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Changes in Urban Walking Before and During the COVID-19 Pandemic in a Metropolitan City of South Korea

Dong Ha Kim[1] and Seunghyun Yoo[1,2]

[1] Institute of Health and Environment, Seoul National University, South Korea

[2] Department of Public Health Sciences, Graduate School of Public Health, Seoul National University, South Korea

Abstract

This study aimed to assess how social distancing measures impacted the choice of walking as a transportation mode, environmental preferences for walking, and walking practice among urban residents in Seoul, the capital city of South Korea. Data was collected through an online survey from September 21 to 28, 2020, when the second level of social distancing measures was implemented; 2,112 participants aged 19 years or older were included in the analysis. During the coronavirus disease 2019 (COVID-19) pandemic, the choice of walking as a means of transportation increased by 10.1 percent points, while that of public transportation decreased by 16.9 percent points. Environmental preferences for walking were more than moderate in neighborhood public open spaces, neighborhood streets, and riverside trails. Despite the increased choice of walking as a means of transportation during the COVID-19 pandemic, walking practices by purpose decreased significantly. In particular, the decrease in walking practice was more pronounced in utilitarian purpose than in leisure purpose. The present study suggests that social distancing measures have an overall effect on environmental preferences, travel attitudes, and behaviors related walking among urban residents in the metropolitan city. To break the physical inactivity habits established during the pandemic, guidelines for promoting walking should be developed, with a focus on increasing the frequency of walking practice. In the post-COVID-19 era, urban and transportation planning in metropolitan cities need to adjust their focus on the development of neighborhood assets related to walking as a health promotion strategy for the upcoming pandemic.

Keywords: Physical activity, Social distancing, Pandemic, Health promotion, Active living

On January 30, 2020, the World Health Organization (WHO) officially declared that the spread of the novel coronavirus disease 2019 (COVID-19) was a "public health emergency of international concern" (WHO, 2020). Since the report of the first case in Wuhan, China in December 2019, COVID-19 has spread to 222 countries, and as of October 1, 2021, 233,503,524 confirmed cases and 4,777,503 deaths have been reported (WHO, 2021). As it swept around the globe, countries worldwide needed strict containment measures to control the outbreak of the infectious disease.

Social distancing measures (SDM) are effective non-pharmaceutical strategies against the rapid spread of a contagious disease (Min et al., 2020). The main principle of SDM is to minimize contact among individuals and separate low-risk population groups from high-risk ones (Ministry of Foreign Affairs in Korea, 2020). These measures are used in addition to isolation, quarantine, stay-at-home advisory, closure of schools, curfew by district, and cancelation of social gatherings (Fong et al., 2020). Almost all authorities worldwide have mandated or encouraged SDM during the COVID-19 pandemic (Madhuripan et al., 2020).

South Korea (hereafter, Korea) is one of the countries that has made remarkable progress in preventing COVID-19 through SDM without any lockdown. In the early stages of the COVID-19 pandemic, the Korean government introduced a three-level social distancing scheme and specific guidelines that were differentiated according to the severity of the outbreak (Ministry of Foreign Affairs in Korea, 2020). Furthermore, policies have been implemented to claim fines or damages for violations of SDM directives by the authorities. Through these institutionalized efforts, Korea succeeded in flattening the COVID-19 curve with the effect of SDM, which reduced the number of confirmed cases of unknown transmission routes and mass infection (Choe & Lee, 2020).

Although the effectiveness of SDM in preventing COVID-19 transmission was evident, general concerns began to emerge regarding the negative effects of long-term SDM on active urban life (Caputo & Reichert, 2020; Stockwell et al., 2021). It is easy to predict that SDM, which control and manage public behaviors, have drastically modified urban walking practices for both recreation and transportation. However, there is insufficient evidence to compare how much daily urban walking has changed before and after the implementation of SDM. Moreover, only studies with small sample sizes have been conducted in small and medium-sized cities (Louro et al., 2021). This shows that comparative studies with large sample sizes and the metropolitan context can supplement the knowledge gap on the effect of SDM on active urban life based on walking. Therefore, this study aimed to assess how the SDM impacted the choice of walking as a transportation mode, environmental preferences for walking, and walking practice among urban residents in Seoul, the metropolitan city of Korea.

