

Original Paper

# The COVID-19 Pandemic and Daily Steps in the General Population: Meta-analysis of Observational Studies

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## Abstract

**Background:** The COVID-19 pandemic has the potential to accelerate another pandemic: physical inactivity. Daily steps, a proxy of physical activity, are closely related to health. Recent studies indicate that over 7000 steps per day is the critical physical activity standard for minimizing the risk of all-cause mortality. Moreover, the risk of cardiovascular events has been found to increase by 8% for every 2000 steps per day decrement.

**Objective:** To quantify the impact of the COVID-19 pandemic on daily steps in the general adult population.

**Methods:** This study follows the guidelines of the MOOSE (Meta-analysis Of Observational Studies in Epidemiology) checklist. PubMed, EMBASE, and Web of Science were searched from inception to February 11, 2023. Eligible studies were observational studies reporting monitor-assessed daily steps before and during the confinement period of the COVID-19 pandemic in the general adult population. Two reviewers performed study selection and data extraction independently. The modified Newcastle-Ottawa Scale was used to assess the study quality. A random effects meta-analysis was conducted. The primary outcome of interest was the number of daily steps before (ie, January 2019 to February 2020) and during (ie, after January 2020) the confinement period of COVID-19. Publication bias was assessed with a funnel plot and further evaluated with the Egger test. Sensitivity analyses were performed by excluding studies with low methodological quality or small sample sizes to test the robustness of the findings. Other outcomes included subgroup analyses by geographic location and gender.

**Results:** A total of 20 studies (19,253 participants) were included. The proportion of studies with subjects with optimal daily steps (ie,  $\geq 7000$  steps/day) declined from 70% before the pandemic to 25% during the confinement period. The change in daily steps between the 2 periods ranged from  $-5771$  to  $-683$  across studies, and the pooled mean difference was  $-2012$  (95% CI  $-2805$  to  $-1218$ ). The asymmetry in the funnel plot and Egger test results did not indicate any significant publication bias. Results

remained stable in sensitivity analyses, suggesting that the observed differences were robust. Subgroup analyses revealed that the decline in daily steps clearly varied by region worldwide but that there was no apparent difference between men and women.

**Conclusions:** Our findings indicate that daily steps declined substantially during the confinement period of the COVID-19 pandemic. The pandemic further exacerbated the ever-increasing prevalence of low levels of physical activity, emphasizing the necessity of adopting appropriate measures to reverse this trend. Further research is required to monitor the consequence of long-term physical inactivity.

**Trial Registration:** PROSPERO CRD42021291684; [https://www.crd.york.ac.uk/prospero/display\\_record.php?RecordID=291684](https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=291684)

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## KEYWORDS

COVID-19; daily steps; physical activity; meta-analysis

## Introduction

Physical activity has been crucial for preventing and treating multiple chronic health conditions [1,2] and premature mortality [3,4], while the number of daily steps is a primary proxy measure for physical activity [5]. Daily step goals can be tailored to meet individual needs and when used with a monitor are effective in promoting physical activity [6]. Previous studies have found that higher daily steps are associated with multiple health benefits, such as lower risk of cardiovascular disease [7], diabetes [8,9], and all-cause mortality [10-13]. For example, the risk of all-cause mortality in adults shows a declining trend with an increase in daily steps and plateaus at approximately 7000 steps per day [12,13]. In contrast, a decrease in daily steps is responsible for a range of unhealthy outcomes, such as increased risk of cardiovascular disease [14], compromised muscle metabolism [15], and elevated systemic inflammation [15,16]. Specifically, the risk of cardiovascular events was reported to increase by 8% for every 2000 steps per day decrement [14]. A sharp reduction in daily steps might also reduce leg lean mass and induce impairments of myofibrillar protein synthesis in healthy elderly individuals, accompanied by increased circulating inflammatory markers [15,16].

Although global responses were far from homogeneous, most countries adopted restriction measures in varying forms to limit the transmission of COVID-19, such as physical distancing, working from home, and closing schools [17]. These measures have resulted in unprecedented changes in all aspects of daily life [18], and physical activity is certainly one of the aspects being most affected. Recently, several studies reported a significant decline in daily steps during the confinement period of the COVID-19 pandemic [19-23]. One study found that the daily steps of young adults in Singapore decreased by 42% on average during the lockdown period compared with the time before the pandemic [20]. Another study reported a sharp, 30% reduction in daily steps in Chinese citizens and a significant increase in the proportion of adults with frequent low daily steps ( $\leq 1500$  steps/day for  $\geq 14$  days) during the confinement period [19]. By contrast, one study reported only a 5% reduction in daily steps 30 days after the start of lockdown in Australia [22]. These findings indicate the possibility of geographically specific variations in the relationship between COVID-19-related restrictions and daily steps, which limits the generalization of conclusions drawn from single country-based analyses. Therefore, a systematic review is needed to consolidate the

current understanding of the impact of COVID-19 on daily steps in order to enlighten future interventions and research directions. In addition, a few studies have also evaluated whether the impact of COVID-19 on physical activity varied by gender. One study suggested that men had more reduction in time spent in moderate-vigorous physical activities and a larger increase in sedentary behaviors than women during the pandemic [24]. However, another study failed to confirm this finding [25].

