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Article title: Longitudinal changes in physical activity of early-stage breast cancer survivors in Japan during and after the COVID-19 lockdown

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Running Title: COVID-19 and Physical Activity Changes in Breast Cancer Survivors

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ABSTRACT

***Purpose*:** This study investigated the changes in the physical activity of Japanese breast cancer survivors during and after the state of emergency declaration (SOED) due to the spread of COVID-19.

***Methods*:** Participants were survivors of stage I-IIa breast cancer diagnosed between the ages of 18 and 60 years who wore a wearable device (Fitbit Versa) before and after the SOED period. Outcomes included steps per day on weekdays and weekend days and holidays, sedentary time, and time spent engaged in various levels of physical activity.

***Results*:** Seventeen participants were included in the analysis. Steps per day decreased significantly from 8450 ± 905 steps before the SOED to 6085 ± 526 steps during, and 6871 ± 776 steps after the SOED on weekdays ($p < 0.05$). No difference in sedentary time was observed before, during, and after the SOED period on weekdays or weekend days, or holidays. Time spent engaged in light physical activity was significantly shorter on weekdays, decreasing from 251 ± 15 minutes before the SOED to 216 ± 15 minutes during, and 223 ± 16 minutes after the SOED ($p < 0.05$). Time spent engaged in moderate to vigorous physical activity was significantly shorter on weekdays before the SOED at 154 ± 39 minutes, dropping to 101 ± 29 minutes during, and increasing to 136 ± 38 minutes after the SOED ($p < 0.05$).

***Conclusion*:** Participants spent less time engaged in all levels of physical activity on weekdays during the SOED. Therefore, during lockdowns, it is important to maintain higher intensities of physical activity on weekdays. Because steps and time spent engaged in light physical activity did not recover after the SOED period, breast cancer survivors need to focus on these parameters after lockdowns while also paying attention

to infection prevention.

Key words**:** COVID-19, lockdown, exercise habit, physical activity, sedentary time, active time

表題名：

早期乳がんサバイバーにおける新型コロナウイルス感染症緊急事態宣言前後の身体活動の縦断的研究

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抄録

目的：本研究は、新型コロナウイルス感染症緊急事態宣言（SOED）期間中及びその前後における日本の乳がんサバイバーの身体活動の変化を調査した。

方法：参加者は、18 歳から 60 歳の間にステージ I～IIa の乳がんと診断され、SOED 期間前後にウェアラブルデバイス（Fitbit Versa）を着用した乳がんサバイバーであった。評価指標は、平日および週末・祝日の一日の歩数、座位時間、および強度別の身体活動時間が含まれた。

結果：17 名の参加者が分析対象となった。SOED 期間中および後の平日の一日の歩数は、SOED 期間前の 8450 ± 905 歩から、期間中は 6085 ± 526 歩、期間後は 6871 ± 776 歩へと有意に減少した（$p < 0.05$）。平日または週末・祝日の SOED 期間前、中、後における座位時間は、差が無かった。SOED 期間中および後の平日の低強度の身体活動時間は、SOED 期間前の 251 ± 15 分から、期間中は 216 ± 15 分、期間後は 223 ± 16 分へと有意に短縮された（$p < 0.05$）。平日の SOED 期間中の中・高強度の身体活動時間は、SOED 期間前の 154 ± 39 分から期間中は 101 ± 29 分へと有意に減少し（$p < 0.01$）、SOED 期間後には 136 ± 38 分へと回復した（$p < 0.05$）。

結論：参加者は SOED 期間中の平日にすべての強度の身体活動時間が減少した。したがって、SOED 中には、平日の身体活動の強度を維持することが重要である。SOED 期間後に歩数と低強度の身体活動時間が回復しなかったため、乳がんサバイバーは SOED 後の身体活動に注意する必要がある。

Introduction

The global and national burden of breast cancer remains significant, with an estimated 2.3 million women diagnosed with breast cancer in 2022, as reported by the World Health Organization [1]. In Japan, recent statistics from the National Cancer Center indicate that approximately 97,000 women were diagnosed with breast cancer in 2019 [2]. The number of breast cancer survivors is increasing year by year [2, 3] and physical activity and exercise are considered important because there is a strong association between physical activity and risk of all-cause mortality among breast cancer survivors [4]. Longitudinal studies have shown that cardiorespiratory fitness in women is associated with breast cancer mortality [5]. Proactive physical activity is recommended for cancer survivors as a means of maintaining and improving quality of life after cancer treatment [6, 7]. However, a systematic review found that breast cancer survivors who had not undergone chemotherapy had a lower median $\dot{V}O_2$peak compared with healthy sedentary women (24.6 mL/kg/min vs. 29.7 mL/kg/min) [8] suggesting that breast cancer survivors engaged in less physical activity and were sedentary for longer periods.

