# Physical Distancing Measures and Walking Activity in Middle-aged and Older Residents in Changsha, China During the COVID-19 Epidemic Period: Longitudinal Observational Study

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## *Abstract*

**Background:** Physical distancing measures taken to contain the coronavirus disease 2019 (COVID-19) transmission may substantially reduce physical activity levels and cause individuals to adopt a more sedentary lifestyle.

**Objective:** To describe change in daily steps, an important component of daily physical activity, and examine risk factors for frequent low daily steps around the COVID-19 epidemic.

**Methods:** We used data collected from the Step Study, a population-based longitudinal study of walking activity among residents aged ?40 years in Changsha, China. Daily steps were collected via smartphone linked to WeChat, a social-network platform. We plotted mean daily steps and the prevalence of low daily steps (?1,500 steps/day) 30 days before (reference period) and 30 days after (epidemic period) January 21, 2020 (date of the first COVID-19 case diagnosed in Changsha), and compared it with the same corresponding period from 2019. We examined the relation of risk factors for the prevalence of frequent low daily steps (?1,500 steps/day for ?14 days) using logistic regression.

**Results:** Among 3,544 participants (mean age: 51.6 years; females: 34.6%), mean daily steps dropped from 8,097 to 5,440 and the prevalence of low daily steps increased from 3% to 18.5%, during reference and epidemic periods, respectively. No such phenomenon was observed during the corresponding period in 2019. Older age and female sex were both associated with higher prevalence of frequent low daily steps and were more pronounced during the epidemic period (P for interaction<.01). More education was associated with a lower prevalence of frequent low daily steps during the reference period but not the epidemic period (P for interaction=.34). Body mass index or comorbidity was not associated with frequent low daily steps during either period.

**Conclusions:** Daily steps of residents aged ?40 years during the COVID-19 period in Changsha dropped significantly, especially among the old adults and females. While successful physical distancing, measured by the rapid downward trend in daily step counts of residents, played a critical role in the containment of COVID-19 epidemic, our findings of an increase in prevalence of frequent low daily steps raise concerns about unintended effects on physical activity.

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# Original Manuscript

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**Running title**: Physical distancing measures and walking activity

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**Abstract**

**Background:** Physical distancing measures taken to contain the coronavirus disease 2019 (COVID-19) transmission may substantially reduce physical activity levels and cause individuals to adopt a more sedentary lifestyle.

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**Results:** Among 3,544 participants (mean age: 51.6 years; females: 34.6% [1,226/3,544]), mean daily steps dropped from 8,097 to 5,440 and the prevalence of low daily steps increased from 3% (2,287/76,136 person-day) to 18.5% (12,951/70,183 person-day), during reference and epidemic periods, respectively. No such phenomenon was observed during the corresponding period in 2019. Older age (*P* for interaction=.001) and female sex (*P* for interaction<.001) were both associated with higher prevalence of frequent low daily steps and were more pronounced during the epidemic period. More education was associated with a lower prevalence of frequent low daily steps during the reference period but not the epidemic period (*P* for interaction=.34). Body mass index or comorbidity was not associated with frequent low daily steps during either period.

**Conclusions:** Daily steps of residents aged ≥40 years during the COVID-19 period in Changsha dropped significantly, especially among the old adults and females. While successful physical distancing, measured by the rapid downward trend in daily step counts of residents, played a critical role in the containment of COVID-19 epidemic, our findings of an increase in prevalence of frequent low daily steps raise concerns about unintended effects on physical activity.

**Key words**: COVID-19; pandemic; physical distancing; steps; walking activity

## Introduction

Coronavirus disease 2019 (COVID-19) has caused tremendous morbidity and mortality worldwide [1]. To control this highly contagious infectious disease, many countries have implemented “physical distancing” and “shelter in place” to contain COVID-19 transmission [2,3]. However, such measures may substantially reduce physical activity levels and cause individuals to adopt a more sedentary lifestyle [4].

There is ample evidence that regular physical activity is crucial for health, with physical inactivity characterized as the fourth leading cause of global mortality [5]. Results from the National Health and Nutrition Examination Survey (NHANES) and the Women’s Health Study both showed that a lower number of daily steps, which is an important component of daily physical activity, was significantly associated with higher all-cause mortality [6,7]. Studies also demonstrated that individuals who walked less than 1,500 daily steps for 14 days were at a higher risk of muscle mass loss and low insulin sensitivity [8,9]. To date several studies have reported changes in daily steps of residents in areas affected by COVID-19 [10-14]; however, none of these studies specifically described the prevalence of frequent low daily steps (≤1,500 steps/day for ≥14 days over one month) [8,9], a strong predictor for poor health outcome, and examined its risk factors.

Using data collected from the Step Study, a longitudinal study conducted among the urban residents in Changsha, China, we therefore described the trends of daily steps around the COVID-19 epidemic period in 2020 and compared them with that around the similar period one year earlier. We examined relation of several socio-demographic and anthropometric factors as well as comorbidity to the prevalence of frequent low daily steps.

## Methods

**Study population**

The Step Study (registration number: ChiCTR1800017977) is a population-based longitudinal study initiated in September 2018 in Changsha, China. The aims of the Step Study were to describe patterns of walking activity, factors related to walking activity, and its sequelae among the community-living population. Participants in the Step Study comprised individuals who had their annual physical checkup at the Xiangya Hospital, Central South University in Changsha, China [15,16]. To be eligible for the Step Study, participants had to meet the following criteria: 1) Changsha resident; 2) aged ≥40 years; 3) owned a personal smartphone and had a WeChat account; and 4) willing and able to give consent. Individuals with severe mental illness were ineligible. During each annual physical checkup, participants were queried about their socio-demographic and lifestyle factors, comorbidities, health-related symptoms and signs (e.g., joint pain) and ability to perform daily activities. They also received clinical examinations and laboratory tests, including physical function tests (e.g., lower limb muscle strength measurements).