To fill this knowledge gap, we conducted a meta-analysis of observational studies to quantify both global and regional impacts of confinement during the COVID-19 pandemic on daily steps in the general adult population, and we also examined whether the decline in daily steps differed between men and women.

## Methods

### Protocol and Registration

The MOOSE (Meta-analysis Of Observational Studies in Epidemiology) [26] and PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 [27] guidelines were followed for reporting this study (Multimedia Appendix 1). The protocol for this study was prospectively registered in the PROSPERO database (CRD42021291684).

### Search Strategy

A preliminary search was conducted on PubMed, EMBASE, and Web of Science to retrieve studies that reported daily step data both before and during the confinement period of the COVID-19 pandemic in the general adult population published before November 22, 2021. Further, an updated search was performed on February 11, 2023, to add recently published articles. The detailed search strategy is listed in Multimedia Appendix 2 [28-31]. The International Standard Randomized Controlled Trial Number Register (ISRCTN) and the World Health Organization COVID-19 database were also searched for potential gray literature. The reference lists and citing articles of relevant literature on this topic were also checked to find possible studies that could be included in this research. The language of publication was not restricted.

### Eligibility Criteria and Study Selection

We included observational studies that reported daily steps before and during the confinement period of the COVID-19 pandemic in the general adult population. The reference period

was restricted to  $\leq 2$  years before the time points when the government implemented the confinement measures. Further

eligibility criteria are listed in [Textbox 1](#).

**Textbox 1.** Eligibility criteria for study screening.

Inclusion criteria
Study type: Observational studies
Participants: General adult population (average age over 20 years)
Outcomes: Daily steps, measured using monitoring devices including wearable physical activity trackers (eg, pedometers, accelerometers, smartwatches, and smart bands) and smartphones mobile apps (eg, iPhone Health, Google Fit, WeChat, and Exercise Health)
Other criteria: Daily step data collected both before and during the confinement period of COVID-19. The reference period was restricted to $\leq 2$ years before the time points when the government implemented the confinement measures
Exclusion criteria
Study type: Any non-observational study (eg, reviews, randomized controlled trials, and case reports), conference abstracts
Participants: Children, adolescents, athletes, specific patient groups, participants with particular conditions (eg, pregnant women or elderly individuals at high risk of falls)
Outcomes: Data other than daily steps (eg, physical activity measured using questionnaires alone or data measured by wearable devices that are classified as light, moderate, or vigorous physical activity)
Other criteria: Studies offering financial incentives that may promote physical activity (eg, rewards for individuals who achieve predetermined goals through monitors), studies lacking available data for meta-analysis

Two independent reviewers (LS and WR) screened all titles and abstracts. The full text of potentially relevant literature was further evaluated. A third reviewer (ZW) arbitrated the decision if a consensus was not reached.

### Data Extraction

Two authors (LS and WR) extracted the following data independently: study design, country and continent (Africa, Asia, Europe, North America, South America, and Oceania) where the study was conducted, the sample size used for daily step analysis, participant characteristics (ie, mean age and female ratio), monitoring devices used to measure daily steps, the algorithm used to analyze daily steps, data collection duration, and COVID-19 restriction measures by the government at the time of data collection. The outcomes of interest were the total number of daily steps before and during the confinement period of COVID-19 and the percentage change between the 2 periods. If not reported, the mean (SD) of the outcome was estimated based on the methods provided by the Cochrane Handbook [32]. If data needed to be extracted from graphs, the GetData digitizer was used [33]. This tool has been validated and has good accuracy and precision for data extraction; it has been used in meta-analysis by previous studies [34]. Disagreements, if any, were resolved by consulting with a third reviewer (ZW). When any desired information related to daily steps was missing or unclear, the corresponding author was contacted via email to request or confirm the relevant data, as appropriate. If the data could not be obtained, the study was excluded from the meta-analysis.

### Risk of Bias and Quality of Individual Studies

The modified Newcastle-Ottawa Scale (NOS) for applicable observational studies was used to assess the methodological quality and risk of bias in each study [28-30]. Specifically, the modified NOS consists of 3 domains: *selection* (maximum 3 stars), *comparability* (maximum 2 stars), and *outcome* (maximum 2 stars). Therefore, 1 study can be awarded a

maximum of 7 stars. Studies with 6 to 7 stars were rated as high quality, those with 5 stars were rated as moderate quality, and those with 4 or fewer stars were rated as low quality [29]. Two reviewers (LS and ZW) rated the methodological quality of each study independently, and discrepancies, if any, were discussed for consensus or resolved by consulting a third reviewer (YW).

### Data Synthesis and Analysis

A random effects meta-analysis was conducted using Stata software (version 14.0; StataCorp). The change in daily steps was calculated using the mean difference (MD) with the 95% CI between the mean (SD) of daily steps before and during the confinement period of COVID-19. The Cochran Q statistic of the inconsistency index ( $I^2$ ) was used to test statistical heterogeneity across studies [32,35]. An  $I^2$  value of more than 75% indicated high heterogeneity [32]. Publication bias was assessed with a funnel plot and further evaluated with the Egger test [36]. To test the robustness of the findings on the primary outcome (ie, the number of daily steps), we performed 3 sensitivity analyses. First, we conducted an analysis that eliminated each study one at a time. Second, we performed an analysis that removed the studies rated as having low methodological quality. Third, we performed an analysis that excluded the studies with a small sample size (less than 140) based on the recommendations of Dunton and colleagues [37]. Finally, we also conducted subgroup analyses according to country, continent, and gender.