Several studies have reported decreased physical activity in the general population due to the spread of COVID-19 and the resulting lockdowns[9-11]. These lockdowns placed restrictions on daily life, including limitations on outdoor activities. A previous report suggested that reduced levels of physical activity during the COVID-19 pandemic led to an increased risk of cardiovascular disease [12]. For example, a study conducted in Japan showed that the COVID-19 pandemic played a role in declining physical activity in the elderly population [13]. However, no studies have investigated changes in the physical activity of Japanese

breast cancer survivors or their recovery during and after the state of emergency declaration (SOED) period.

In assessing the impact of the COVID-19 pandemic on the physical activity patterns of breast cancer survivors in Japan, it is crucial to establish a pre-pandemic baseline for comparison. To this end, we refer to the study conducted by Amagasa et al.[14], which provides objective data on physical activity levels among middle-aged Japanese adults before the pandemic. According to their findings, the average daily sedentary time was reported as 481.1 minutes, low-intensity activity time was 379.5 minutes, and moderate-to-vigorous physical activity time was 69.9 minutes. These data serve as a valuable benchmark for understanding typical activity levels and evaluating the extent of changes in physical activity among our study participants during the pandemic period.

Wearable devices such as activity trackers and smartwatches make it possible to continuously measure and monitor physiological data. A study of objective physical activity levels reported that lockdown measures were associated with a significant decrease in the number of steps taken by hemodialysis patients [15]. In Japan, a nationwide longitudinal study was conducted from January 1, 2019 to January 1, 2021, using triaxial accelerometer-based physical activity monitors. Compared with 2019, a significant reduction in the number of steps was observed in March 2020 among the young and elderly male population as well as young women in the metropolitan area [16]. However, the physical activity of Japanese breast cancer survivors using wearable devices during the SOED is not clear.

Previous research also shows that patterns of physical activity can differ significantly between weekdays and weekends. For instance, a study by Smith et al. [17] has shown that differences in work hours

and leisure time between weekdays and weekends lead to variations in activity levels. This distinction is critical in our study as it helps us understand how the SOED, rather than the disease itself, affected the daily routines and recovery phases of breast cancer survivors.

Therefore, the purpose of this study was to investigate the changes in physical activity of breast cancer survivors before, during, and after the SOED period, based on data obtained from wearable devices. We hypothesized that breast cancer survivors engaged in less physical activity at all levels during and after the SOED period compared with before.

Methods

Participants

This study targeted 50 female survivors of stage I-IIa breast cancer who were treated at the National Cancer Center Hospital in Tokyo, Japan and whose medical records were provided by their oncologists. We examined Fitbit data collected from the habit-B program, which started in 2019 and concluded in 2021 [18]. The participants were aged 18–60 years at the time of diagnosis. They had undergone surgery 2–13 months earlier and did not require any cancer drug treatments except for postoperative hormone therapy. They were all living in Japan between May 2019 and November 2020. The recruitment of participants took place at the National Cancer Center Hospital from May 27, 2019, to August 14, 2020. Those who wore a Fitbit Versa before, during, and after the SOED period were included in the analysis. All participants provided written informed consent before participation. The study was approved by the Institutional Ethics Committee of the National Cancer Center Hospital [ID: 2018-274].

Exclusion criteria were failure to wear the Fitbit Versa before, during, and/or after the SOED. Of the 50 participants targeted, 17 had complete data on steps taken, sedentary time, and time spent engaged in light, moderate, and vigorous physical activity, while 16 had complete data on time spent engaged in light and moderate-to-vigorous physical activity. Notably, only 1 participant had complete data on time spent engaged in light and moderate-to-vigorous physical activity but not on sedentary time or steps per day before, during, and after the SOED period.

The SOED period

The state of emergency declared by the Japanese government lasted from April 7 to May 25, 2020, with a total duration of 49 days, including 31 weekdays and 18 weekend days and holidays. In addition to the data recorded during the SOED period, we also examined data from the 30 weekdays and 16 weekend days before the SOED period as well as the 29 weekdays and 12 weekend days after the SOED period (Fig. 1). Ren Fig 1.