Methods

Setting

This study was conducted in Seoul, a metropolitan city with a population of approximately 10 million people. Seoul has an urban built-up area of approximately 605 km^2, with a population density of 16,376 persons/km^2 in 2020 (Seoul Metropolitan Government [SMG], 2021). Seoul's land use is highly mixed (Seong et al., 2021), and high-rise apartments account for 80.6% of the total housing stock (SMG, 2021). Since 2015, the SMG has operated a public bicycle system for active transportation (SMG, 2018). Additionally, over 90% of the population in Seoul lives within a five-minute walk from a bus or metro station, and free transfers between modes of public transportation are available (SMG, 2018). From a disease prevention perspective, the SMG has been implementing more intensive SDM than other cities in Korea because it is more vulnerable to the spread of the disease due to its compact and dense environment (Shon, 2021).

Study design and participants

We adopted a descriptive cross-sectional study design to assess changes in Seoul citizens' daily walking, means of transportation, and environmental preferences before and during the COVID-19 pandemic using an online questionnaire. The survey was conducted via an online platform from a research company called Macromill Embrain.

The company recruited participants by sending survey invitations containing general information about the survey, including its purpose and consent statement via e-mail or text messages, to registered survey panel members who met the inclusion criteria, which entailed that each participant must be: (a) a resident in Seoul, (b) aged 19 years or older, and (c) a Korean speaker. The company enrolled participants via a quota sampling method considering the gender, age, and population size of each administrative district in Seoul. The target sample size was 2,000 out of 8,379,486 adults in Seoul (as of June 2020), with a sample error of ± 2.19% at a 95% confidence level.

The survey period was from September 21 to 28, 2020, when the second level of SDM was implemented in Seoul. During the second level of SDM, high-risk facilities were shut down, and other public use facilities were obligated to follow prevention measures (Ministry of Foreign Affairs in Korea, 2020). The company that conducted the online survey protected the confidentiality of the participants, and we collected data without personal information to identify them.

Measures

The Korean national surveys, including the measure of walking, were reviewed, and questions were adopted to compare the situation before and during the COVID-19 pandemic (Korea Disease Control and Prevention Agency, 2020; Ministry of Land Infrastructure and Transport, 2020). The structured questionnaire comprised questions to identify changes before and during the COVID-19 pandemic in areas of (a) choice of walking as a means of

transportation, (b) environmental preferences for walking, and (c) walking practice by purpose. We also collected information about the sociodemographic characteristics of the participants. These factors included gender, age, level of education, occupation class, marital status, duration of residence, number of household members, car ownership, and monthly household income in South Korean won (KRW). We also investigated perceived health status on a scale of 1 to 3 (poor = 1, moderate = 2, good = 3).

To measure changes in the choice of walking as a mode of transportation before and during the COVID-19 pandemic, we asked, "What is the main mode of transportation you currently choose when going out?" and "Before the COVID-19 pandemic, what was the main mode of transportation you chose when going out?" These questions included both the recreation and work purposes of the transportation modes. The responses were classified as follows: walking, cycling, public transportation (i.e., bus, subway, and passenger trains), automobile/taxi, and personal mobility vehicles (i.e., electric scooters, hoverboards, and the Segway).

Environmental preferences for walking were classified into two categories: (a) pedestrian environment (e.g., neighborhood streets, downtown streets, and riverside trails), and (b) neighborhood living facilities (e.g., healthcare, religious, leisure and cultural, commercial, and sports facilities, as well as public open spaces). To compare the differences in environmental preferences before and during the pandemic, we asked, "Compared to before the COVID-19 pandemic, where have you come to prefer as a place for walking?" The respondents rated the aforementioned question on a 5-point Likert scale ranging from 1 to 5 (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree).