## Results

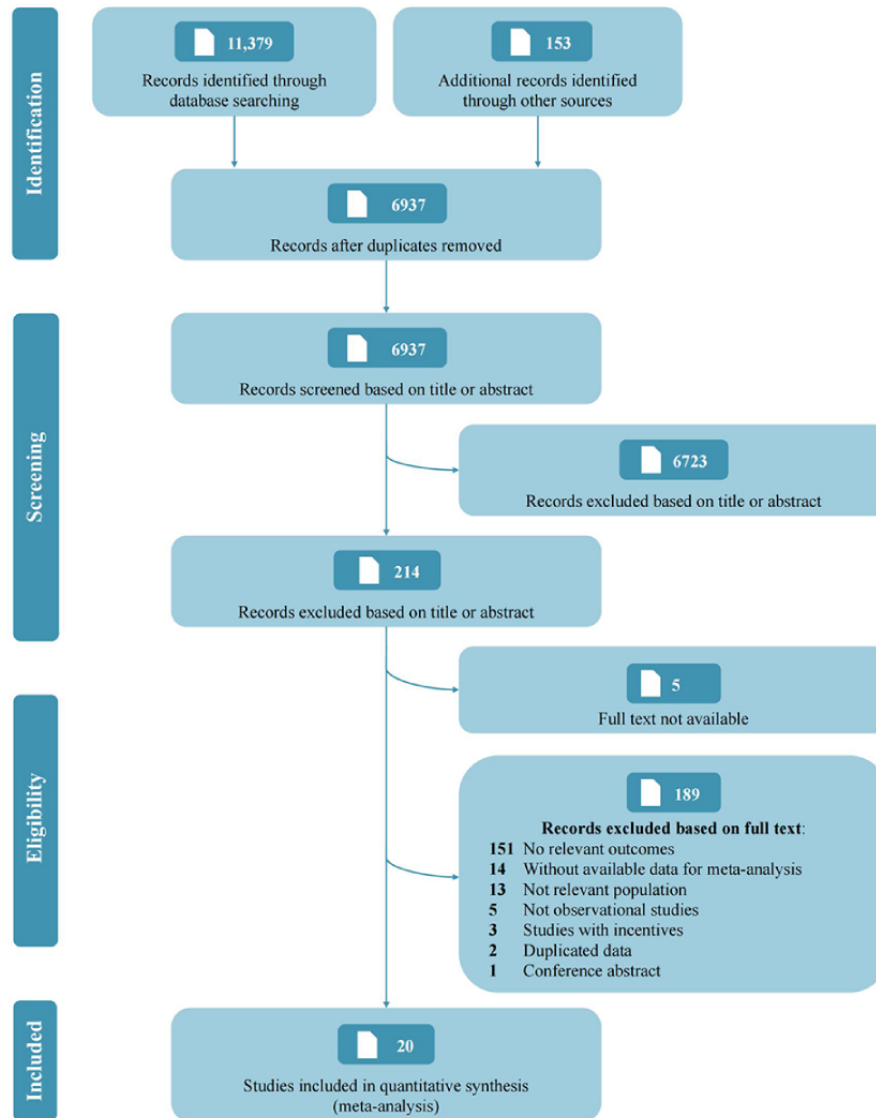
### Study Selection

A total of 6937 unduplicated records were preliminarily retrieved, and 214 potentially eligible studies were identified after the title and abstract screening. Then, 5 studies were excluded because the full text was unavailable, and full text

assessments were made of the remaining 209 articles. Another 189 articles were eliminated. Of these, 151 studies did not report relevant outcomes (ie, daily steps), 14 did not provide necessary data for meta-analysis, 13 focused on irrelevant populations, 5 were not observational studies, 3 were conducted with financial

incentives, 2 reported duplicated data, and 1 was a conference abstract. The remaining 20 studies were included in the meta-analysis [19,20,37-54]. Figure 1 shows the PRISMA flow diagram.

**Figure 1.** PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram.



## Study Characteristics

The included studies were conducted in Australia [38], Canada [39], China [19,40-43], France [38], Italy [44], Japan [45-48], Norway [49], Singapore [20], South Korea [50], Spain [51], the United Kingdom [38,52], and the United States [37,38,53,54], and all of them investigated the change in daily steps in the early stage of COVID-19 (from January to September 2020). The reference pre-COVID-19 period was from January 2019 to March 2020. The detailed duration of observation for each

study is shown in Table 1. Nine studies measured daily steps with smartphones [19,37,40,41,43,45,46,50,54], 8 with wearable activity trackers [20,38,39,47,48,51-53], and 2 with both wearable activity trackers and smartphones [44,49]; 1 study did not specify the measurement device used in the survey [42]. One study provided 4 groups of data from 4 countries separately [38]. Therefore, the 20 studies included a total of 19,253 participants, and 23 sets of data were included in the meta-analysis. Additional study characteristics are summarized in Table 1.