Outcome measures

The primary outcome parameters were measured using a Fitbit Versa, and the participants were instructed to wear the device continuously, except when taking a shower or charging the battery. The primary adherence measure during the study was data collected and uploaded to the Internet by Fitbit. Each participant's Fitbit recorded the daily totals for steps, sedentary time, and time spent engaged in light and

moderate-to-vigorous physical activity, which were downloaded at the end of the study. To ensure high compliance with Fitbit device wear, our research team monitored the data for completeness and accuracy. If data collection lapses were detected, participants were promptly reminded via email to wear their devices consistently. For persistent gaps, follow-up phone calls were made to resolve any issues and emphasize the importance of ongoing participation. Fitbit wear time was determined using a combination of step count and heart rate (HR) data. Minutes with either recorded HR or step count > 0 were classified as wear time. For analysis inclusion, we required ≥600 minutes (10 hours) of daily wear time [19]. To ensure comprehensive representation of participants' activity patterns, only data from individuals who adhered to the protocol for ≥60% of the study duration were included in the final analysis [18]. This approach aligns with established practices in wearable device research, balancing data quality with participant retention. We calculated steps per day, time spent engaged in light and moderate-to-vigorous physical activity, and sedentary time for weekdays as well as for weekend days and holidays.

In addition to the physical activity data collected through Fitbit devices, our study also gathered comprehensive demographic and clinical information from each participant. This included age, cancer diagnosis history, types of treatment received, and current health status. These data were collected using structured questionnaires administered at the beginning of the study period. Detailed descriptions of the data collection methodologies are documented in our protocol paper [18].

Statistical analysis

Data from before, during, and after the SOED period were compared using a one-way repeated analysis of variance with corresponding measures. The data collected from the participants' Fitbits were used to calculate the average value for each of the following parameters: steps per day, sedentary time, and time spent engaged in different levels of physical activity on weekdays and weekend days and holidays. The analysis was performed using a two-tailed test, with the level of statistical significance set at $p < 0.05$. In cases where significant effects were observed, post-hoc tests with Bonferroni corrections for multiple comparisons were conducted. All statistical analyses were performed using SPSS Statistics ver. 28 (IBM Corp., Armonk, NY).

Results

The demographic and clinical data of the 17 participants are shown in Table 1. The mean ± standard deviation for age and body mass index were 48 ± 7 years and 21.4 ± 2.6 kg/m^2, respectively. Ren Table 1. The average number of days meeting the inclusion criteria for wear time was 86 ± 7 of the 90 weekdays during the study period and 43 ± 5 of the 46 holidays during the study period.

The analysis revealed a significant decrease in steps per day on weekdays both during the SOED period (6085 ± 526 steps) and after (6871 ± 776 steps) compared with before (8450 ± 905 steps) (during vs. before: $p < 0.001$, after vs. before: $p < 0.05$; Fig. 2). However, there was no significant difference among the timepoints on weekend days and holidays (before SOED: 6969 ± 1261 steps, during SOED: 6427 ± 1203 steps, after SOED: 6811 ± 800 steps). There were also no significant differences in sedentary time on weekdays or weekend days or holidays during and after the SOED period compared with before (Fig. 3).

Sedentary time on weekdays was 766 ± 27 min/day before SOED, 791 ± 36 min/day during SOED, and 791 ± 41 min/day after SOED. For weekend days and holidays, the values were 721 ± 27 min/day before SOED, 740 ± 45 min/day during SOED, and 744 ± 43 min/day after SOED. Ren Fig 2. Ren Fig 3.

Time spent in light physical activity on weekdays was significantly shorter during (216 ±15 min) and after (223 ± 16 min) the SOED period compared with before (250 ± 15 min) (during vs. before: $p < 0.001$, after vs. before: $p < 0.05$; Fig. 4). No significant difference was observed on weekends and holidays, with values of 232 ± 20 min before SOED, 211 ± 23 min during SOED, and 218 ± 25 min after SOED. Ren Fig 4.

Time spent engaged in moderate-to-vigorous physical activity (MVPA) was significantly shorter on weekdays during the SOED period (101 ± 29 min) than before (154 ± 39 min of MVPA/week) and after (136 ± 38 min) (during SOED vs. before SOED: $p < 0.01$, during SOED vs. after SOED: $p < 0.05$; Fig. 5), but this was not the case on weekend days or holidays. There was no change in time spent engaged in MVPA on weekend days or holidays before, during, or after the SOED period, with values of 112 ± 35 min before SOED, 131 ± 61 min during SOED, and 124 ± 47 min after SOED. Ren Fig 5.

