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Workstyle change effects on physical activity and health consciousness in Japan: Results from COVID-19 lifestyle activity survey

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ABSTRACT

The importance of daily trips as the daily general physical activity (PA) generator has been attracting more attention than ever. Workers had been obtaining certain amount of PA by commuting; however, the COVID-19 pandemic has brought a rapid spread of teleworking, which may lead to a loss of PA. To analyze the effect of workstyle change on the PA amounts, we assessed diary data from three time points in Japan: Before, During, and After the first lockdown in April 2020. Participants (n = 4,484) were divided according to workstyle change patterns. Their PA amounts were calculated by associating metabolic equivalent (MET) values with their diary data. Purposes of the trips were considered to distinguish the pure workstyle change effect and the lockdown effect. Workers’ health consciousness was also examined from a questionnaire survey. Results revealed that telework drastically reduces PA associated with daily trips for any transport mode. Teleworkers tend to make more non-commuting trips than commuters, but the PA amount associated with total daily trips is higher for commuters. Young workers who newly started teleworking during the pandemic significantly reduced PA. Women teleworkers tend to have less PA amount than men during the lockdown. Workers who had been teleworking since before the COVID-19 pandemic had the lowest consciousness about the health effects of daily trip reduction. Continuous and courteous support aimed at maintaining a certain amount of PA with daily trips and exercise habits might be a key measure to safeguard worker health, especially for the young teleworkers in a long-term.

Introduction

As the average life expectancy is increasing, more attention is being paid to the importance of physical activity (PA) as a means of maintaining health. In the field of public health, studies have revealed that walking, cycling, and use of public transport significantly contribute to ensuring PA and maintain good health of people (Batista Ferrer et al., 2018; Liao et al., 2016; Shaw et al., 2017). Trips in everyday life associated with commuting, going shopping, and other activities might take an important role in ensuring health in this busy world.

Workers employed outside their home (commuters) spend a certain amount of time “commuting” every day. Many workers commute by public transport, bicycle, and on foot in urban areas of Japan. Consequently, they gain a certain amount of PA automatically from their daily trips. However, workers employed at home (teleworkers) do not take trips every day. For that reason, they have less opportunity to gain some amount of PA. Therefore, teleworking might be a threat to regular physical activity (Tanaka et al., 2021). The teleworking system increasingly introduced in Japan have been growing in recent years (Ministry of Internal Affairs and Communications, 2020), but the extent to which teleworking might contribute to physical inactivity has yet to be revealed.

In Japan, the COVID-19 outbreak began in early 2020. A state of emergency was first declared by the government on April 7, 2020, in large cities with high number of infected people, to prevent the spread of infection and to avoid the malfunction of health care system (Office for COVID-19 and Other Emerging Infectious Disease Control, C. S. G. of J., 2020). Since the infection had rapidly spread and 70 % of the patients’ route of infection was unknown, the government declared a state of emergency for entire country on April 16, 2020 (Office for COVID-19 and Other Emerging Infectious Disease Control C., 2020a). In the policy of the declaration, business entities were required to reduce 40 % of commuting, prefectoral municipalities were required to reduce at least 70 % of the contact possibilities of the residents, and people were

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requested to refrain from going out. It should be noted that the state of emergency was not declared to strongly regulate people’s behavior but to encourage voluntary self-restraint. On May 4, 2020, the policy was updated and business entities in prefectures with relatively higher number of infected people were required to reduce 70% of commuting and to strongly promote telework (Office for COVID-19 and Other Emerging Infectious Disease Control C, 2020b). As the number of newly infected people of the day got smaller, the state of emergency declaration was lifted on May 14, 2020, excepting 7 prefectures with relatively higher number of infected people (Office for COVID-19 and Other Emerging Infectious Disease Control C, 2020c). On May 25, 2020, the state of emergency declaration was lifted in entire country, however, the requirement of 70% reduction of commuting and promotion of telework was not lifted (Office for COVID-19 and Other Emerging Infectious Disease Control C, 2020d). As the infection situation had calmed down, on July 22, 2020, the government launched “Go To Travel campaign” (Go To トラブル事務局, 2020) which encourages travels and outings by providing subsidies for travelers and business entities, in order to revive the economy hit by COVID-19 pandemic. Looking at the human mobility behavior for example in Tokyo, it had decreased by around 50% by April 15, 2020: one week after the state of emergency had declared. Human mobility metrics showed correlation with a decrease in the estimated effective reproduction of COVID-19 (Yabe et al., 2020). However, even though the number of infected people was getting larger again when Go To Travel campaign was raised (the second wave), more people were in town compared to the state of emergency (Tokyo Metropolitan Government, 2022).