For each participant, walking activity measured as daily step counts was collected through a smartphone linked to WeChat. WeChat is a multi-purpose social network platform (Tencent Inc. Shenzhen, China), with approximately 1.1 billion monthly active users in China [17]. One of its applications can extract daily step count information from the accelerometer-sensor in a smartphone. Thus, when a participant is a WeChat user and wears a smartphone, his/her step counts can be captured by WeChat's application.

This study was approved by the Ethics Committee of Xiangya Hospital, Central South University (#201806910), and written informed consent was obtained from study participants.

**Study outcome**

The outcome variable was daily step counts recorded from the accelerometer-sensor in the smartphone and extracted by WeChat. To be eligible for the current analysis of the daily step counts, we required that a participant wears his/her smartphone for ≥10 hours on that day, a standard convention for measuring daily walking [18,19]. The smartphone wear time was calculated as the difference between the times of the first recorded step counts and the last recorded step count each day. This algorithm has been used in the Activity Inequality Project to calculate daily step counts from more than 700,000 individuals across 111 countries [19]. Participants with no valid daily step count were excluded in the current analysis. We defined a low daily step count as ≤1,500 steps/day [8,9]. If a participant had ≥14 days of low daily step counts over a 30-day period we consider that person as having experienced frequent low daily steps [8,9].

We conducted two validation studies to assess the accuracy of daily step counts collected from WeChat. To determine the accuracy of steps measured at various walking speeds from iOS and Android devices, we visually counted steps from 14 subjects walking on a treadmill at 4.8, 6.4, 8.0 and 9.6 km/h while subjects held/wore smartphones in different positions (i.e., pants pocket, hand and arm). These methods are consistent with previous studies [20-22]. We found step count accuracy to be high with intra-class correlation coefficients (ICCs) ranging from 0.64 to 0.99. Second, we assessed the accuracy of step counts extracted from WeChat in free-living conditions. Specifically, 36 participants from the Step Study were instructed to wear a Fitbit Charge 3 (Fitbit Inc. San Francisco, CA USA), as the criterion measure [23], and their personal smartphone for seven consecutive days [24]. The results also demonstrated a moderate to high agreement on step counts, with ICCs ranging from 0.67 to 0.81. Detailed information from these validation studies are shown in **Multimedia Appendix 1**.

**Study exposures**

Information on age, sex, educational level, height, weight, and comorbidity were obtained from the annual physical checkup visit. Body mass index (BMI) was calculated. The modified Charlson Comorbidity Index (CCI) was computed based on self-reported comorbidities [25].

**Statistical analyses**

On January 22, 2020, one day after the first case of COVID-19 was diagnosed in Changsha (January 21, 2020, i.e., the index day) the municipal government issued an emergency notice to implement physical distancing measures (i.e., staying at home, closing schools, working from home if possible, travelling only when necessary, and cancelling mass gatherings) [26,27]. In the current analysis we defined the time interval from January 22, 2020 to February 20, 2020 (30 days after the index date) as the COVID-19 epidemic period, and the time interval from December 22, 2019 to January 20, 2020 (30 days before the index date) as the reference period. Since the COVID-19 epidemic occurred around the holiday season of Chinese New Year, for purpose of comparison we also used data collected between January 2, 2019 and March 3, 2019, which corresponded to the same Chinese lunar calendar period. Details of the selection of study periods are shown in **Multimedia Appendix 2**.

First, we plotted the mean daily steps from December 22, 2019 to February 20, 2020 (around COVID-19 epidemic period) and mean daily steps from January 2, 2019 to March 3, 2019 (historic comparison period), respectively, using a 3-day moving average smooth method [28]. Second, we used the same approach to plot the prevalence of low daily steps (≤1,500 steps/day) for the corresponding periods. We calculated the mean difference (MD) and its 95% confidence interval (95% CI) for daily steps using Generalized Estimating Equations (GEE) between the epidemic period and reference period in year 2020, and the corresponding periods in year 2019, respectively. Specifically, we included each qualified daily step count into the GEE model using PROC

GENMOD procedure in SAS with identity links to calculate the MD and its 95% CI between the epidemic period and reference period. We added the REPEATED statement to account for correlation of the repeated measurements of individuals' daily step counts [29].

Similarly, prevalence ratios (PR) were calculated for the prevalence of low daily steps (≤1,500 steps/day) between the two comparative time periods in 2019 and 2020, respectively [30]. Finally, we estimated the prevalence of frequent low daily steps (≤1,500 steps/day for ≥14 days over 30 days) during epidemic and reference periods and examined the relation of age, sex, BMI, educational level and comorbidity to the prevalence of frequent low daily steps using logistic regression. We tested the additive effect measure of modification of physical distancing with each of the risk factors mentioned above by adding an interaction term in the regression model [31].

All *P* values were 2-sided and *P* <.05 was considered statistically significant for all tests. All statistical analyses were conducted using SAS V.9.4.