Discussion

This study aimed to examine the impact of the SOED period on objective physical activity levels in breast cancer survivors in Japan. To this end, we first performed a retrospective analysis of the effect of the SOED period in Japan on physical activity and sedentary time before, during, and after the SOED period, based on data recorded by wearable devices. The major findings of this study are that breast cancer survivors

spent less time engaged in all levels of physical activity during the SOED period on weekdays, as expected. We also found that time spent engaged in light physical activity did not recover after the SOED period, although time spent engaged in MVPA did. In contrast, no changes in any level of physical activity were found on weekend days before, during, or after the SOED period. These results have practical implications for maintaining physical activity in the event of another lockdown.

Higher levels of physical activity have been shown to help maintain and enhance physical health and quality of life and they also play a critical role in reducing short-term and long-term morbidity and mortality [20]. Both the American Cancer Society[21] and the Japan Breast Cancer Society[22] recommend a minimum of 150 min of moderate physical activity or 75 min of vigorous physical activity per week in addition to routine physical activity in daily life. Furthermore, the Japan Breast Cancer Society strongly urges breast cancer survivors to maintain a high level of physical activity. Our results revealed a significant decrease in the number of steps per day on weekdays both during and after the SOED period compared with before. Importantly, the participants took 8392 ± 890 steps per day before the SOED period, which was higher than the average of 6685 steps for Japanese women aged 20–64 years [23]. This means that Japanese breast cancer survivors took on average more steps than women in a similar age group who did not have breast cancer. However, during the SOED period, the number of average steps (6085 ± 526 steps) was lower than the average for Japanese women as a whole, likely because people living in Japan were asked to stay at home and thus did not have the chance to maintain their usual steps, which supports our hypothesis.

Time spent engaged in light physical activity decreased significantly during and after the SOED

period on weekdays, although there was no such change on weekend days and holidays, which indicates that the SOED period had no substantial impact on any outcome parameters on weekends and holidays. This highlights the importance of finding ways to encourage physical activity during emergency situations on weekdays. Because time spent engaged in moderate-to-vigorous physical activity decreased significantly on weekdays during the SOED period compared with before and after, these findings suggest that the SOED period had a negative impact on all levels of physical activity on weekdays. However, there was no significant difference between the number of steps per day and time spent engaged in light physical activity during and after the SOED period, suggesting that these two outcome parameters did not immediately recover after the SOED period. Based on these results, we assume that the participants took fewer steps and spent less time engaged in all levels of physical activity during the SOED period, especially on weekdays. Additionally, we observed that both the number of steps per day and the time spent engaged in light physical activity did not return to pre-SOED levels after the declaration was lifted. During and after a lockdown, it is important to focus on walking and engaging in low-intensity exercise on weekdays while also paying attention to infection prevention.

According to World Health Organization guidelines[20], adults should do at least 150–300 min of moderate-intensity aerobic physical activity or 75–150 min of vigorous aerobic physical activity throughout the week; however, the time the participants spent engaged in MVPA on weekdays during the SOED period was only accumulated a total of 101 ± 29 minutes of MVPA across all weekdays. In a study by Haider et al., time spent engaged in MVPA was associated with higher odds of mental well-being and lower odds of

depressive symptoms and anxiety symptoms due to social restrictions imposed during the COVID-19 pandemic [24]. Because that study showed that breast cancer survivors experienced psychological problems such as depression, fear of recurrence, and anxiety, we believe that it is crucial for breast cancer survivors to engage in high levels of physical activity, especially under circumstances such as a lockdown.

Strengths and Limitations:

Strengths:

One of the major strengths of this study is its ability to measure changes in step counts and physical activity levels before, during, and after SOED among Japanese breast cancer survivors. Few studies globally have managed to capture such data continuously through a period of emergency like the SOED. Even purely descriptive statistics from this dataset are considered valuable as they provide insights into the impact of the pandemic on a specific and vulnerable population.

Limitations:

The sample size of this study is relatively small, and the study may be subject to selection bias, potentially affecting the representativeness of the data. Additionally, there is a general scarcity of baseline data on typical step counts and physical activity levels among Japanese breast cancer survivors, which limits the conditions under which the results can be interpreted. This scarcity highlights the need for a cautious interpretation of our findings within the specific context of this study.