The COVID-19 pandemic accelerated the introduction of teleworking and altered many workers’ lifestyles. Different from long-standing teleworkers, many workers were forced to switch suddenly to teleworking because of the declaration of a state of emergency under the COVID-19 pandemic. As commuting contributes to physical health by ensuring certain amount of PA, that sudden change might have exerted some effects on the workers’ health. Their health consciousness might have also been affected by experiencing sudden change of workstyle. Assessing how workers’ daily trips changed during the COVID-19 pandemic and how their health consciousness got affected is important now because the number of teleworkers is expected to increase at an accelerating rate. The actual PA changes associated with daily trips and the response of health consciousness to these changes have yet to be revealed. It should be clarified as more workers will experience workstyle changes eventually. Also, the findings might indicate future effects on health exerted by pandemics and workstyle changes.

This paper aims to, firstly, reveal how the workstyle change to telework affected the PA amount associated with daily trips. By grouping workers according to their workstyle change patterns, this paper tries to distinguish between pure effects of commuting behavior change and pandemic effects (e.g., declaration of a state of emergency, fear for infection). Secondly, it aims to reveal how the workstyle change relates to health consciousness of workers. The difference in health consciousness in workstyle change patterns indicates how they view the lifestyle change; therefore, it will be predictable how the future workstyle change might affect workers’ health consciousness and their trip behavior. The final goal is to illustrate who is most at the risk of physical inactivity and for whom it is important to promote physical activity, in order to prevent potential chronic physical disorders among workers. A sudden shift to telework happened over the world during the COVID-19 pandemic and it has been strongly promoted (OECD, 2021), therefore, understanding a situation in Japan will be a significant step to predict what will happen over the world.

### Literature review

Telework effects for workers have been recently examined from various perspectives. The immediate telework introduction during the COVID-19 caused self-reported less exercise and adverse physical symptoms (Niu et al., 2021), however, this study does not consider the actual PA amount change. As for the effect of teleworking on transport, it is pointed out that the frequency of trips by active transport is larger in teleworkers than in commuters (Eldér, 2020). However, the number of samples of teleworking is relatively small in this study, and it does not discuss the trip duration and associated PA level. Other telework advantages and disadvantages were reviewed (Buonmoro et al., 2021), but no studies clarified the health outcomes of commuting behavior change.

Studies of changes in commuting behavior during the COVID-19 pandemic have been conducted. Some reported decreased usage of public transport; in many countries an avoidance of public transport because of fear of infection was observed (Shibayama et al., 2021); the usage of public transport had significantly decreased under COVID-19 restriction and did not revert to the previous level even after the restriction was removed (Thomas et al., 2021); greater percentage of public transport commuters shifted to telework than car commuters (Harrington & Hadjiconstantinou, 2022). On the other hand, the COVID-19 pandemic turned out to be the momentum to the shift to active transport commuting; safety concerns about infection are associated with higher active transport usage in commuting (Cusack, 2021); to some degree commuters hope to switch to active transport for future work (Harrington & Hadjiconstantinou, 2022). The studies above have pointed out the changes in modal travels, however, the related health effects have yet to be examined.