**Results**

A total of 7,262 Changsha residents aged ≥40 years had a physical checkup at the study center between September 2018 and January 2020, and 4,145 of them (57.1%) had a WeChat account and agreed to participate in the Step Study. Of these, 3,544 with at least one valid daily step count during the study period were included in the analysis (**Table 1)**. The mean age was 51.6 (standard deviation [SD]: 8.9) years, 1,226 (34.6%) participants were females, and the mean BMI was 24.0 (SD: 4.3) kg/ $m^2$. Two thousand six hundred and sixteen (73.8%) participants were Android users, 765 (21.6%) were iOS users, and 163 (4.6%) participants' phone types were unknown.

**Table 1.** Baseline characteristics of included participants.

| | Total sample (n=3,544) | Males (n=2,318) | Females (n=1,226) |
|---|---|---|---|
| **Age (years), mean (SD[a])** | 51.6 (8.9) | 51.6 (8.8) | 51.5 (9.0) |
| **Age (years), n (%)** | | | |
| 40-49 | 1,733 (48.9) | 1,117 (48.2) | 616 (50.2) |
| 50-59 | 1,190 (33.6) | 818 (35.3) | 372 (30.3) |
| 60-70 | 452 (12.7) | 271 (11.7) | 181 (14.8) |
| ≥70 | 169 (4.8) | 112 (4.8) | 57 (4.7) |
| **BMI[b] (kg/m$^2$), mean (SD)[c]** | 24.0 (4.3) | 24.8 (4.2) | 22.5 (4.3) |
| **BMI (kg/m$^2$), n (%)[d]** | | | |
| <25 | 1,908 (59.6) | 1,043 (49.2) | 865 (80.0) |
| ≥25 | 1,294 (40.4) | 1,075 (50.8) | 219 (20.0) |
| **Education, n (%)[d]** | | | |
| High school or below | 564 (22.1) | 328 (19.7) | 236 (26.5) |
| Junior college | 621 (24.3) | 372 (22.4) | 249 (27.9) |
| University or above | 1,369 (53.6) | 962 (57.9) | 407 (45.6) |
| **CCI[e], n (%)** | | | |
| 0 | 2,759 (77.8) | 1,789 (77.2) | 970 (79.1) |
| ≥1 | 785 (22.2) | 529 (22.8) | 256 (20.9) |

[a]SD, standard deviation.

[b]BMI, body mass index.

[c]n=3,202.

[d]n=2,554.

[e]CCI, Charlson Comorbidity Index.

As shown in **Figure 1** and **Table 2**, daily steps (mean: 8,097 steps/day, range: 6,942 to 9,153 steps/day) during the reference period (30 days prior to COVID-19 epidemic in 2020) were similar to that during the corresponding period in 2019 (mean: 7,872 steps/day, range: 6,649 to 8,912 steps/day). However, the daily steps decreased substantially after implementing physical distancing measures from 8,624 steps/day on the day before the index day to 4,121 steps/day on Day 4 after the index day, and this trend remained during the rest of the epidemic period. Compared with the reference period, the mean daily steps dropped by 2,678 steps (95% CI: 2,582 to 2,763). This trend, however, was not observed during the corresponding period in 2019.

**Figure 2** and **Table 2** present the prevalence of low daily steps (≤1,500 steps/day) in 2019 and 2020. The prevalence of low daily steps was similar during the reference period in 2020 (3.0%, 2,287/76,136 person-day) and the corresponding period in 2019 (3.3%, 1,006/30,647 person-day). In contrast, the prevalence of low daily steps increased substantially after implementing physical distancing measures from 2.0% (53/2,693) on the day prior to the index date to 25.5% (639/2,505) on Day 4 after the index date, and such a trend continued during the rest of the follow-up period. Compared with the reference period the PR of low daily steps was 6.2 (95% CI: 5.8 to 6.7). No such trend, however, was observed during the entire historic comparison period in 2019.

**Table 2.** Associations of time period with daily step count and prevalence of low daily steps (≤1,500 steps/day).

| | Year 2019 | | Year 2020 | |
|---|---|---|---|---|
| **Daily step count** | **Mean (SD[a])** | **MD[b] (95% CI[c])[e]** | **Mean (SD)** | **MD (95% CI)[e]** |
| Reference period | 7,872 (4,842) | 0 (reference) | 8,097 (4,793) | 0 (reference) |
| Epidemic period | 7,472 (4,979) | -413 (-501, -325) | 5,440 (4,571) | -2,672 (-2,763, -2,582) |
| **Low daily steps** | **Person-day (%)** | **PR[d] (95% CI)[e]** | **Person-day (%)** | **PR (95% CI)[e]** |
| Reference period | 1,006 (3.3) | 1.0 (reference) | 2,287 (3.0) | 1.0 (reference) |
| Epidemic period | 1,488 (5.1) | 1.6 (1.4, 1.7) | 12,951 (18.5) | 6.2 (5.8, 6.7) |

[a]SD, standard deviation.

[b]MD, mean difference.

[c]CI, confidence interval.

[d]PR, prevalence ratio.

[e]MDs and PRs were adjusted for age and sex.

As shown in **Table 3**, only 12 (0.4%) of 2,879 participants had walked less than ≤1,500 steps/day for 14 days or more (frequent low daily steps) during the 2020 reference period; however, the prevalence of frequent low daily steps increased to 7.4% (196/2,655) during COVID-19 epidemic period after physical distancing measures were implemented. Older age (*P* for interaction=.001) and female sex (*P* for interaction<.001) were both associated with higher prevalence of frequent low daily steps than their counterparts during the reference and COVID-19 epidemic periods, and such associations were more pronounced during the epidemic period. Participants with university education or more had a lower prevalence of frequent low daily steps than those with only high school or less education during the reference period but this was not observed during the COVID-19 epidemic period. No significant interaction between physical distancing implementation and education on prevalence of frequent low daily steps was observed (*P* for interaction=.34). There was no apparent association of either BMI or CCI with prevalence of frequent low daily steps during either period.