Furthermore, while the Fitbit Versa is widely used in physical activity research, it is crucial to acknowledge the inherent limitations of such wearable devices. Previous research has demonstrated that, although these devices generally provide high reliability and accuracy in typical settings, discrepancies may occur under specific conditions, particularly when measuring various intensities of physical activity [25]. In our study, we observed extended durations of MVPA among participants, which necessitates careful interpretation of this data.

Moreover, in this study, we compared the number of steps recorded by the Fitbit Versa with the figures reported in the National Health and Nutrition Survey Japan, which served as a reference. However, it is crucial to recognize the limitations associated with this comparison due to the differing methodologies and devices used to measure physical activity in each instance. Considering these limitations, we utilized the data from the National Health and Nutrition Survey Japan as a necessary reference due to the scarcity of standard step data for the Japanese population. This further underscores the need for caution in interpreting comparative data and ensuring that conclusions drawn are appropriately contextualized.

Conclusion

In this study, we found that breast cancer survivors engaged in less physical activity on weekdays during the SOED period, but this pattern was not observed on weekend days or holidays. Based on these findings, we concluded that promoting higher levels of physical activity on weekdays during similar future events might be beneficial. Additionally, our results indicate the potential importance of encouraging activities such as walking to help increase step counts, particularly after periods of reduced physical activity

due to restrictions such as lockdowns. Lastly, the development and implementation of home-based exercise programs might be a valuable strategy to support sustained physical activity among breast cancer survivors in similar situations.

Conflicts of interests

The authors have no conflicts of interest relevant to this article.

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Authors' contributions

RY contributed to the data analysis, interpretation of the data, and drafting of the manuscript. YK contributed to the conception and design of the study and the data analysis. KT contributed to the data analysis, assembly of the data, and the drafting and revising of the manuscript. TS contributed to the data analysis, interpretation of the data, and the revising of the manuscript. AS performed medical checkups and recruitment and revised the manuscript. EO contributed to the conception and design of the study, the data analysis, the interpretation of the data, and the drafting and revising of the manuscript. All authors read and approved the final manuscript and agree to be accountable for all aspects of the work. KT and EO are the co-corresponding authors for this manuscript.

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Figure and Table Legends

Table 1. Demographic and clinical characteristics of the participants

Figure 1. Timeline graph showing the start and end dates of the COVID-19-related state of Emergency declaration (SOED) in Japan, as well as the periods 30 days before and 29 days after the declaration.

Figure 2. Steps per day on weekdays (A) and on weekend days and holidays (B). The y-axis shows mean steps/day, with each bar representing the mean step count and the error bars indicating the standard deviation. The x-axis shows the three target periods. The grey bar on the right shows the mean steps per day of age-matched Japanese women.

Figure 3. Sedentary time on weekdays (A) and on weekend days and holidays (B). The y-axis shows the mean min/day, with each bar representing the mean sedentary time and the error bars indicating the standard deviation. The x-axis shows the three target periods.

Figure 4. Time spent engaged in light physical activity on weekdays (A) and on weekend days and holidays (B). The y-axis shows the mean min/day, with each bar representing the mean time spent engaged in light physical activity and the error bars indicating the standard deviation. The x-axis shows the three target periods.

Figure 5. Time spent engaged in moderate-to-vigorous physical activity on weekdays (A) and weekends and holidays (B). The y-axis shows the mean min/week, with each bar representing the mean time spent engaged in moderate-to-vigorous physical activity and the error bars indicating the standard deviation. The x-axis shows the three target periods.

Table 1. Demographic and Medical Characteristics

Characteristics	*N* = 17
Age, mean (*SD*), y	48 (7)
Height (cm), mean (SD)	159.9 (6.7)
Body weight (kg), mean (SD)	54.9 (7.8)
Body mass index, mean (*SD*), kg/m^2	21.4 (2.6)
Breast cancer stage	
I, *n* (%)	11 (64)
IIA, *n* (%)	6 (36)
Tumor	
Estrogen receptor positive, *n* (%)	16 (93.5)
Progesterone receptor positive, *n* (%)	16 (93.5)
HER2 positive, *n* (%)	1 (6.5)
Hormone therapy, *n* (%)	15 (88)
Tamoxifen, *n* (%)	13 (87)
Anastrozole, *n* (%)	1 (6.5)
Other, *n* (%)	1 (6.5)
Receiving radiotherapy, *n* (%)	7 (41)
Time since surgery, mean (SD), months	4 (3)
Physical Activity (PA)	
Steps (n/day)	7187 (914)
Sedentary time (min/day), mean (SD)	783.6 (58.9)
Lightly PA time (min/day), mean (SD)	229.2 (18.8)
Moderate-Vigorous PA time (min/day), mean (SD)	144.3 (72.1)