Numbers of studies have been conducted to elucidate the PA change during the COVID-19 pandemic. During the first wave of the pandemic, nationwide/partial lockdown and stay-at-home orders were imposed in many countries; a worldwide decrease in number of daily steps was observed using smartphone-tracking data (Tison et al., 2020). Some studies pointed out the relation between PA change and socio-demographic characteristics; young people, university students, and single people tend to have decreased their PA level the most during the COVID-19 pandemic (Castañeda-Babarro et al., 2020; López-Valenciano et al., 2021; McCarthy et al., 2021; Ong et al., 2021). Previous fitness habits relate to PA change; very active men reported particularly great decrease in PA and increase in sedentary behavior (Castañeda-Babarro et al., 2020). The characteristics of living communities and the degree of social distancing in a region were also the indicator of the degree of PA change during the pandemic (Zenic et al., 2020). These studies above clarified the effects of socio-demographical characteristics and living environment on the change of total PA per day under lockdowns and stay-at-home requirements. However, they do not consider the telework effects which might have had big impact on workers’ lifestyles, nor they consider what activity the candidates gain the PA amounts from. Further study is needed to detect the workstyle change effect on PA.

Changes in physical heath and particularly its negative association with mental health is also reported; increased sedentary time is associated with poorer mental health and subjective vitality (Cheval et al., 2021); poorer health behaviors including physical inactivity were associated with poorer mental health (Ingram et al., 2020); changes in PA, sleep quality, smoking, and alcohol consumption were associated with higher level of depression, anxiety, and stress symptoms (Stanton et al., 2020). But the COVID-19 pandemic has brought some positive effect on physical health too; some people improved their physical health by walking and moderate PA in leisure time during the lockdown (Cheval et al., 2021; Malaglanti et al., 2021). The association between PA change and mental health is revealed by these studies above, however, the future health concern has yet to be revealed.

Nevertheless, no study in the relevant literature has described a relation between changes in PA and commuting behavior during the COVID-19 pandemic. Moreover, there is no study revealing a relation between changes in commuting behavior and awareness of PA and health. In this study we anticipate distinguishing pure telework effects and lockdown effects on the PA level, by considering workstyle and trip purpose, using trip data of three time points under the COVID-19 pandemic.
pandemic in Japan. Because the number of teleworkers is expected to increase, an urgent need exists to clarify the amount of PA related to commuting and related attitudes, and to indicate measures that policymakers should consider as working styles change.

**Data and methods**

**Study design and analyses**

This study is aimed at elucidating changes in the amount of PA associated with commuting and health consciousness of workers. Therefore, worker respondents were divided into groups according to workstyle change patterns during the COVID-19 pandemic. Metabolic equivalent (MET) was used to assess the amount of PA related to daily trips. One MET represents the amount of oxygen consumed while sitting at rest. Therefore, the MET concept is used widely for expressing the energy cost of PA as a multiple of the resting metabolic rate (Jette et al., 1990). The evaluation index is the product of a MET value and time: METs \( \times \) h. We connected the MET value of a trip by each mode of transport to the relevant activity time survey data and calculated the amount of PA associated with daily trips.

The workstyle change effect was assessed from 2 perspectives: total daily trips and pure effect of commuting trips. To assess the PA change in total daily trips, the mean amount of PA by each mode of transport was shown in Fig. 1. Modes of transport were grouped into three: public transport to the relevant activity time survey data and calculated the amount of PA associated with daily trips.

To clarify the pure effect of workstyle change, daily trips were classified into three types: one type of commuting trip and two types of non-commuting trip, according to the purpose of the trip. Firstly, activities and locations were divided into three: (a) at home, (b) work outside, and (c) other activities outside. Then, the trip purposes were classified as shown in Fig. 1. Modes of transport were grouped into three: public transport, private transport (car, motorcycle, and other), and active transport (bicycle and walk). The amounts of PA were compared among workstyle change patterns and socio-demographical variables.

We also analyzed how workers regard health effects of physical inactivity because of daily trip reduction, using response data to one question from the attitude survey in CLAS (Ministry of Land, Infrastructure, Transport and Tourism, 2020). The answers were tabulated and compared among workstyle change patterns. A residual analysis was applied to find significant difference.

**Data source and sample**

For this study, we used activity time survey data, attitude survey data, and attribute information from the “COVID-19 Lifestyle Activity Survey” (CLAS) conducted by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) during August 3–25, 2020. This survey was performed online to approximately 3,000 participants from the Tokyo metropolitan area and 9,000 participants from other cities in Japan with populations greater than 300,000, yielding data from 12,872 respondents.

