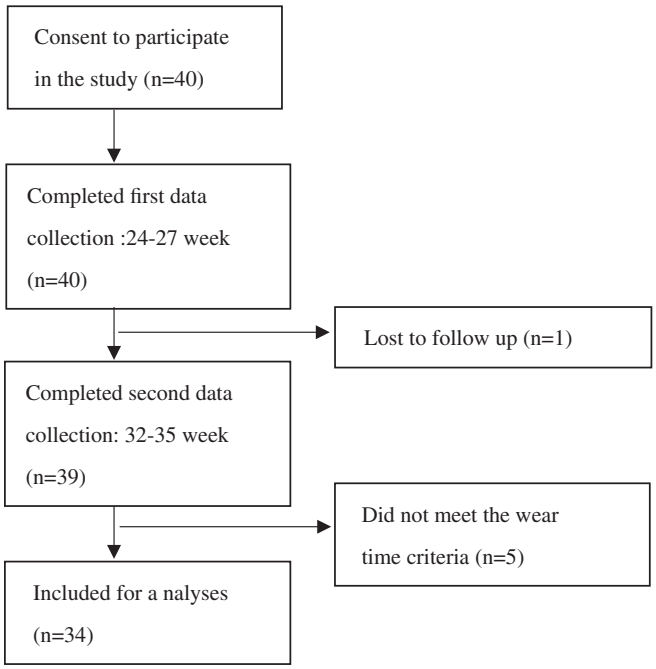

FIGURE 1 Flow of participants in this study

3.3 | Change in PA during pregnancy by lifestyle

In the sub-group analysis, PA parameters in the 2nd and 3rd trimesters were compared based on the lifestyle groups (full-time housewife group, 11 women; currently working group, 10 women; stopped-working group, 13 women).

In the full-time housewife group, the total PA (MET-hr/day) increased significantly from the 2nd to the 3rd trimester ($p = .02$). In the currently working group, there was no significant difference in any of the measures. In the stopped-working group, the total PA ($p < .01$) and MVPA ($p = .03$) decreased significantly from the 2nd to the 3rd trimester (Table 2).

In the full-time housewife group, the amount of PA for each hour significantly increased at 12:00 hr (from 1.57 to 1.81 METs, $p = .02$), 18:00 hr (from 1.67 to 1.79 METs, $p = .05$), and 22:00 hr (from 1.27 to 1.39 METs, $p = .02$). In the currently working group, the amount of PA for each hour significantly increased at 9:00 hr (from 1.63 to 1.80 METs, $p = .02$), 10:00 hr (from 1.62 to 1.74, $p = .04$), and 16:00 hr (from 1.60 to 1.77, $p = .04$). In the stopped-working group, the amount of PA for each hour significantly decreased at 7:00 hr (from 1.48 to 1.21 METs, $p < .01$), 8:00 hr (from 1.73 to 1.33 METs, $p = .02$), and 18:00 hr (from 1.76 to 1.58, $p = .04$) (Figure 2).

4 | DISCUSSION

In this longitudinal study, we measured the amount of PA in 34 primiparous women during the 2nd and 3rd trimesters of