**Table 1.** Characteristics of studies and participants included in the meta-analysis.

Study	Country/Continent	Participants, n	Age (years)	Female, %	Device	Algorithm	Definition of restriction measures	Observation period	Reference period
Azuma et al [45] 2021	Japan/Asia	530 <sup>a</sup>	— <sup>b</sup>	75.1	Smartphone (iPhone Health)	Averaged data from 9 weekly averages	Declared emergency (closed schools and “stay at home” recommendation issued)	Feb 24 to Apr 26, 2020	Feb 24 to Apr 26, 2019
Bird et al <sup>c</sup> [52] 2021	UK/Europe	190	Range 18-85	77.9	Mobile device (eg, smart-watch)	—	Lockdown	March to May 2020	Before March 2020
Buoite Stella et al [44] 2021	Italy/Europe	197	—	—	Smart technology devices (eg, smartphone, smart band, and smartwatch)	Weekly average	Lockdown	Mar 23 to Mar 29, 2020	One week in Jan 2020
Ding et al <sup>c</sup> [40] 2021	China/Asia	301	—	76.4	Smartphone (WeChat)	Averaged data from 14-day data	Lockdown	Mar 11 to Mar 24, 2020	Dec 28, 2019, to Jan 10, 2020
Dunton et al [37] 2020	US/North America	149	Range 18-74	—	Smartphone (iPhone Health)	Monthly average	Declared “shelter in place” and “stay at home” orders	Apr 2020	Feb 2020
Gollwitzer et al [54] 2022	US/North America	220	Mean 35.2	41.4	Smartphone (iPhone Health)	Weekly average	Social distancing	Apr 3 to Apr 9, 2020	Apr 3 to Apr 9, 2019
He et al [41] 2020	China/Asia	339	Women: mean 37.6; men: mean 36.4	53.4	Smartphone (eg, Exercise Health, Keep)	Average data during the observation period	Semilockdown (assembly was suspended, and curfew and quarantine measures were implemented in some districts)	Jan 27 to Mar 1, 2020	Dec 23, 2019, to Jan 26, 2020
Henriksen et al <sup>d</sup> [49] 2021	Norway/Europe	113	Mean 40.6	56.2	Wearable activity trackers (Apple, Fitbit, Garmin, Oura, Polar, Samsung, and Withings), and smartphones (Google Fit and Apple Health)	Monthly average	Lockdown	Mar 13 to Mar 31, 2020	Mar 2019
Hudgins et al [53] 2021	US/North America	80	Mean 32.2	—	Wearable activity trackers	Monthly average	Academic break in 2020, during which the university transitioned to remote learning	30 days after spring break 2020	30 days before spring break 2020
Ji et al [42] 2022	China/Asia	781	—	—	—	—	—	—	—
Kara-georghis et al [38] 2021	US/North America	1029	Mean 40.7	76.4	Electronic devices	Self-reported daily steps based on devices' records	Declared “stay at home” order	Mar 21 to Apr 7, 2020	Before Mar 21, 2020
Kara-georghis et al [38] 2021	UK/Europe	392	Mean 51.2	80.1	—	—	National lockdown	After Mar 23, 2020	Before Mar 23, 2020
Kara-georghis et al [38] 2021	France/Europe	734	Mean 37.7	76.0	—	—	National lockdown	After Mar 16 2020	Before Mar 16 2020
Kara-georghis et al [38] 2021	Australia/Oceania	386	Mean 42.5	72.5	—	—	Interstate border closures <sup>e</sup>	After Mar 19, 2020	Before Mar 19, 2020



Study	Country/Continent	Participants, n	Age (years)	Female, %	Device	Algorithm	Definition of restriction measures	Observation period	Reference period
Obuchi et al [46] 2021	Japan/Asia	2587	—	76.7	Smartphone	Weekly average	Declared emergency (closed schools and issued “stay at home” recommendation)	Apr 21 to Apr 27, 2020	Apr 30 to May 6, 2019
Ong et al <sup>c</sup> [20] 2021	Singapore/Asia	1824	Mean 30.9	51.6	Wearable activity tracker (Fitbit)	Averaged data from 3-week data	Lockdown	Apr 7 to Apr 27, 2020	Jan 2 to Jan 22, 2020
Park et al [50] 2021	South Korea/Asia	1163 <sup>a</sup>	Mean 23.7	45.6	Smartphone (iPhone Health)	Monthly average	Level 2.5 (gatherings of more than 50 people indoors and more than 100 people outdoors were prohibited)	Sep 2020	Jan to Dec 2019
Sañudo et al [51] 2020	Spain/Europe	20	Mean 22.6	47	Xiaomi Mi Band 2 wrist-worn accelerometer	Weekly average	Lockdown	One week, between Mar 24 and Apr 3, 2020	One week in Feb 2020
Sato et al [47] 2022	Japan/Asia	2846	Mean 45.9	59.6	Accelerometer (Panasonic)	Average data during the observation period	Declared emergency (closed schools and issued “stay at home” recommendation)	Apr 7 to May 13, 2020	Jan 1 to Feb 29, 2019
Wang et al <sup>c</sup> [19] 2020	China/Asia	3544	Mean 51.6	34.6	Smartphone (WeChat)	Monthly average	Declared emergency (physical distancing measures were issued)	Jan 22 to Feb 20, 2020	Feb 2 to Mar 3, 2019
Woodruff et al [39] 2021	Canada/North America	121	Mean 36.2	80	Wearable activity trackers (Apple, Fitbit, Samsung, Garmin)	—	Declared emergency (physical distancing measures were issued)	Based on the date each person began physically distancing/self-isolating	Based on the date each person began physically distancing/self-isolating
Yamada et al [48] 2023	Japan/Asia	678	—	—	Wearable activity tracker (EW-NK63)	Monthly average	Declared emergency (closed schools and issued “stay at home” recommendation)	April 2020	April 2019
Zhu et al [43] 2021	China/Asia	1029	Range 18-76	69.1	Smartphone (WeChat)	Self-reported daily steps based on smartphone’s records	Lockdown	Three months after entering isolated life	Jan 21 to Jan 25, 2020