In the activity time survey, respondents reported “where they were” and “what activity they did”, or “what mode of transport they used” every 15 min for three time points: weekdays before the COVID-19 pandemic (Before), weekdays during the first declared state of emergency of April 16 – May 13 (During), and on Thursday, July 30, 2020 (After) (Appendix A presents the response options). For Before and After time points, average weekday behavior was asked. If a respondent traveled for even a moment during 15 min, then the respondent reported the mode of transport used for the trip. If the respondent used multiple modes of transport, then the main means was reported. The order of priority of the main means of transportation was railway, bus, car, motorcycle, bicycle, and walking.

The number of infected people per day was higher for “After” than “During”. However, smartphone tracking data showed that more people were in town After than During (Tokyo, 2020). At After, the state of emergency ceased. The “Go To Travel campaign” to encourage travels and outings was put into practice by the government (Go To, 2020). Inferring that the number of people staying in town remained at the same level thereafter, people’s behavior at After resembles the behavior continuing afterwards. Because consistent fear of infection might persist for some time and because other pandemics might happen at any time, analyzing the first effects of workstyle and health consciousness is necessary.

To analyze changes in PA associated with changes in daily trips during the COVID-19 pandemic, a sub-sample of 4,484 respondents of second and tertiary industry workers who worked for more than 4 hr at all three time points (Before/During/After) was specifically examined. In addition, some responses were excluded: they included logically incorrect or unusual answers, such as performing the same activity for more than 22 hr, or traveling for more than 10 hr, or included no travel for some activities taking place outside of the home.

Workstyle change patterns

Workstyles changed for many workers during the COVID-19 pandemic. Some workers shifted their main work location from their office to home in the During period. Some returned to working at their offices. Some continued working from home in the After period. Based on the results of the activity time survey, we defined “Teleworkers” as those workers doing a “work” activity taking place “at home” for more than 4 hr at each time point. Workers working completely at the office or working at home < 4 hr per day (mainly working at the office) are defined as “Commuters.” Respondents were therefore divided into groups according to the workstyle at each time point (Before/During/After): C/C/C continued commuting during the COVID-19 pandemic; C/T/C teleworked only in the During period; C/T/T started teleworking in the During period and did not revert to commuting; and T/T/T were teleworking before the COVID-19 pandemic. Their respective characteristics are presented in Table 1.

Calculating the amount of PA

The intensity of activity associated with daily trips differs according to the mode of transport used for the trip. Therefore, an appropriate MET value must be applied for each trip to assess the amount of PA. The MET values of activities including transportation have been measured, published, and updated (Ainsworth et al., 2011) but they are inappropriate for direct application for trip time data for some reasons. Firstly, they do not consider if the public transport riders are standing or sitting. Since conditions of congestion in public transport in Japan vary by time of day (Ministry of Land, 2018), the body postures of the riders should be
considered. Secondly, “riding in a bus or train” and “riding in a car or truck” are regarded as having equal intensity even though several studies have revealed that the amounts of PA for trips by public transport are higher and contribute more to health than for trips by car (Batista Ferrer et al., 2018; Liao et al., 2016; Shaw et al., 2017). Thirdly, the trip data from CLAS provides only a main means of transport in each 15 min period and does not always include last-mile trips in it, which means a 15-min trip with 10-min bus ride and 5-min walk is provided as a 15-min bus trip. Therefore, the MET value considering last-mile trips should be applied. At the end, driving a car and riding in a car are both regarded as “trip by car” in CLAS, even though the energy costs of PA differ between driving and riding (Ainsworth et al., 2011).

To address the traffic conditions prevailing in Japan and to apply adequate MET value for the CLAS trip data, we first re-calculated the MET value by reference to a previous Japanese study (Oba et al., 2013). National Person Trip Survey in Japan (NPTS) (Ministry of Land, Infrastructure, Transport and Tourism, 2015) conducted by MLIT in 2015 and the original MET value unit reported by Ainsworth et al., 2011 (presented in Table 2) were used for re-calculation. NPTS collected detailed trip data of weekdays from 47,300 households in the same cities as presented in Table 2) were used for re-calculation. NPTS collected detailed trip data of weekdays from 47,300 households in the same cities as surveyed by the CLAS. Units of MET values for this study (METm) were calculated from NPTS trip data through the process described below.