TABLE 2 Physical activity among pregnant women based on trimester of pregnancy

		2nd trimester		3rd trimester						
		Mean	(SD)	Mean	(SD)	T value[a]	*P* value[a]		F value[b]	*P* value[b]
Amount of physical activity (METs-hr/day)										
Total PA	All ($n = 34$)	33.1	(1.7)	32.8	(2.1)	−0.80	.22			
	FH ($n = 11$)	32.4	(1.7)	33.7	(2.1)	2.71	.02*	2nd	1.15	.33
	CW ($n = 10$)	33.2	(1.8)	33.3	(2.1)	0.25	.81	3rd	3.72	.04*
	SW ($n = 13$)	33.5	(1.7)	31.7	(1.7)	−3.75	<.01*			
MVPA	All ($n = 34$)	3.0	(1.9)	2.7	(1.8)	−1.10	.14			
	FH ($n = 11$)	2.0	(1.5)	2.4	(2.4)	0.83	.42	2nd	2.64	.09
	CW ($n = 10$)	3.2	(1.6)	3.3	(1.5)	0.16	.88	3rd	0.72	.50
	SW ($n = 13$)	3.7	(2.2)	2.5	(1.5)	−2.53	.03*			
Cumulative time spent at each intensity of PA (min/day)										
SB	All ($n = 34$)	388.7	(111.8)	382.9	(87.7)	−0.43	.34			
	FH ($n = 11$)	332.9	(71.6)	366.0	(79.4)	1.39	.20	2nd	2.34	.11
	CW ($n = 10$)	429.7	(128.5)	393.1	(86.8)	−1.53	.16	3rd	0.29	.75
	SW ($n = 13$)	404.3	(114.8)	389.3	(99.4)	−0.72	.48			
LPA	All ($n = 34$)	394.4	(99.5)	402.7	(120.5)	0.64	.74			
	FH ($n = 11$)	423.3	(122.0)	470.1	(107.3)	2.08	.06	2nd	0.69	.51
	CW ($n = 10$)	384.4	(99.4)	403.0	(144.8)	0.75	.47	3rd	3.71	.04*
	SW ($n = 13$)	377.6	(79.2)	345.4	(83.0)	−2.03	.06			
MPA	All ($n = 34$)	43.3	(28.1)	38.7	(23.8)	−1.05	.15			
	FH ($n = 11$)	30.5	(20.2)	34.4	(29.2)	0.62	.55	2nd	2.19	.13
	CW ($n = 10$)	43.7	(19.9)	45.8	(20.3)	0.38	.72	3rd	0.65	.53
	SW ($n = 13$)	53.8	(35.5)	36.9	(21.8)	−2.05	.06			
VPA	All ($n = 34$)	1.1	(2.9)	0.7	(1.6)	−0.87	.20			
	FH ($n = 11$)	0.3	(0.6)	1.0	(2.3)	1.19	.26	2nd	0.64	.53
	CW ($n = 10$)	1.7	(84.2)	1.1	(1.5)	−0.49	.64	3rd	1.73	.19
	SW ($n = 13$)	1.3	(2.8)	0.0	(0.2)	−1.64	.13			
MVPA	All ($n = 34$)	44.4	(28.4)	39.4	(24.6)	−1.13	.13			
	FH ($n = 11$)	30.9	(20.5)	35.5	(31.1)	0.69	.51	2nd	2.35	.11
	CW ($n = 10$)	45.4	(20.8)	46.9	(20.4)	0.27	.80	3rd	0.66	.52
	SW ($n = 13$)	55.1	(35.4)	36.9	(21.8)	−2.21	.05*			

Abbreviations: CW, currently working group; FH, full-time housewife group; LPA, light intensity physical activity; MPA, moderate intensity physical activity; MVPA, moderate to vigorous physical activity; PA, physical activity; SB, sedentary behavior; SW, stopped working group; VPA, vigorous intensity physical activity.

[a]Paired *t* test.

[b]Repeated measures analysis of variance.

*$p < .05$.

pregnancy using a triaxial accelerometer. To the best of our knowledge, this is one of the few longitudinal studies to objectively measure normal everyday PA in Japanese women during pregnancy.

Regarding previous studies, Watanabe et al. (2013) reported, in a longitudinal accelerometer study, that the mean MVPA in the 2nd and 3rd trimesters were 24.3–-29.2 min/day and 20.9–21.0 min/day, respectively, which is lower than the PA in this study. Kawajiri, Nakamura, Nagasaka, et al. (2017) in a cross-sectional accelerometer study, showed that pregnant women had about 80 min/day of MVPA on working days and about 30 to 40 min on non-working days. In this study, the MVPA of employed pregnant women was 45.4–55.1 min, and the MVPA of non-employed pregnant women was 30.9–36.9 min, similar to the findings of Kawajiri et al.