<sup>a</sup>Observations are reported instead of participants for these studies, because of uncertainty about the number of participants who were double counted (before and after the confinement period).

<sup>b</sup>Not available.

<sup>c</sup>Data for daily steps were obtained from the authors for these studies.

<sup>d</sup>Only 106 of 113 participants provided characteristics in this study.

<sup>e</sup>“Interstate border closures” means that Australia closed its borders to all noncitizens and nonresidents. This started on March 20, 2020, with no exceptions for Australian citizens, permanent residents, or their immediate families. Furthermore, a lockdown policy started in Australia on March 23, 2020.

## Quality Assessment

Thirteen studies (65%) were rated as having moderate to high methodological quality (Multimedia Appendix 2, Table S1). Considering the widespread weaknesses of small sample size, imbalanced gender ratio, limited age range of the study sample, and poor nationwide representativeness, only 2 studies were rated as having national representativeness of the exposed cohort (ie, samples during the confinement period of COVID-19). Thus, 10% of the included studies received 3 stars in the

*selection* dimension, 30% received 2 stars in the *comparability* dimension, and 60% received 2 stars in the *outcome* dimension.

## Quantitative Synthesis

As shown in Figure 2, the proportion of studies with subjects with optimal daily steps (ie,  $\geq 7000$  steps per day) declined from 70% before the pandemic to 25% during the confinement period. The change in daily steps between the 2 periods ranged from  $-5771$  to  $-683$ . The pooled MD from the random effects pooled analysis was  $-2012$  (95% CI  $-2805$  to  $-1218$ ; Figure 3), with significant heterogeneity among studies ( $P < .001$ ;  $I^2 = 97.6\%$ ).

The funnel plot shows a symmetrical horizontal distribution for each study relative to the vertical line, suggesting the absence of reporting bias (Multimedia Appendix 2, Figure S1). The Egger publication bias indicated a lack of publication bias (Multimedia Appendix 2, Figure S2). Sensitivity analysis, performed by omitting each study one by one, revealed that the change in daily steps was not significantly altered by any

individual study (Multimedia Appendix 2, Figure S3). Moreover, the results remained robust in sensitivity analyses after removing low-quality studies (MD=-1714, 95% CI -2809 to -618) and after removing small-sample studies (MD=-2024, 95% CI -2836 to -1212). The percentage change in daily steps varied from -69.6% to -10.6% across different studies (Figure 4).

Figure 2. Average daily steps around the period before and during the confinement period across studies.