Figure 1

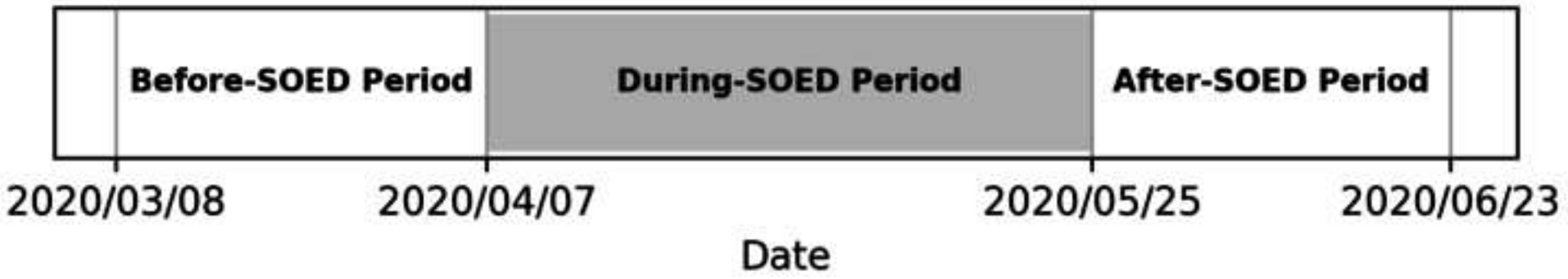

Figure 2

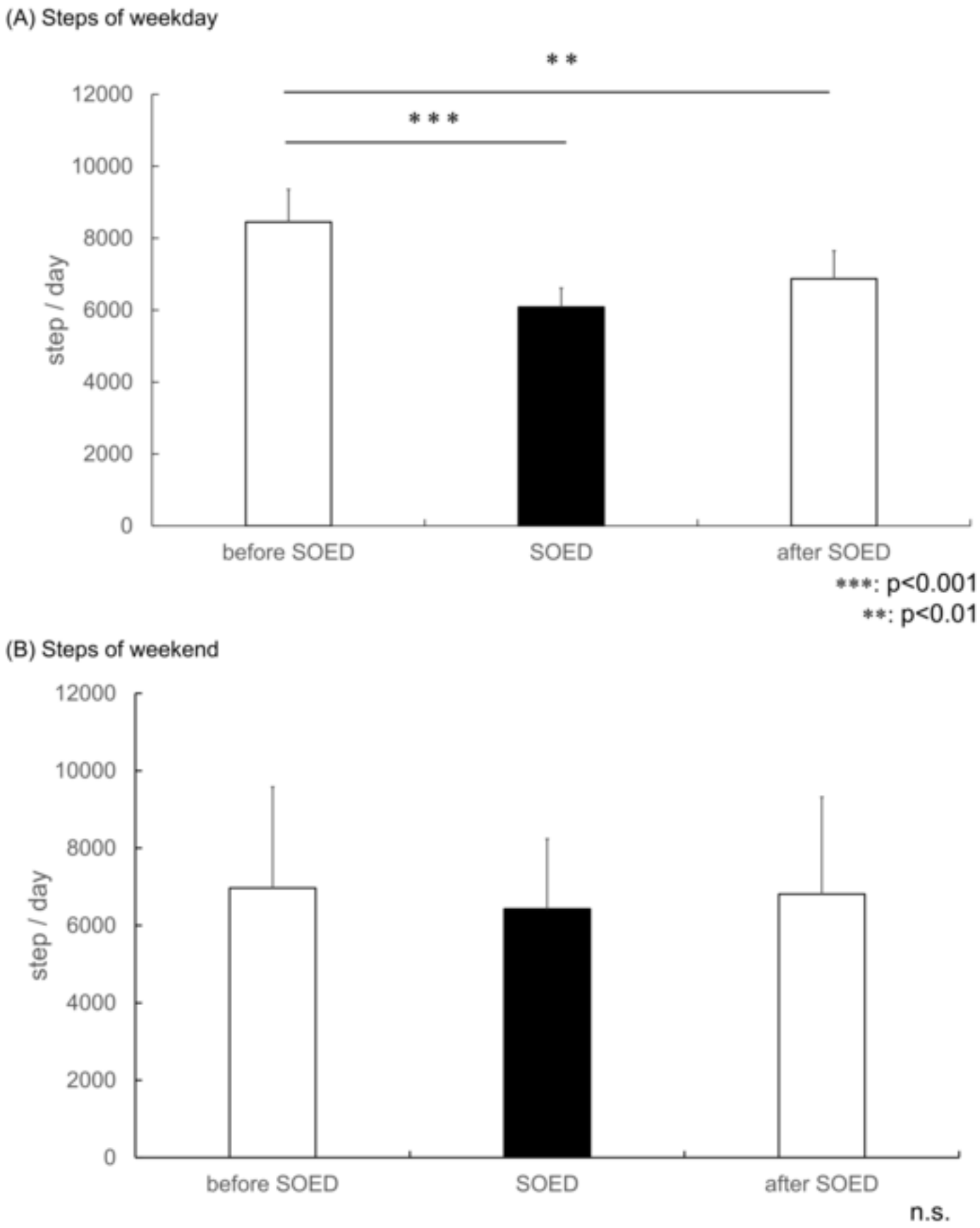