**Table 3.** Association of prevalence of frequent low daily steps (≤1,500 steps/day for ≥14 days) and basic characteristics**.**

| | Reference period | | | Epidemic period | | | P for interaction |
|---|---|---|---|---|---|---|---|
| | Number | Case (%) | PR[a] (95% CI[b])[e] | Number | Case (%) | PR (95% CI)[e] | |
| **Total** | 2,879 | 12 (0.4) | - | 2,655 | 196 (7.4) | - | |
| **Age** | | | | | | | .001 |
| 40-49 | 1,543 | 1 (0.1) | 1.0 (reference) | 1,470 | 84 (5.7) | 1.0 (reference) | |
| 50-59 | 957 | 8 (0.8) | 9.9 (1.2, 80.0) | 871 | 69 (7.9) | 1.7 (1.2, 2.3) | |
| 60-70 | 308 | 2 (0.7) | 9.2 (0.8, 102.6) | 257 | 32 (12.5) | 2.2 (1.5, 3.4) | |
| ≥70 | 71 | 1 (1.4) | 21.0 (1.3, 331.8) | 57 | 11 (19.3) | 3.0 (1.6, 5.7) | |
| **Sex** | | | | | | | <.001 |
| Males | 1,904 | 7 (0.4) | 1.0 (reference) | 1,793 | 75 (4.2) | 1.0 (reference) | |
| Females | 975 | 5 (0.5) | 2.2 (0.6, 7.9) | 862 | 121 (14.0) | 3.4 (2.5, 4.6) | |
| **BMI[c]** | | | | | | | .250 |
| <25 | 1,557 | 7 (0.5) | 1.0 (reference) | 1,415 | 109 (7.7) | 1.0 (reference) | |
| ≥25 | 1,006 | 3 (0.3) | 0.8 (0.2, 3.2) | 269 | 61 (6.2) | 1.2 (0.9, 1.7) | |
| **Education** | | | | | | | .335 |
| High school or below | 441 | 6 (1.4) | 1.0 (reference) | 389 | 45 (11.6) | 1.0 (reference) | |
| Junior college | 522 | 2 (0.4) | 0.3 (0.1, 1.7) | 460 | 31 (6.7) | 0.7 (0.4, 1.0) | |
| University or above | 1,228 | 2 (0.2) | 0.2 (0.0, 1.1) | 1,134 | 90 (7.9) | 1.0 (0.7, 1.4) | |
| **CCI[d]** | | | | | | | .345 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 2,294 | 9 (0.4) | 1.0 (reference) | 2,115 | 150 (7.1) | 1.0 (reference) |
| ≥1 | 585 | 3 (0.5) | 0.9 (0.2, 3.8) | 540 | 46 (8.5) | 1.1 (0.7, 1.5) |

[a]PR, prevalence ratio.

[b]CI, confidence interval.

[c]BMI, body mass index.

[d]CCI, Charlson Comorbidity Index.

[e]PRs were adjusted for age and sex.

## Discussion

Using objective data collected from the longitudinal Step Study we found that daily steps among middle-aged and older residents in Changsha dropped rapidly and substantially (on average 2,672 fewer daily steps) after implementing physical distancing measures during the COVID-19 epidemic period. In addition, more than 7% (196/2,655) of residents had walked ≤1,500 steps/day for ≥14 days over the one-month period compared with 0.4% (12/2,879) of residents in the month prior to the epidemic. The reduction of steps/day during the COVID-19 epidemic was more pronounced among older adults and females.

## Comparison with previous studies

To date, several studies have reported changes in daily steps during the COVID-19 epidemic [10-14]. One worldwide study based on a smartphone app (Argus) showed that mean daily steps in different regions decreased by 5.5% and 27.3% (287 and 1,432 steps/day) within 10 and 30 days after declaration of COVID-19 pandemic [10]. Another study that used a wristwatch with an embedded accelerometer (Withings) demonstrated a marked decrease in daily steps (from 25% to 54%) in countries adopting a total lockdown following the official dates of home confinement [11]. Similar findings were also reported in other countries [12-14]. Our results concurred and demonstrated that such a change also occurred in the Chinese population. Furthermore, we examined daily steps within the same period in the previous year and observed that no such change during this period, minimizing potential impact of the holiday season of Chinese New Year on daily steps.

In addition, we found that the effect of implementation of physical distancing measures on frequent low daily steps was more pronounced among older adults and females. Previous studies have examined relations of socio-demographic and anthropometric factors as well as comorbidity to walking activities. The results from the NHANES reported that advancing age (odds ratio=1.95, per 16.7 years increments) and female sex (odds ratio=1.86) both had higher odds of walking less than 5,000 steps/day [32]. Another study showed that more years of education was associated with increased walking activity; with one additional year of education associated with a 560 daily steps increase [33]. Our results corroborate these findings. However, after implementation of physical distancing measures, prevalence of frequent low daily steps among residents with university or above education was similar to those with high school or below education, suggesting both groups followed physical distancing measures and reduced their outdoor walking activities. Nevertheless, the magnitude of relative increase in the prevalence of frequent low daily steps during COVID-19 epidemic appeared to be greater among residents with university or above education than those with high school or below education, indicating the former is more likely to follow instructions and communicate effectively with health providers [33,34]. Previous studies also showed that both BMI and comorbidities (e.g., hypertension and diabetes) were associated with less daily steps [6,7,35,36], but this was not the case in the present study nor was any association modified by implementation of physical distancing measures.