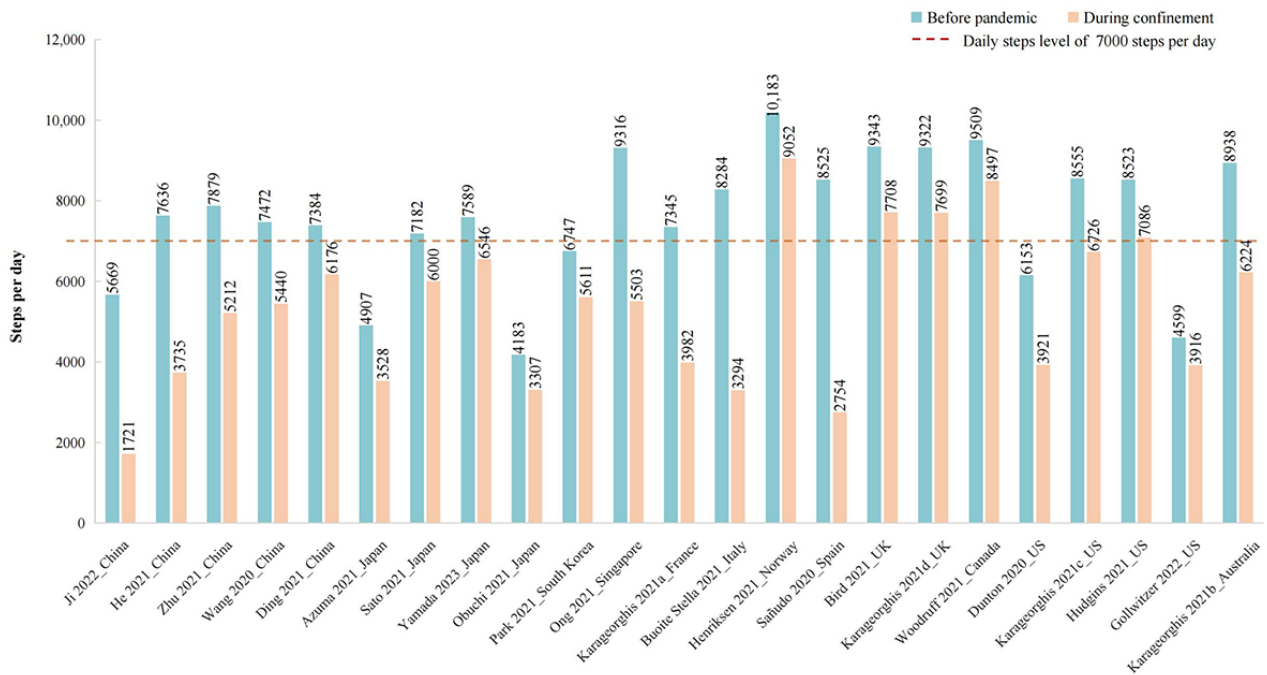
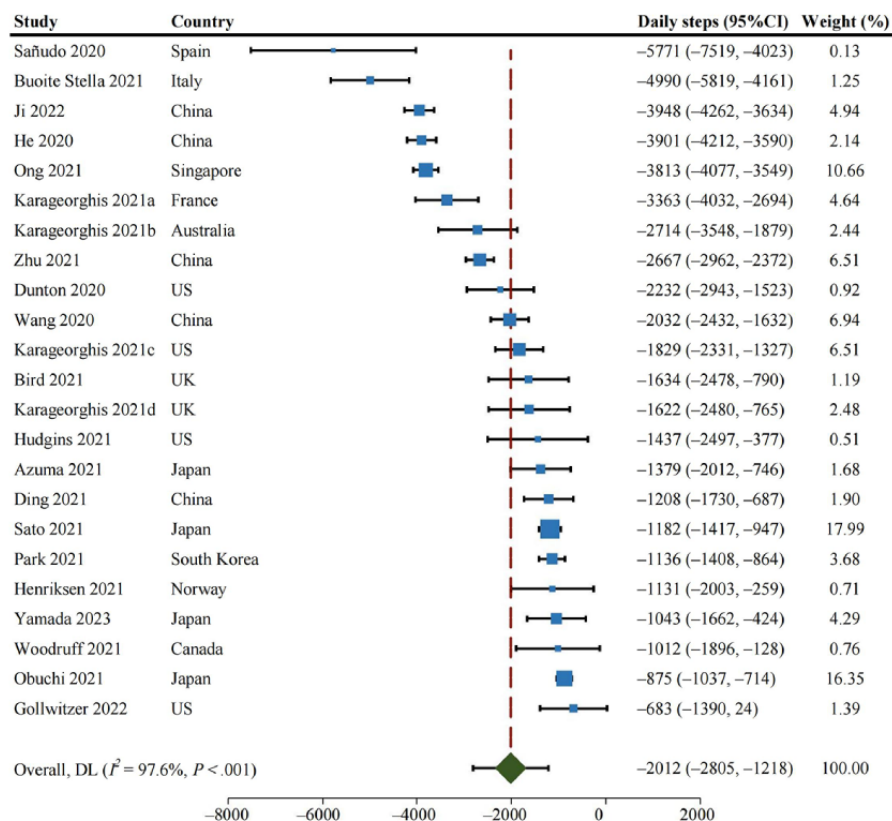
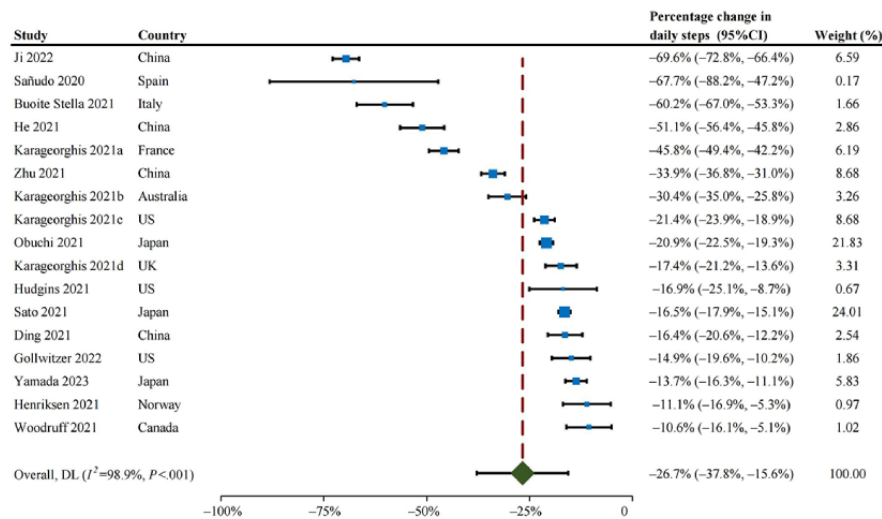


Figure 3. Forest plot of reduction in daily steps during the confinement period. DL: DerSimonian and Laird method.