\[
PA_j = \sum_m MET_m \times \text{hour}_m
\]

\[
\text{if } = \text{public transport} = \begin{cases} 9:00 < \text{ST} < 17:00, \text{then } MET_m = \frac{MET_{pub, std}}{2} + \frac{MET_{pub, stand}}{2} \\ \text{other, then } MET_m = MET_{pub, stand} \end{cases}
\]

\[
MET_m = \text{average of } MET \text{ whose main mode of transport is } m
\]

Herein, \(PA_j\) represents the amount of PA [METs × h] of trip \(j\). \(MET_m\) denotes the original unit of MET value [METs] presented in Table 2, \(\text{hour}_m\) stands for the time [h] spent on transportation mode \(m\) in trip \(j\), and MET expresses the MET intensity per hour of trip \(j\). In considering the congestion conditions on public transport in Japan, \(MET_m\) for public transport is defined according to the starting time (ST) of the trip (Oba et al., 2013). \(MET_m\) is the unit of MET value for this study: the average of MET in each main mode of transport \(m\). Table 3 presents the calculated unit of MET value for each main mode of transportation in this study.

### Table 1
Sample characteristics by workstyle change patterns.

| Status of workstyle change | C/C/C | C/T/C | C/T/T | T/T/T |
|---------------------------|-------|-------|-------|-------|
| Overall                   | 2,859 | (63.8%) | 585 | (13.0%) | 426 | (9.5%) | 614 | (13.7%) | 4,484 |
| Gender                    |       |       |       |       |       |       |       |       |       |
| Man                       | 1,950 | (63.0%) | 409 | (13.2%) | 294 | (9.5%) | 442 | (14.3%) | 3,095 |
| Women                     | 909   | (65.4%) | 176 | (12.7%) | 132 | (9.5%) | 172 | (12.4%) | 1,389 |
| Age (yr)                  |       |       |       |       |       |       |       |       |       |
| 18–39                     | 830   | (60.9%) | 220 | (16.1%) | 125 | (9.9%) | 178 | (12.1%) | 1,363 |
| 40–59                      | 1,510 | (65.6%) | 270 | (11.7%) | 215 | (9.3%) | 306 | (13.3%) | 2,301 |
| 60–                      | 519   | (63.3%) | 95 | (11.6%) | 76 | (9.3%) | 130 | (15.9%) | 820 |
| Occupation                |       |       |       |       |       |       |       |       |       |
| Management                | 435   | (60.6%) | 115 | (16.0%) | 80 | (11.1%) | 88 | (12.3%) | 718 |
| Technical                 | 655   | (57.1%) | 174 | (15.2%) | 135 | (11.8%) | 184 | (16.0%) | 1,148 |
| Clerical                  | 771   | (62.9%) | 201 | (16.4%) | 139 | (11.3%) | 114 | (9.3%) | 1,225 |
| Sales                     | 153   | (74.3%) | 18 | (8.7%) | 13 | (6.3%) | 22 | (10.7%) | 206 |
| Service                   | 248   | (71.9%) | 18 | (5.2%) | 14 | (4.1%) | 65 | (18.8%) | 345 |
| Security                  | 30    | (93.8%) | 2 | (6.3%) | 0 | (0%) | 0 | (0%) | 32 |
| Production process        | 139   | (93.3%) | 2 | (1.3%) | 3 | (2.0%) | 5 | (2.4%) | 149 |
| Transportation/Machine    | 36    | (87.8%) | 2 | (4.9%) | 1 | (2.4%) | 2 | (4.9%) | 41 |
| Construction/Minining     | 54    | (77.1%) | 6 | (8.6%) | 2 | (2.9%) | 8 | (11.4%) | 70 |
| Carring/Cleaning/Packing  | 50    | (92.6%) | 2 | (3.7%) | 0 | (0%) | 2 | (3.7%) | 54 |
| Others                    | 288   | (58.1%) | 45 | (9.1%) | 39 | (7.9%) | 124 | (25.0%) | 496 |