**Public health implications**

Physical distancing measures play a critical role in containing COVID-19 transmission and monitoring population mobility data can provide evidence of whether people are complying with these measures [37]; however, the impact of physical distancing on other aspects of daily life should not be overlooked. Recently, Hall and colleagues [4] commented that “The world is experiencing an extraordinary, life-altering challenge due to the COVID-19 pandemic. Many countries have become accustomed to a new normal – ‘social distancing’ and ‘shelter in place’ are now a part of everyday vernacular and life”. The authors warned that this health crisis has the potential to further impact and accelerate the physical inactivity and sedentary behavior pandemic.

Our data showed that average daily steps among the residents in Changsha dropped by more than 30 percent (from 8,097 to 5,440) during the COVID-19 epidemic period after implementation of physical distancing measures. These data raise concerns about the potential adverse effect of such measures on health and well-being. Previous studies have showed that higher daily steps are associated with better cardiometabolic profiles and lower all-cause mortality [6,7,38]. Other studies have also found that a decrease in daily steps of 2,000 steps, irrespective of previous habitual step counts, increases the risk of insulin sensitivity and higher cardiovascular events [39,40]. Thus, our findings have important implications for public health recommendations and the prevention of other health crises during the COVID-19 pandemic. Furthermore, our data showed that the reduction in daily steps is much more common among older adults and females. In general, older adults and females are more likely to develop sedentary behaviors, placing them at greater risk of various diseases related to inactivity [32,41]; thus, the worsening trend of physical inactivity during COVID-19 epidemic period compounds the risk of sequelae related to a sedentary lifestyle.

It is uncertain as to how long it will take to completely control the COVID-19 pandemic worldwide. If similar trend toward a sedentary lifestyle is seen in other countries, the avoidance of further sedentary lifestyle behaviors and promotion of regular physical activity during this time are an urgent global public health issue. It is also unknown whether the observed decline in daily walking is a temporary phenomenon that may revert back to baseline levels after the disease is under the control; thus, further longitudinal studies are needed so that evidence-based strategies can be developed and implemented to encourage greater participation in regular physical activity.

**Strengths and limitations**

Several strengths of our study are noteworthy. First, we utilized data from a large population-based longitudinal study (Step Study), which allowed not only investigation of COVID-19 related changes in daily step counts in over 3,500 residents, but also inclusion of a historic comparison period from the prior year to account for secular trend in daily step counts. Second, the study took advantage of a social network platform (WeChat) via a smartphone to capture daily step count data in real-time among the community-living population. As a smartphone has become a daily necessity for most adults, this approach allowed long-term monitoring of daily step count trends. This contrasts to previous studies using wearable devises (accelerometers) that generally only collect step count data for a relatively short period, such as one week or less [42]. It can be challenging to extrapolate such short-term data to describe step count patterns over a long period owing to various potential confounders [42].

Potential limitations of our study also deserve comment. First, the WeChat app may underestimate daily step counts because some individuals may not always carry their smartphone with them [43], especially when the participants were housebound. Thus, some light walking activities at home may not be captured. However, one previous study reported that the average wear-time of smartphones among Chinese was more than 13 hours during day time, indicating that most walking activities should be captured by a smartphone [19]. Second, although our validation study demonstrated that daily step counts collected from iOS and Android devices both showed close agreement with actual step counts under controlled laboratory settings, previous studies found that iOS and Android devices have different accuracies in capturing the daily step count under free-living conditions [44]. This has potential for misclassification of daily step counts in the present study. Third, participants in our study were slightly younger (51.6 vs. 54.8 years) and more likely to be male (65.4% vs. 51.2%) than those who aged ≥40 years and lived in Changsha according to the latest census data in 2010. However, our results showed that prevalence of frequent low daily steps increased more among women and older people, suggesting that the overall prevalence of frequent low steps among all residents in Changsha aged ≥40 years may be even higher than what was reported in our study. Fourth, participants in our study were recruited from the urban residents in Changsha who came to Xiangya hospital for their annual health checkup. The percentage of WeChat users among these individuals (57.1%) was higher than that of the population with the same age range in China (41.5%) [45]. Thus, our findings may not generalizable to residents living in other parts of China, especially those live in the rural areas. Finally, we were unable to capture the intensity of steps, e.g., slow vs. fast steps; however, total steps/day has recently been shown to be an important predictor of mortality independent of step intensity [6].

## Conclusions

Using data collected from a large population-based longitudinal study, we demonstrated that walking activity, indicated by daily step count, decreased rapidly and substantially during the COVID-19 epidemic period among middle- to older-aged Chinese residents living in urban areas. These results suggest that appropriate strategies need to be taken to facilitate residents to actively engage in regular physical activity while maintaining personal hygiene and physical distancing. They also call for further studies to evaluate whether such low levels of walking activity after implementing physical distancing measures will be maintained and whether they will have significant adverse impact on health outcomes.

**Multimedia Appendix 1**

Validation study.

**Multimedia Appendix 2**

Diagram of the Study Periods.

**Ethics approval and consent to participate**

This study was approved by the Ethics Committee of Xiangya Hospital, Central South University (#201806910), and written informed consent was obtained from study participants.

**Consent for publication**

Not applicable.

**Availability of data and materials**

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

**Competing interests**

No conflict of interest for any of the authors.