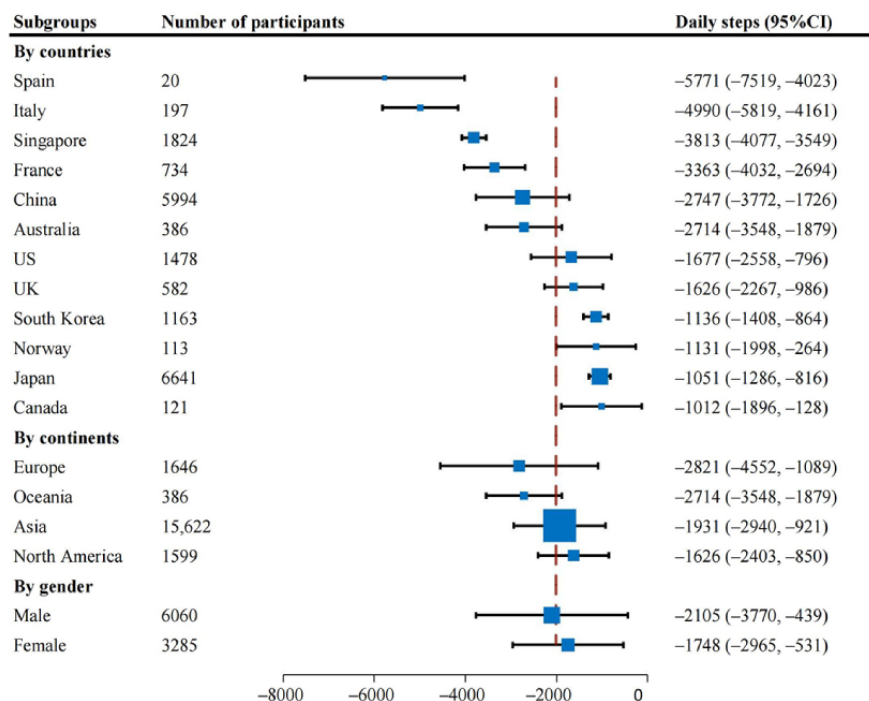
**Figure 4.** Percentage reduction in daily steps during the confinement period of the COVID-19 pandemic. DL: DerSimonian and Laird method.



Country-specific analyses (Figure 5) showed that the most significant decline in daily steps occurred in subjects from Spain (MD=-5771, 95% CI -7519 to -4023), followed by Italy (MD=-4990, 95% CI -5819 to -4161) and Singapore (MD=-3813, 95% CI -4077 to -3549). The decline in daily steps was less in subjects from Canada (MD=-1012, 95% CI -1896 to -128), Japan (MD=-1051, 95% CI -1286 to -816), and Norway (MD=-1131, 95% CI -1998 to -264). In terms of continent, European subjects presented the most significant reduction in daily steps but with a wide CI (MD=-2821, 95%

CI -4552 to -1089), followed by subjects from Oceania (MD=-2714, 95% CI -3548 to -1879) and Asia (MD=-1931, 95% CI -2940 to -921), while subjects from North America presented the smallest decline in daily steps (MD=-1626, 95% CI -2403 to -850). Of the studies that provided gender-specific data [20,41,43,45-47,52], no apparent difference was observed in the change in daily steps between men (MD=-2105, 95% CI -3770 to -439) and women (MD=-1748, 95% CI -2965 to -531).

**Figure 5.** Pooled subgroup results of reduction in daily steps during the confinement period of the COVID-19 pandemic.



## Discussion

### Principal Results

Our study quantified the change in daily steps during the confinement period of COVID-19. The proportion of studies with subjects with optimal daily steps (ie,  $\geq 7000$  steps/day)

declined from 70% before the pandemic to 25% during the confinement period, and the average number of daily steps was reduced by 2000. Our results also suggest a possible inequality in physical activity across countries, whether before or during the pandemic. However, given that most included studies lacked sufficient nationwide representativeness, this difference should



be interpreted cautiously. Furthermore, there was no apparent gender difference in the decline in daily steps before and during the confinement period of COVID-19.

### Possible Explanations and Clinical Implications

The population-level trends in daily steps during the confinement period of COVID-19 may reflect public panic about the virus and adherence to confinement measures (ie, physical distancing and sheltering in place) [55,56]. Our findings are not surprising given that COVID-19 restriction measures deprived the general population of many opportunities for physical activity, such as commuting, shopping, sports, and vacations or trips. In addition, the observed differences in the change in daily steps across studies may reflect regional variations in enforcement and behavioral changes [57,58]. Socioeconomic inequalities might also influence such variations among regions and disparities in the ability to engage in or access recreational physical activity within areas [59].