### Table 2
Original unit of MET value used to calculate the unit of MET value in this study.

| Mode of transport | Conditions | 2011 Compendium of Physical Activities (Ainsworth et al., 2011) | METm | CODE | Major heading | Specific activities |
|-------------------|------------|---------------------------------------------------------------|------|------|---------------|---------------------|
| Public transport  | Sitting     | 1.3                                                           | 16,016 | 1 | transportation | riding in a bus or train |
| Car               | Standing    | 2.5                                                           | 09,071 | 2 | miscellaneous | standing, miscellaneous |
|                   | Driving     | 2.5                                                           | 16,010 | 3 | transportation | riding in a car or truck |
| Motorcycle        |             | 3.5                                                           | 16,030 | 4 | transportation | automobile or light truck (not a semi) |
| Bicycle           |             | 5.8                                                           | 01,019 | 5 | bicycling     | bicycling, leisure, 9.4 mph |
| Walking           | Age < 60 yr | 3.5                                                           | 17,190 | 6 | walking       | 2.8 mph, 3.2 mph, level, moderate pace, firm surface |
|                   | Age ≥ 60 yr | 3.0                                                           | 17,170 | 8 | walking       | 2.8 mph, level, moderate pace, firm surface |
| Other (Taxi, etc.)|             | 1.3                                                           | 16,015 | 9 | transportation | riding in a car or truck |

### Table 3
Calculated units of MET value for main modes of transport in this study.

| Mode of transport | METm value [METs] | Age < 60 yr | Age ≥60 yr |
|------------------|------------------|-------------|------------|
| Public transport | 2.69             | 2.44        |            |
| Car              | 2.38             | 2.22        |            |
| Motorcycle       | 3.50             | 3.50        |            |
| Bicycle          | 5.78             | 5.77        |            |
| Walking          | 3.50             | 3.00        |            |
| Other            | 1.30             | 1.30        |            |

Then using the unit of MET value \(MET_m\), we calculated the amount of PA associated with daily trips for each COVID-19 pandemic time point connected to CLAS. It is calculated as shown below.
Herein, \( PA_i \) represents the amount of PA [METs × h] of individual \( i \) at time point \( t \). Also, \( hour_{mt} \) stands for the time [h] individual \( i \) spent on transportation mode \( m \) at time point \( t \). Fig. 2 presents the distribution of the calculated \( PA_i \).

**Health consciousness**

Daily trip reduction might engender chronic physical inactivity. The level of anxiety associated with this phenomenon might change people’s behavior related to daily trips and exercises. To analyze how workstyle changes through the COVID-19 pandemic are related to health consciousness, we specifically examined a question from the attitude survey data in CLAS: “Do you think that physical inactivity because of reduced daily trips will be a disadvantage attributable to shifting of activity locations online?” The response options were “Does not apply to my life”, “Strongly disagree”, “Disagree”, “Neither agree nor disagree”, “Agree”, and “Strongly agree.” We tabulated the answers according to respondents’ workstyle change patterns. Since the respondents’ current workstyle or telework experience are not asked, they answer to it according to their future prediction. Therefore, distribution of the answers excepting “Does not apply to my life” in each group presents the level of concern about the health effects caused by loss of daily trips. A residual analysis was performed to find significant difference of the concern in workstyle change patterns.

**Results**

**Amount of PA**

The mean amount of PA for each mode of transport is shown in Fig. 3, as grouped by workstyle change patterns for the three time points: Before, During, and After. Fig. 4 presents the mean amount of PA for each trip purpose and mode of transport, by workstyle change patterns. Figs. 5 and 6 introduce the further subdivision of the data presented by Fig. 4 by gender and age groups. Results of Tukey’s Multiple Comparison are presented in Table 4. The modes “motorcycle” and “other” were excluded from the table because no significant difference was found for them.

Fig. 3 shows that commuters have much more PA associated with daily trips than teleworkers do, irrespective of the time point. Commuting behavior is a driving factor of the amount of PA associated with daily trips for workers. However, the transportation mode used for commuting and the total amount of PA differ among workstyle change pattern groups: C/C/C workers use cars more, on average, than commuters of other groups; moreover, they reported less PA. Originally, the C/T/T workers, for whom the COVID-19 pandemic was a trigger to the shift to telework, were walking and using public transport. They had the highest rate of PA at the Before time point, probably because teleworking was strongly encouraged in cities where public transport networks are well-developed, in contrast to rural areas. Among teleworkers, C/T/T workers walk more and reported higher amounts of PA than T/T/T workers at the After time point.