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**Authors' contributions**

GL and CZ had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. CZ and GL are joint corresponding authors. All authors have read, provided critical feedback on intellectual content and approved the final manuscript. Concept and design: CZ, GL, YW and YZ. Acquisition, analysis, or interpretation of data: All authors. Drafting of the manuscript: YW, CZ, GL and YZ. Critical revision of the manuscript for important intellectual content: All authors. Statistical analysis: YZ and JW. Obtained funding: CZ, GL and JW. Administrative, technical, or material support: YW, CZ and GL. Supervision: GL, YZ and CZ.

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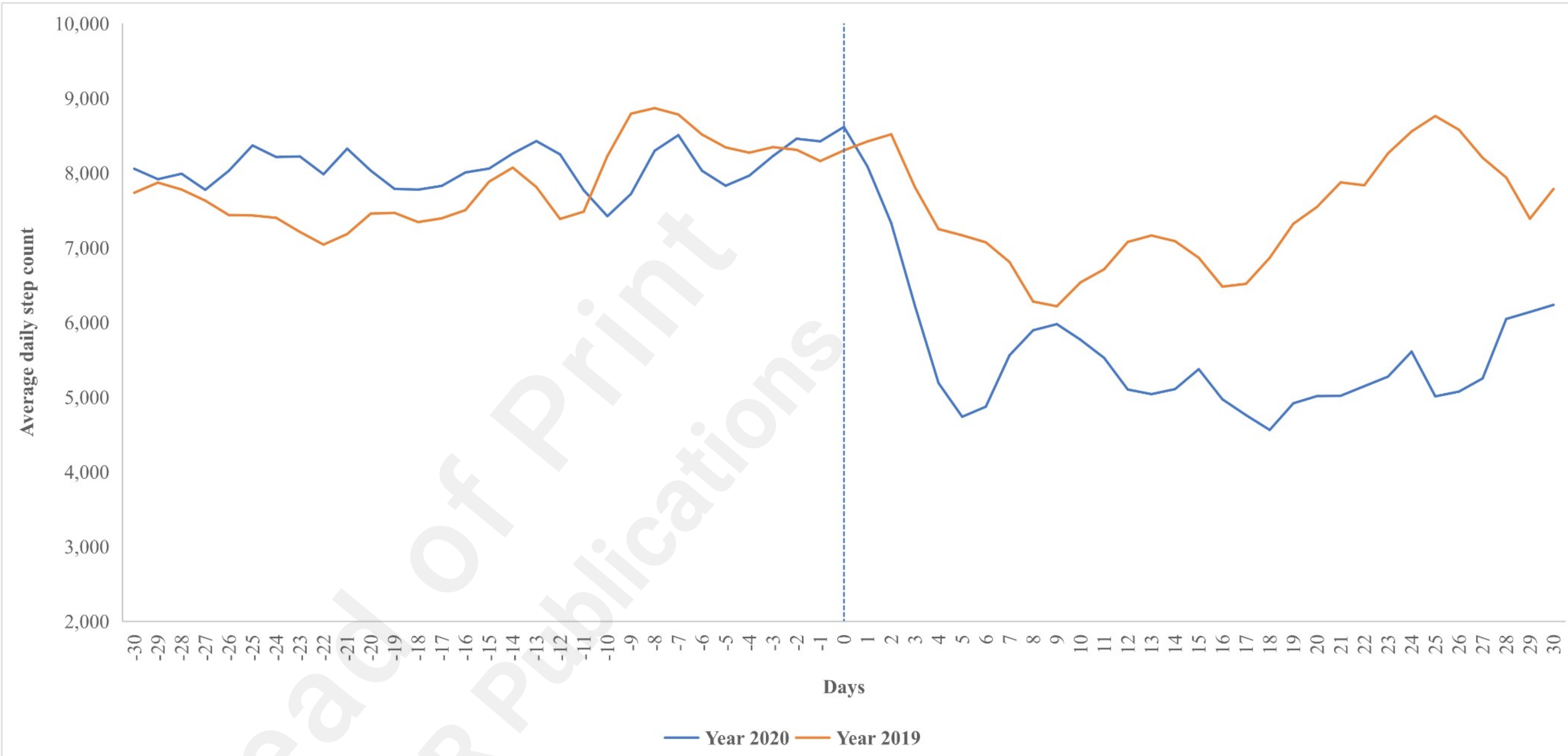



**Figure 1. Average daily step count around Chinese Lunar New Year period among participants in 2019 and 2020.** Day 0 represents the index date – in year 2020, this represents the date of first COVID-19 case diagnosed in Changsha.