Daily steps are strongly associated with health outcomes [7-16]. Recent studies indicate that over 7000 steps per day is the critical physical activity standard for minimizing the risk of all-cause mortality [12,13]. Moreover, the risk of cardiovascular events increases by 8% for every 2000 steps per day decrement [14]. We found that daily steps declined by 2000, and half of the included studies reported that average daily steps declined to below 7000 during the confinement period of the COVID-19 pandemic. Such findings imply that the pandemic further exacerbated the ever-increasing prevalence of low-level physical activity [60,61], emphasizing the necessity of adopting appropriate measures to reverse this trend. Furthermore, this meta-analysis focused on observational studies based on monitoring devices. Since monitoring devices may encourage users to engage in physical activities [6], the number of daily steps during the confinement period might have been even lower in the population than was currently observed in the samples. In addition, the impact of COVID-19 on daily steps may persist in the long term. Although some researchers report that daily steps gradually recovered to the prepandemic level after the lifting of restriction measures [49,62], more studies argue that worldwide daily steps remain depressed compared with the prepandemic level (ie, the immediate 2 years before the outbreak of COVID-19) [59,63-66]. Thus, the consequences of long-term physical inactivity, which may be further exacerbated, should be addressed.

### Comparison With Previous Work

Our finding of a reduction in daily steps during the confinement period of the pandemic is consistent with findings from previous studies using different physical activity metrics [67,68]. An earlier meta-analysis found that sedentary time significantly increased, by 126.9 minutes per day in adults and by 46.9 minutes per day in the elderly, during the confinement period of the pandemic [67]. Another systematic review reported that most of the included studies revealed a decrease in physical activity in most participants [68]. All studies showed an increased sedentary time in healthy adults and those with medical conditions during the lockdown period [68]. According to this evidence, public health messages about staying active during the pandemic appear to have had little effect on the

population's engagement in physical activity [69]. In addition, 2 studies explored gender differences in the change in physical activity during the COVID-19 pandemic but had inconsistent conclusions [24,25]. One study found that men had more clearly decreased moderate-vigorous physical activity and increased sedentary behaviors than women during the pandemic [24]. However, another study failed to show significant differences between men and women in self-reported decline in physical activity [25]. Our meta-analysis adopted a primary indicator of physical activity, ie, daily steps, and found that daily steps declined substantially during the COVID-19 confinement period. Such a decline varied by region but not by gender. These results are consistent with previous studies [24,25,67,68].

Based on data collected from 187 countries and districts by a smartphone app, Tison and colleagues [59] found that mean daily steps declined by 5.5% (287 steps) within 10 days of the pandemic declaration by the World Health Organization and by 27.3% (1432 steps) within 30 days. The authors also reported noticeable differences across regions; for example, Italy, France, Brazil, and Iran exhibited a more than 40% maximum decrease, while Sweden exhibited a maximum reduction of daily steps of less than 10% [59]. Furthermore, regional differences were significant. For example, several studies showed that the decline in daily steps during confinement varied considerably among Chinese adults from different provinces [40,41,43]. One nationwide study in Japan found that daily steps declined significantly after the declaration of a state of emergency in urban areas but not rural areas [62].

### Limitations

Several limitations should be acknowledged. First, daily step data are lacking from Africa and South America, limiting the generalizability of our findings. Second, when comparing regional differences across countries, we could not rule out potential sampling bias, because most of the included studies lacked sufficient nationwide representativeness. Therefore, future studies are needed to verify our findings. Third, since long-term data from the period that confinement was lifted are not suitable for inclusion in a meta-analysis, we could not directly assess the long-term impact of COVID-19 on physical activity levels using meta-analysis techniques. As more published data become available [59,63-66], this will be an important direction for future studies. Fourth, we did not examine the impact of reduced daily steps on health outcomes, owing to a lack of relevant data. Future studies are expected to address this crucial issue. Finally, there was considerable study heterogeneity. Potential explanations include discrepancies in confinement measures across countries or districts and in the adherence to policy of residents, as well as unclear or different time frames over which the average daily steps were calculated, the possibility that monitoring devices were changed in the different reporting periods, and different durations of observation.

### Conclusion

In summary, we found that daily steps declined substantially during the COVID-19 confinement period. Our findings indicate that COVID-19 further exacerbated the ever-increasing prevalence of low levels of physical activity, emphasizing the

necessity of adopting appropriate measures to reverse this trend. long-term physical inactivity. Further research is required to monitor the consequence of

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## Authors' Contributions

ZW, YW, CZ, and GL were responsible for the conception and design of the study. ZW, YW, LS, and WR contributed to study retrieval. ZW and LS contributed to quality assessment. ZW, LS, and WR contributed to data collection. ZW, YW, and JW contributed to statistical analysis. All authors assisted with interpretation. ZW and YW drafted the manuscript. All authors contributed to the revision of the manuscript. All authors read and approved the final manuscript. CZ and GL supervised the study. Authors CZ (zengchao@csu.edu.cn) and GL (lei\_guanghua@csu.edu.cn) are joint corresponding authors for this article.

## Conflicts of Interest

None declared.

## Multimedia Appendix 1

MOOSE checklist.

[\[DOCX File , 17 KB-Multimedia Appendix 1\]](#)

## Multimedia Appendix 2

Supplementary methods and results.

[\[DOCX File , 426 KB-Multimedia Appendix 2\]](#)

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## Abbreviations

**ISRCTN:** International Standard Randomized Controlled Trial Number Register

**MD:** mean difference

**MOOSE:** Meta-analysis Of Observational Studies in Epidemiology

**NOS:** Newcastle-Ottawa Scale

**PRISMA:** Preferred Reporting Items for Systematic Reviews and Meta-Analysis

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