Fig. 4 shows the transport mode and the PA amount change for each trip purpose. From the time point Before to After, C/C/C and C/T/C workers showed a slight increase in use of active transport in p-type1 and p-type2, which contributed to an increase of the PA amount from total daily trip. C/T/T workers showed a considerable increase in use of active transport for non-commuting trips throughout the pandemic, however, considering total daily trips, the PA amount for active transport is relatively lower than Before. Telework might increase the frequency of using active transport as a previous study (Ellidjer, 2020) pointed out, however, it leads to less amount of PA considering the total daily trips.

Fig. 5 shows the difference between genders. C/C/C and C/T/C workers of both men and women groups showed increase in PA amount in non-commuting trips. For C/T/T workers, women had significantly small amount of PA for any trip purpose at During and After, which means sudden change to telework and probably the fact that the fear of infection is more likely to affect women’s travel behavior rather than the men’s one.

In an exploratory variable selection about age groups, significant difference was found between 18 and 29 yr, 30–39 yr, 49–50 yr, and 60–yr. Fig. 6 shows the result. A common trend among all the age groups is that C/C/C and C/T/C workers increased the use of active transport in non-commuting trip from the time point Before to After. Focusing on the age of 18–29, it is notable that C/T/T workers had almost no PA associated with daily trips at During and After, which means newcomers to telework had lost their opportunity of outing and of gaining certain amount of PA from daily trips. It is the only generation/workstyle change pattern that reduced PA amount in non-commuting trips throughout the COVID-19 pandemic. On the other hand, T/T/T workers in this age group kept increasing their PA with active transport even at

**Fig. 2.** Histogram of the calculated \( PA_i \) from all respondent data.
Fig. 3. Mean amounts of PA by each transport mode, by workstyle change pattern.

Fig. 4. Mean amounts of PA for each trip purpose and mode of transport, by workstyle change pattern.

Fig. 5. Mean amounts of PA for each trip purpose and mode of transport, by workstyle change pattern and gender.
During while other age groups showed reduction. Also, this generation uses more public transport for non-commuting trips than other age groups. Focusing on the age of 30–39 yr, T/T/T workers have less amount of PA in total and in active transport than other age groups at any time point. On the other hand, C/T/T workers increased their PA amount by more use of active transport. C/T/T workers of 60-yr initially had the highest amount of PA because of the greatest use of public transport.

Table 4 shows that workstyle changes throughout the COVID-19 pandemic strongly influenced the amount of PA associated with daily trips of workers. C/T/C and C/T/T workers reported significantly reduced PA in almost all modes of transport for the During time period. At After, C/T/C workers reported reversion of the total amount of PA to the same PA level as Before. The C/T/T workers’ PA did not return to the earlier level, but showed a slight increase for each mode of transport from During and 0.677 METs × h in total, indicating that they consciously increased daily trips. The T/T/T workers reported a slight increase in car use at After.
Health consciousness

The aggregate result of the responses to the question and the result of residual analysis is shown in Fig. 7 as a 100% stacked bar graph, excepting "Does not apply to my life" answers. The percentage of "Does not apply to my life" answers in each workstyle change pattern was: 14.8% in C/C/C, 2.0% in C/T/C, 3.0% in C/T/T, and 10.4% in T/T/T. Those who did not experience workstyle change during the COVID-19 pandemic had relatively higher rate of uninterest. The result of residual analysis indicates the significant difference in the workers’ health consciousness among workstyle change patterns during the COVID-19 pandemic. Particularly, approximately 80% of C/T/T workers agreed that physical inactivity caused by daily trip reduction was a bad consequence of the activity location shift to online activities. Also, C/T/C workers followed that pattern. Perhaps a sudden workstyle change to teleworking became a trigger for awareness of the importance of daily trips as a means of gaining a certain amount of PA every day. On the other hand, T/T/T workers, those teleworking for relatively longer period, paid less attention to the effects of daily trip reduction on physical inactivity. It indicates that prolonged telework period may result in workers’ less consciousness about their health. C/C/C workers, those who did not experience telework during the pandemic, also showed less interest/paid less attention. It may lead to ill-preparedness that results in sudden and significant reduction of the amount of PA. Analyses considering socio-demographic groups were performed, but no significant differences were found among the groups.