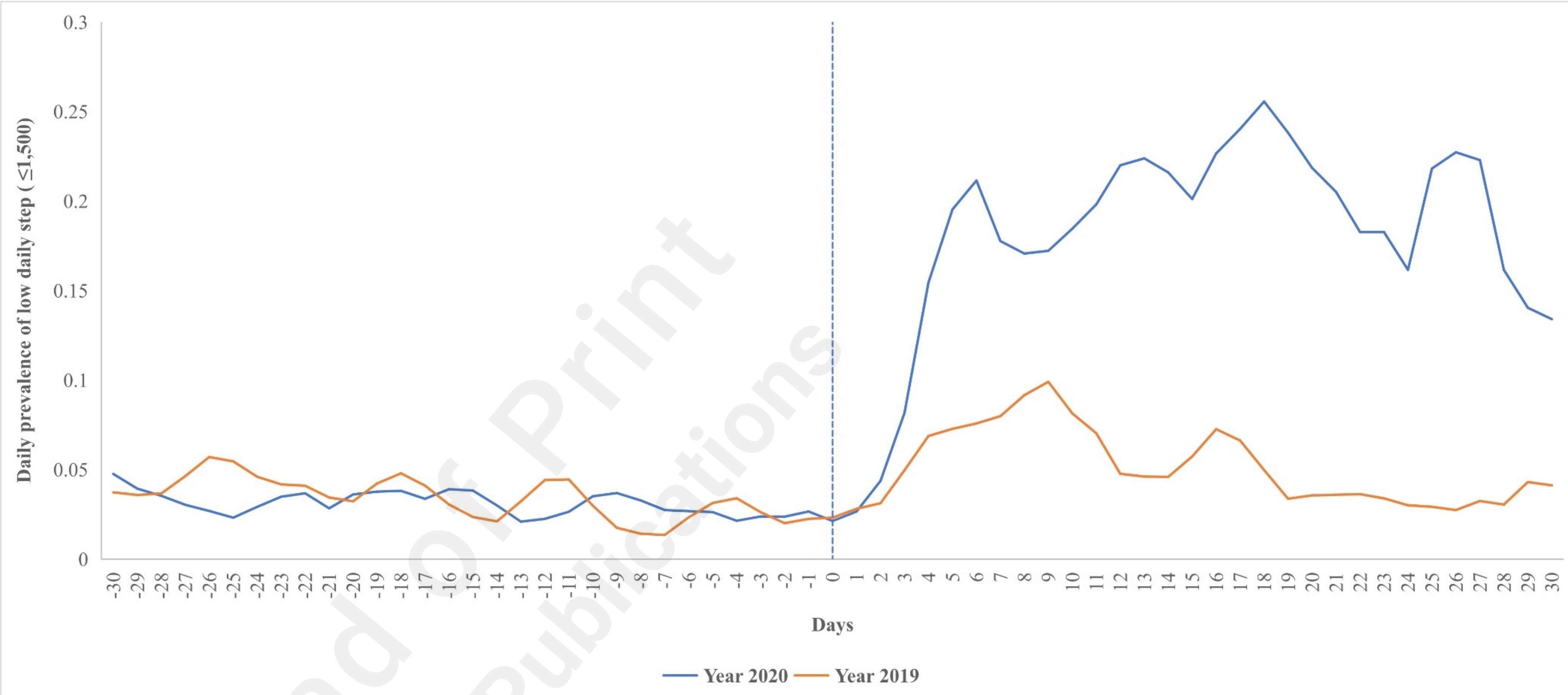


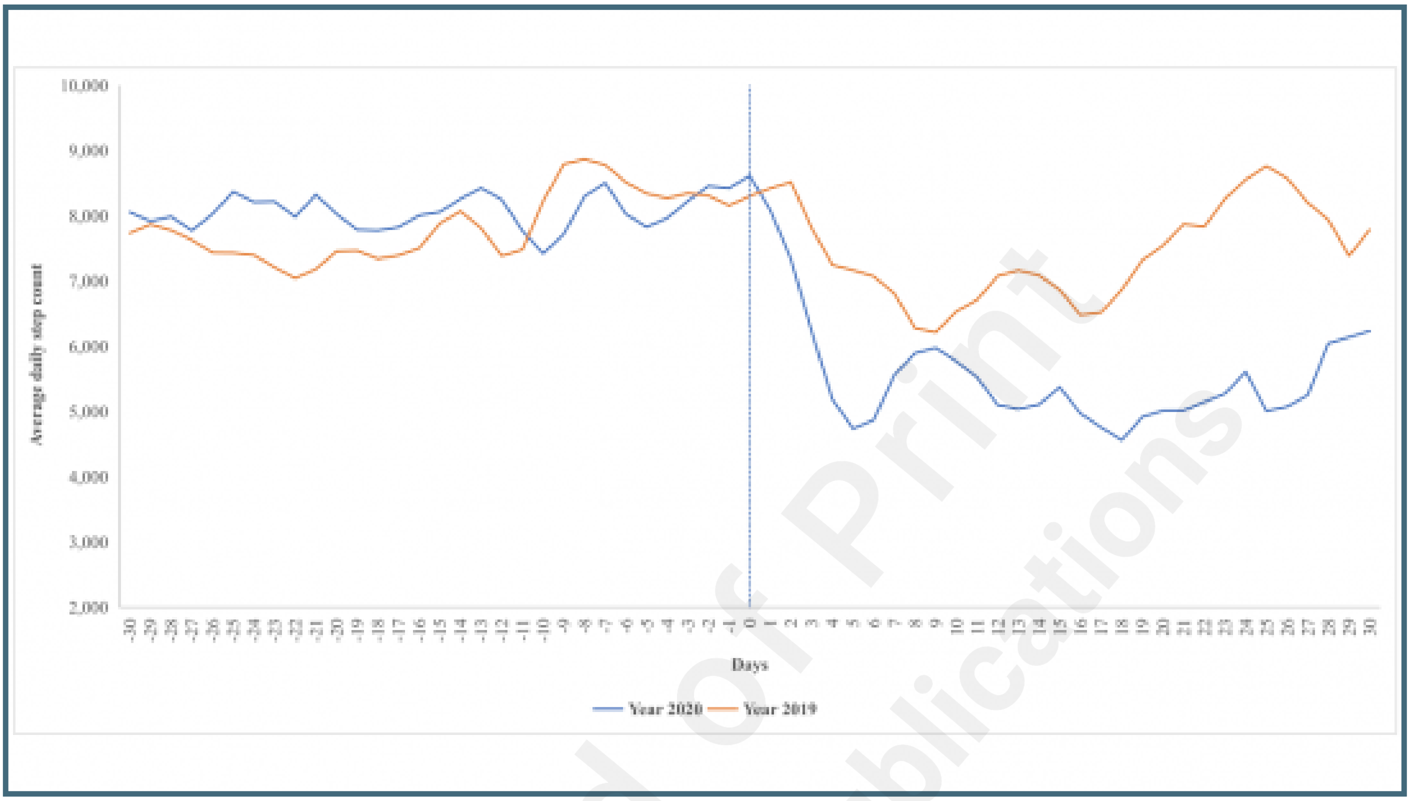

**Figure 2. Prevalence of low daily step count (≤1,500 steps/day) around Chinese Lunar New Year period among participants in 2019 and 2020.**