Figure 3

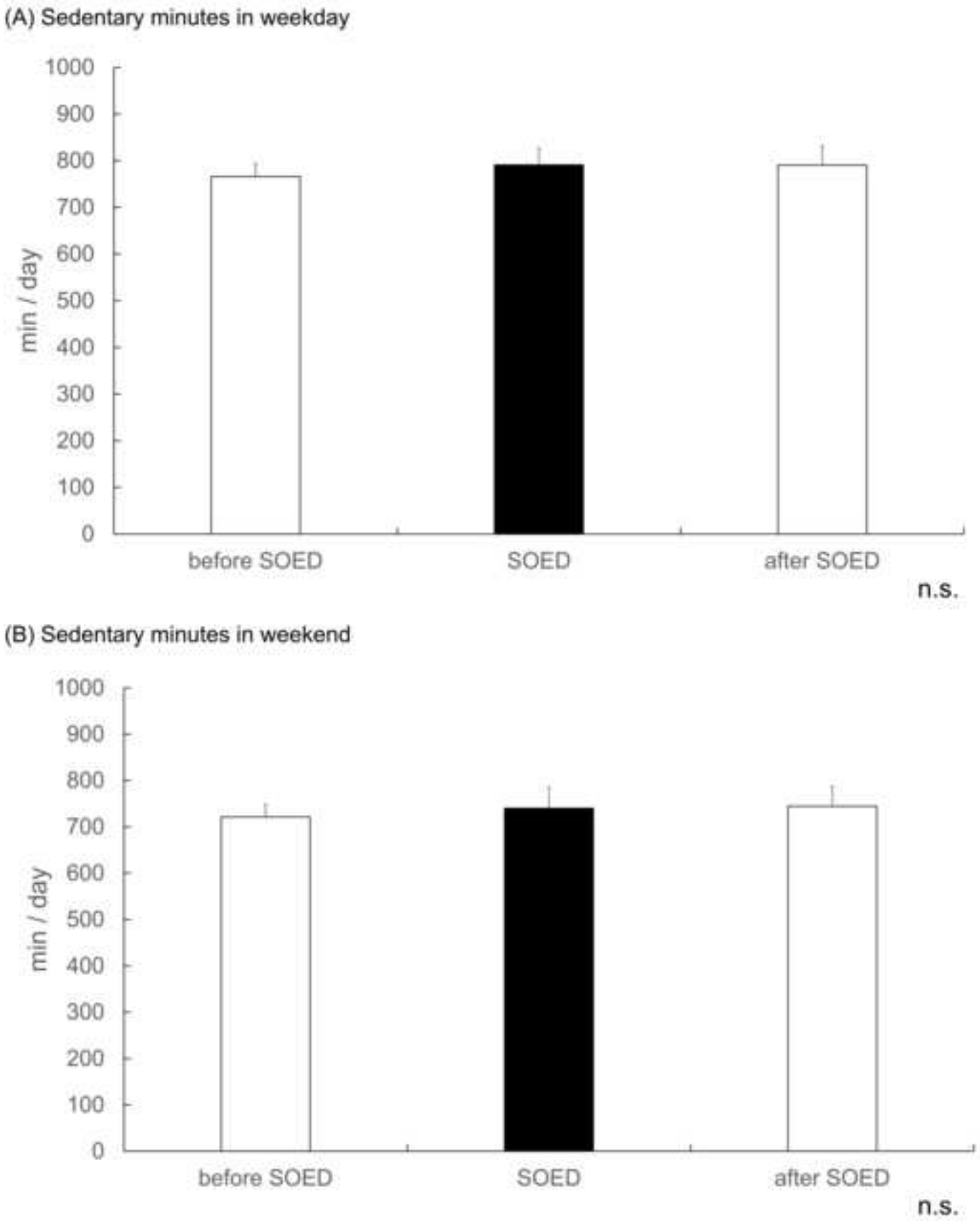

Figure 4

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