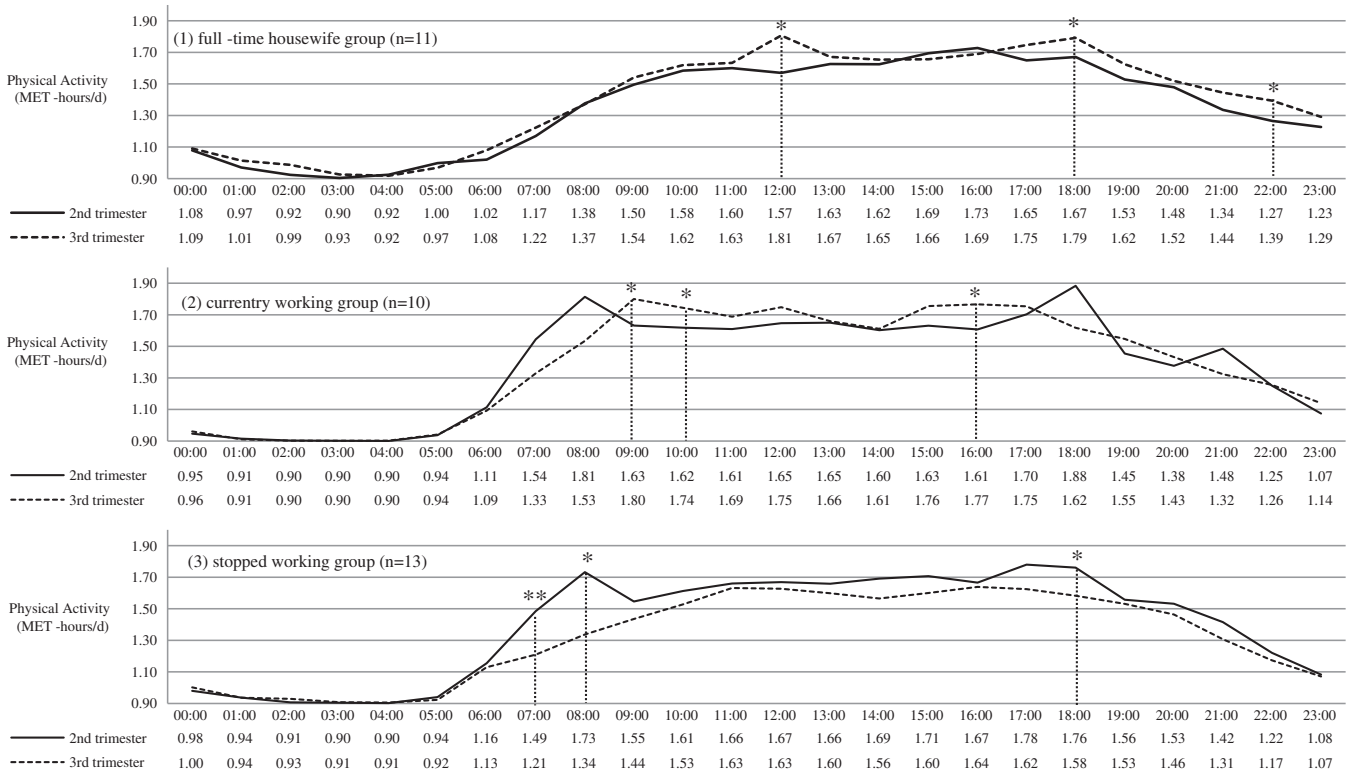

FIGURE 2 Amount of physical activity in each hour during pregnancy based on lifestyle (paired *t* test, $*p < .05$, $**p < .01$)

Overall, we did not find any statistically significant change in PA (METs/hr) between the 2nd and 3rd trimesters of pregnancy. Contrary to our finding, several studies have reported a reduction in the amount of PA from the 2nd to the 3rd trimester (Borodulin et al., 2009; Chasan-Taber et al., 2004; Nascimento et al., 2015; Palmer et al., 2013; Santos et al., 2016). Our use of a triaxial accelerometer for the measurement of PA may have contributed to the difference in the results from previous studies. PA was estimated by previous researchers using questionnaires or pedometers for step counts, but it has been shown that the correlation with the amount of physical activity estimated by the accelerometer is not high (Bell et al., 2013; Chang et al., 2015; Harrison, Thompson, Teede, & Lombard, 2011; Iqbal, Rafique, Badruddin, Qureshi, & Gray-Donald, 2006; Kinnunen et al., 2011; Oostdam, van Mechelen, & van Poppel, 2013). While questionnaires and pedometers have advantages, questionnaires alone are susceptible to bias and pedometers cannot measure non-ambulatory movement. In contrast, a triaxial accelerometer can objectively evaluate the amount of PA and the changes in metabolic rate while also accounting for the participant's body weight, height, and age.

In the sub-group analysis, which compared the changes in PA between the 2nd and 3rd trimesters of pregnancy based on the participants' lifestyle, we found different PA patterns in the full-time housewife, currently working, and stopped working groups. Previous studies did not provide information on the role of employment during pregnancy and its influence on PA. Our study identified longitudinal changes in PA during pregnancy including changes in lifestyle during the course of pregnancy, which were different from the data identified on a cross-sectional survey, especially of pregnant women who were employed.

In the full-time housewife group, the amount of PA increased significantly from the 2nd to the 3rd trimester, which was significant at 12:00, 18:00, and 22:00 hr. This increase in PA could be due to health provider instructions to increase activity in the 3rd trimester in order to promote labor or to prevent excessive weight gain; similar instructions may not have been provided during the 2nd trimester. Kawajiri, Nakamura, Atogami, and Yoshizawa (2016) conducted a semi-structured interview with 10 midwives to identify the nature of PA-related health education in pregnant women, and identified that midwives recommended PA to pregnant women as a means of controlling weight gain and promoting parturition. Owing to the high likelihood of weight gain and the lower risk of premature birth in late pregnancy, midwives may be comfortable recommending PA to pregnant women in the 3rd trimester. However, on the other hand, it is known that work is an inhibiting factor in self-care behavior during pregnancy. In the interviews conducted by Takatsu et al., primiparas reported that they could

not practice recommended health behavior due to work (Takatsu et al., 2013). In a questionnaire survey of 133 postpartum women, it was reported that work-related time constraints and fatigue interfere with leisure PA during pregnancy (Megan, Helen, Paige, & Megan, 2015). Thus, it is expected that the feasibility of self-care behavior is higher in the full-time housewife group than other groups because there is no inhibiting factor of self-care behavior related to working.