Day 0 represents the index date – in year 2020, this represents the date of first COVID-19 case diagnosed in Changsha.

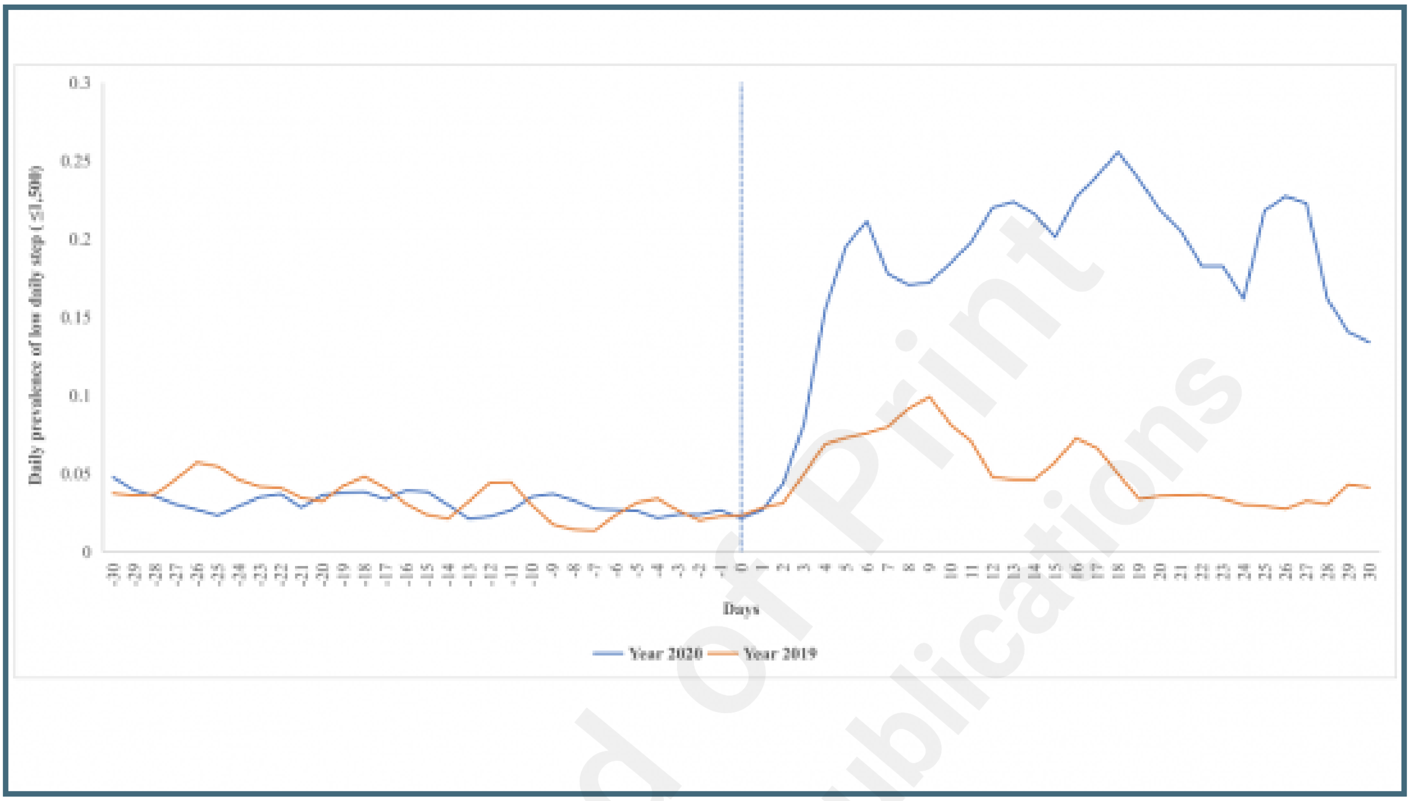
# Supplementary Files

# Figures

Average daily step count around Chinese Lunar New Year period among participants in 2019 and 2020. Day 0 represents the index date – in year 2020, this represents the date of first COVID-19 case diagnosed in Changsha.



Prevalence of low daily step count (?1,500 steps/day) around Chinese Lunar New Year period among participants in 2019 and 2020. Day 0 represents the index date – in year 2020, this represents the date of first COVID-19 case diagnosed in Changsha.



# Multimedia Appendixes

Validation study.
URL: https://asset.jmir.pub/assets/ffb28ca61ff60ed8656ad4c7ff44a313.docx

Diagram of the Study Periods. Chinese New Year Day: January 25, 2020 and February 5, 2019.
URL: https://asset.jmir.pub/assets/26efd4ce0d4463264c7c3f60b60eebaf.png

# CONSORT (or other) checklists

STROBE checklist.
URL: https://asset.jmir.pub/assets/866e74371bd1bf85283be79509867225.pdf