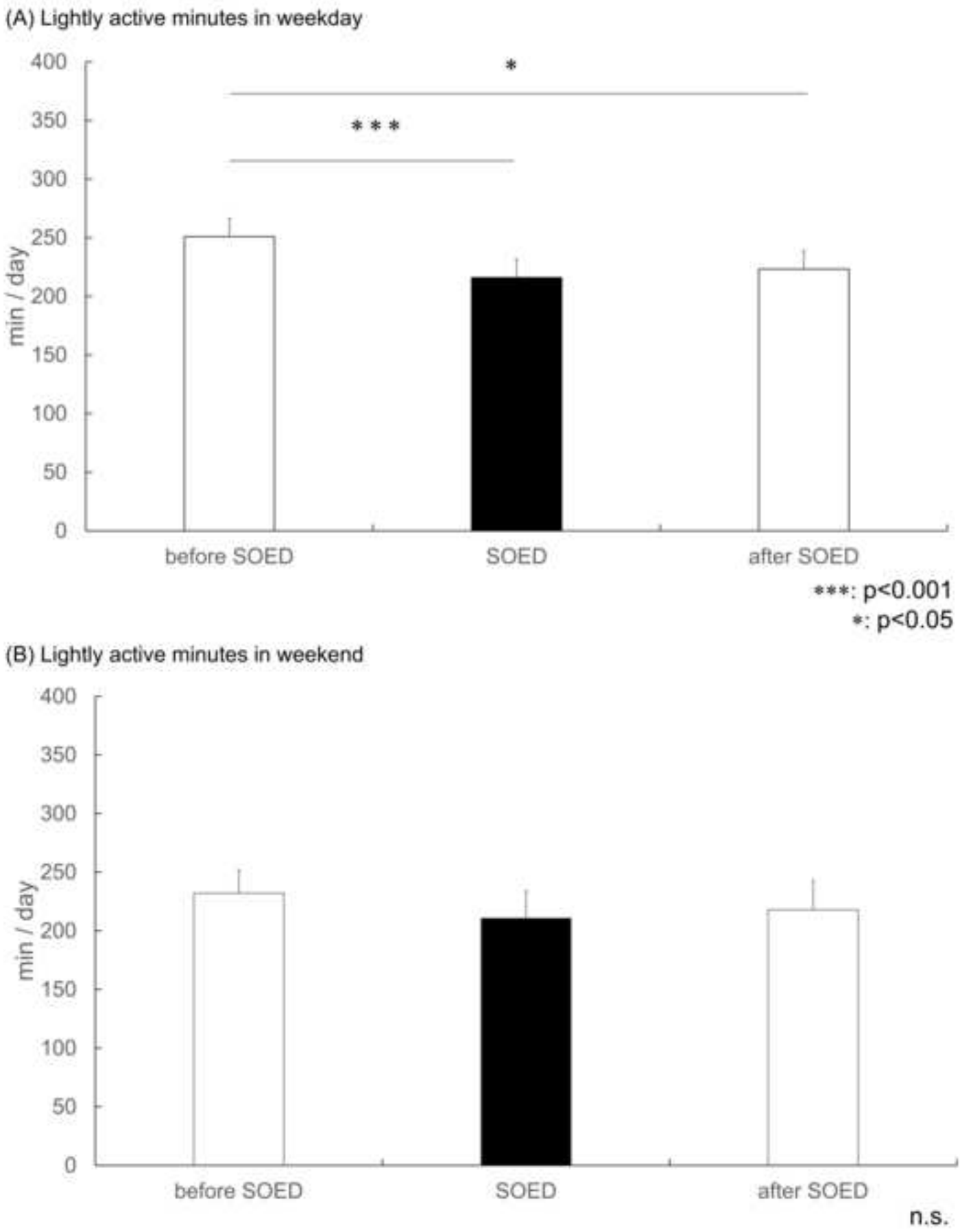

Figure 5

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