In the currently working group, the amount of PA per day did not change from the 2nd to the 3rd trimester, although the time of the maximum PA changed from 8:00 to 9:00 hr in the morning, and from 18:00 to 17:00 hr in the evening. This may be owing to the participants modifying their commuting time to avoid crowds or to intentionally shortened working hours. In Japan, the "maternity health care guidance item contact card" (Ministry of Health, Labor and Welfare, 2018) is mandatorily used by employers to take appropriate care of pregnant or postpartum female employees. These measures include: (a) mitigation of commuting during pregnancy; (b) provision of adequate breaks during pregnancy; and (c) measures to handle pregnancy- or postpartum-related conditions, among others (Ministry of Health, Labor and Welfare, 2018). The women in this group may have used these cards to adjust their working situation.

In the stopped-working group, the amount of PA significantly decreased from the 2nd to the 3rd trimester. In this study, we did not ask participants why they stopped work. However, no one reported a limitation on PA due to pregnancy complications. The reason for this PA decrease may be that participants in this group did not perform activities before leaving for the workplace and during the commute to the workplace. The decrease in the amount of PA at 7:00, 8:00, and 18:00 hr supports this idea. Nakamura et al. (2016) measured the amount of PA on working days and holidays of four working pregnant women and found that PA was significantly greater on working days than on holidays. This result supports our observation. In addition, the significant decrease in the amount of PA for each hour at 7:00, 8:00, and 18:00 hr suggests that the PA-related transportation to the workplace largely contributed to the total amount of PA. In addition, in this study, pregnant women in the stopped-working group would have been recorded immediately after the change in lifestyle because we set the data collection time at 32–35 weeks of gestation, which is considered the beginning of maternal leave in Japan. The decrease in PA among the pregnant women in the stopped-working group may have occurred because they were resting to recover from the physical stress of working.

This study included pregnant women who experienced threatened premature delivery (two in the 2nd trimester, three by the 3rd trimester), and none of them were hospitalized. The diagnosis of impending threatened premature delivery theoretically could have reduced their PA. However, a previous study in Japan found no difference in the mean number of walking steps or mean energy consumption in activities between the outpatients treated for threatened premature delivery and healthy pregnant women (Arii & Natori, 2007). Therefore, we included pregnant women with threatened premature delivery in the analysis.

Disadvantages to the participants in this study included the inconvenience of always wearing the device, the time spent on answering the questionnaire. Considering the burden on the participants, a reward equivalent to 3,000 yen was reasonable, and it was highly possible that the necessary number of participants could not have been recruited if they were not paid. Although the possibility of selection bias caused by the reward cannot be denied, it is considered to be minimized.

Our study had some limitations. First, we did not analyze the relationship between pregnancy outcomes (such as preterm birth or gestational diabetes) and PA. Among the small number of our study participants, there were hardly any adverse events to observe. Even in the previous studies, there is insufficient evidence regarding the influence of PA on pregnancy outcomes. Second, no PA was measured while the participants woke up at night. Because there are a lot of awakenings during pregnancy, our results may have underestimated PA. The third limitation concerns generalizability. Since our research aim was to understand the characteristics of PA during pregnancy, we conducted longitudinal PA monitoring with a small group. We were able to obtain detailed information on changes in the participants' lifestyles and show patterns of changes in PA. However, further studies are needed to improve generalizability, because we sampled only one city in Japan and only in the warm season. Fourth, we did not study PA during the 1st trimester. We analyzed PA in the 2nd and 3rd trimesters as this period involves lifestyle changes such as work interruption, and physical changes due to pregnancy. The change in PA during the 1st trimester is likely to show a different pattern (because of morning sickness or miscarriage). Fifth, we derived the amount of PA per day as the average of a routine week and did not examine whether special events (traveling or moving) or working days and holidays were included. Finally, none of the available accelerometers are validated to estimate the amount of PA in pregnant women. This may have contributed to an error in the estimated value of PA.

5 | CONCLUSION

Objective measurements using a triaxial accelerometer showed no statistically significant change in PA during pregnancy. However, there was a clear pattern in the change in

PA based on the lifestyle changes of our participants with the progression of pregnancy. Future research may enable the development of personalized health guidance by identifying the relationship between PA and pregnancy outcomes. The accelerometers used in this study are commercially available and may be used by pregnant women to monitor their PA. Although our study protocol prevented pregnant women from assessing their PA during the course of the study, our study identifies the future potential to use wearable devices as a health education strategy to modify behavior.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

All the authors contributed to the conception and design of this study. M.K., Y.N., Y.T. carried out the data collection and analysis. M.K. drafted the manuscript. All the authors approved the final version of the manuscript.

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