Discussion

The analysis described in chapter 4 clarified that workstyle changes necessitated by the COVID-19 pandemic exerted a strong influence on the amount of PA associated with daily trips and health consciousness. The PA amount in non-commuting trips by active transport increased for teleworkers, however, the PA amount in total daily trips is significantly greater for commuters and significantly less for teleworkers, irrespective of the time points. This finding indicates that teleworkers still need some extra PA in replacement of that which primarily was ensured by commuting trips, even though the frequency and the PA amount in non-commuting trips increased.

Considering socio-demographics, especially the PA amount of the young adults of 18–29 yr was significantly reduced because of workstyle change to telework. Notably, C/T/T workers of 18–29 yr and T/T/T workers of 30–39 yr had relatively small amount of PA for any purpose or by any mode of transport. It suggests that if C/T/T workers of 18–29

Table 4
Differences of mean amounts of PA for time points, by workstyle change pattern.

| Group       | Comparison (workstyle change) | Differences of Means [METs × h] | Public | Car   | Bicycle | Walking | Total |
|-------------|--------------------------------|---------------------------------|--------|-------|---------|---------|-------|
| C/C/C (n=2,859) | Before-During (C-C) | -0.069                          | -0.004 | -0.016 | -0.006 | -0.099 | +     |
|             | Before-After (C-C)     | -0.022                          | 0.048  | 0.027  | 0.072  | 0.190  | *     |
|             | During-After (C-C)    | 0.047                           | 0.102  | 0.043  | 0.078  | 0.288  | **    |
| C/T/C (n=585)  | Before-During (C-T)   | -3.120                          | -0.658 | -0.393 | -0.860 | -5.088 | **    |
|             | Before-After (C-C)    | 0.018                           | 0.007  | 0.059  | 0.138  | 0.239  |       |
|             | During-After (T-C)    | 3.138                           | 0.665  | 0.452  | 0.998  | 5.328  | **    |
| C/T/T (n=426)  | Before-During (C-T)   | -4.479                          | -0.292 | -0.251 | -0.746 | -5.806 | **    |
|             | Before-After (C-C)    | -4.321                          | -0.161 | -0.044 | -0.544 | -5.107 | **    |
|             | During-After (T-C)    | 0.158                           | 0.131  | 0.207  | 0.201  | 0.699  | **    |
| T/T/T (n=614)  | Before-During (T-T)   | -0.064                          | -0.051 | 0.038  | -0.080 | -0.170 |       |
|             | Before-After (T-T)    | -0.004                          | 0.113  | 0.066  | -0.024 | 0.162  |       |
|             | During-After (T-T)    | 0.059                           | 0.165  | 0.028  | 0.056  | 0.332  | *     |

*p<0.05, **p<0.01.

Fig. 7. Answer to the question about health consciousness and result of residual analysis.
Appendix A. Answer options to activity time survey in CLAS.

| Category              | Answer Options                                                                                                                                 |
|-----------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| Where they were       | At home                                                                                                                                   |
|                       | Around home (within 15 min)                                                                                                               |
|                       | At office                                                                                                                                |
|                       | Around office (within 15 min)                                                                                                             |
|                       | Other                                                                                                                                     |
| What activity they did| Sleeping                                                                                                                                |
|                       | Meals alone or with family                                                                                                               |
|                       | Meals with friends and acquaintances                                                                                                    |
|                       | Work                                                                                                                                     |
|                       | Study (schoolwork)                                                                                                                        |
|                       | Shopping for groceries and necessities                                                                                                  |
|                       | Shopping for other things                                                                                                                 |
|                       | Personal care such as bathing                                                                                                            |
|                       | Household chores such as laundry and cooking                                                                                             |
|                       | Childcare                                                                                                                                |

(continued on next page)
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