Changes in walking practices before and during the pandemic were measured separately for the following purposes: (a) utilitarian walking (i.e., walking for commuting, shopping, and errands), (b) outdoor leisure walking (i.e., walking for health or recreation), and (c) indoor exercise walking (i.e., walking on a treadmill in a fitness center or home). For each walking practice purpose, we asked, "On average, how many days did you walk at least 10 minutes at a time in a week?" and "On such a day, how long did you walk on average?" Additionally, the time frame for these questions was asked separately before and during the pandemic. The responses were classified as follows: a person who walked for 30 min or more (at least 10 min at a time) for at least five days during a week was defined as engaging in walking (WHO, 2010).

Ethical considerations

The approval of the Seoul National University Institutional Review Board was obtained before conducting the study (IRB No. 1912/001-012). The participants provided electronic informed consent that was shown on the first page of the survey by answering a "Yes or No" question before starting the online survey.

Statistical analysis

We conducted statistical analyses using R version 4.0.2 (R Foundation for Statistical Computing, Vienna, Austria). Quantitative variables were reported as mean (M), standard deviation (SD), or frequency (percentage, %).
In addition, t-test and chi-square analysis were used to compare changes in walking practice by purpose before and during the pandemic.

Results

Sociodemographic characteristics

Among the 2,112 participants, 1,032 (49.9%) were men and 1,080 (50.1%) were women, with a mean age of 44.2 years (SD = 13.3), as seen in Table 1. A majority of the participants had received college or higher education (79.0%), followed by those who only received a high school education (20.4%). The most common monthly household income was over 4.00 million won (US$ 3,582; 55.5%), followed by 3.00–4.00 million won (US$ 2,686–$3,582; 18.0%). Among the participants, 72.0% had lived in Seoul for more than 20 years, 61.7% lived with three to four family members, and 57.8% were married. Most participants reported their perceived health status as moderate (52.9%) or good (30.4%).

Table 1. Sociodemographic characteristics of study participants by gender

Variables		Total (N= 2,112)		Men (N = 1,032)		Women (N=1,080)	
		N (%)	Mean ± SD	N (%)	Mean ± SD	N (%)	Mean ± SD
Age							
	20-44	1,064 (50.2)		526 (51.0)		538 (49.8)	
	45-64	937 (44.4)	44.2 ± 11.3	440 (42.6)	44.1 ± 13.4	497 (46.0)	44.2 ± 13.1
	≥65	111 (5.2)		66 (6.4)		45 (4.2)	
Education level							
	Elementary school or less	2 (0.1)		0 (0)		2 (0.2)	
	Middle school	11 (0.5)		4 (0.4)		7 (0.6)	
	High school	431 (20.4)		201 (19.5)		230 (21.3)	
	College or over	1,668 (79.0)		827 (80.1)		841 (77.9)	
Monthly household income†							

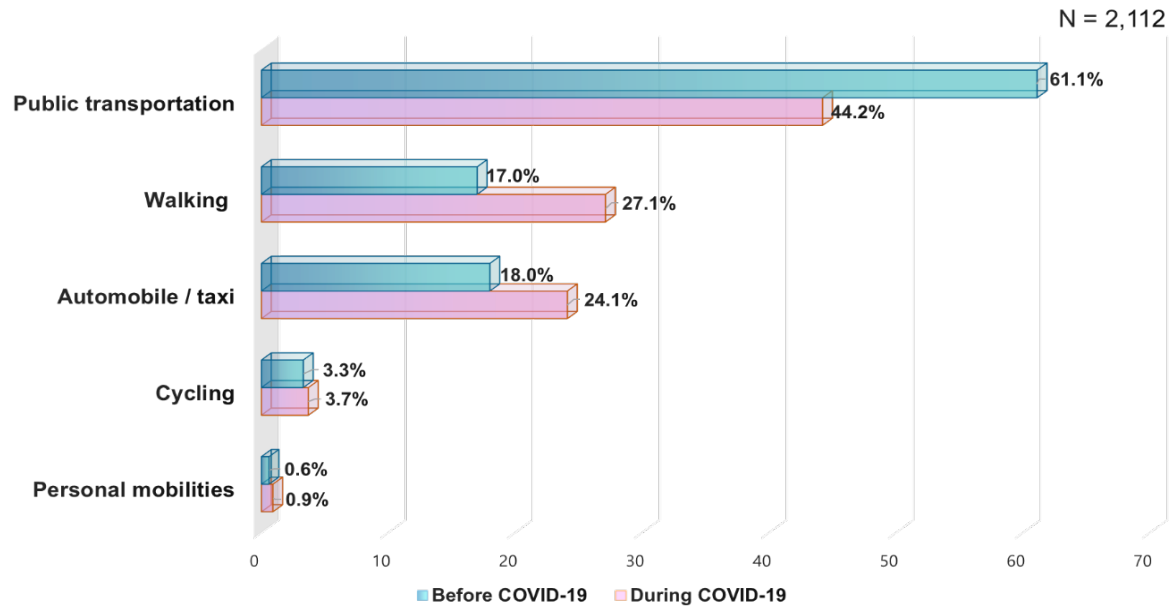
<100	77 (3.6)		43 (4.2)		34 (3.1)	
100-200	170 (8.0)		85 (8.2)		85 (7.9)	
200-300	312 (14.8)		150 (14.5)		162 (15.0)	
300-400	380 (18.0)		199 (19.3)		181 (16.8)	
≥400	1,173 (55.5)		555 (53.8)		618 (57.2)	
Occupation class‡						
High-skilled non-manual	392 (18.6)		237 (23.0)		155 (14.4)	
Moderated skilled non-manual	825 (39.1)		399 (38.7)		426 (39.4)	
Moderated skilled manual	241 (11.4)		153 (14.8)		88 (8.1)	
Low-skilled manual	34 (1.6)		27 (2.6)		7 (0.6)	
Regardless of skill level	429 (20.3)		104 (10.2)		325 (30.1)	
Unemployed	191 (9.0)		112 (10.9)		79 (7.3)	
Duration of residence (years)						
<10y	278 (13.2)		134 (13.0)		144 (13.3)	
10-20	313 (14.8)		152 (14.7)		161 (14.9)	
≥20	1,521 (72.0)		746 (72.3)		775 (71.8)	
Number of household members						
1-2	668 (31.6)		303 (29.3)		365 (33.8)	
3-4	1,303 (61.7)		660 (64.0)		643 (59.5)	
≥5	141 (6.7)		69 (6.7)		72 (6.7)	
Marital status						
Married	1,220 (57.8)		597 (57.8)		623 (57.7)	
Unmarried	810 (38.4)		409 (39.6)		401 (37.1)	
Divorced/bereaved/separated	82 (3.9)		26 (2.5)		56 (5.2)	
Car ownership						
Yes	486 (23.0)		269 (26.1)		217 (20.1)	
No	1,626 (77.0)		763 (73.9)		863 (79.9)	
Perceived health						
Bad (score =1)	353 (16.7)		141 (13.7)		212 (19.6)	
Moderate (score =2)	1,118 (52.9)	2.14 ± 0.67	533 (51.6)	2.21 ± 0.66	585 (54.2)	2.07 ± 0.67
Good (score = 3)	641 (30.4)		358 (34.7)		283 (26.2)	

†: Monthly income unit: 10,000 won (USD1 = KRW 1,116.50 as of June 5, 2020)
‡: High-skilled non-manual: administrators and professionals
Moderate-skilled non-manual: clericals
Moderate-skilled manual: sales, service workers, craftworkers, machine operators
Low-skilled manual: elementary workers
Regardless of skill level: housewives, students, soldiers

Choice of walking as a transportation mode

Before the COVID-19 pandemic, public transportation (61.1%) was the most popular mode of transportation for the study participants, followed by automobile/taxi (18.0%) and walking (17.0%), as seen in Figure 1. On the one hand, during the pandemic, the choice of public transportation as a means of transportation decreased sharply, resulting in a 16.9 percent point decrease from the pre-COVID-19 era. On the other hand, walking, automobile/taxi, bicycles, and personal mobility vehicles tended to increase in popularity as a means of transportation during the pandemic, especially the choice of walking as a transportation mode increased by 10.1 percent points.

Figure 1. Changes in the main mode of transportation before and during the COVID-19 pandemic

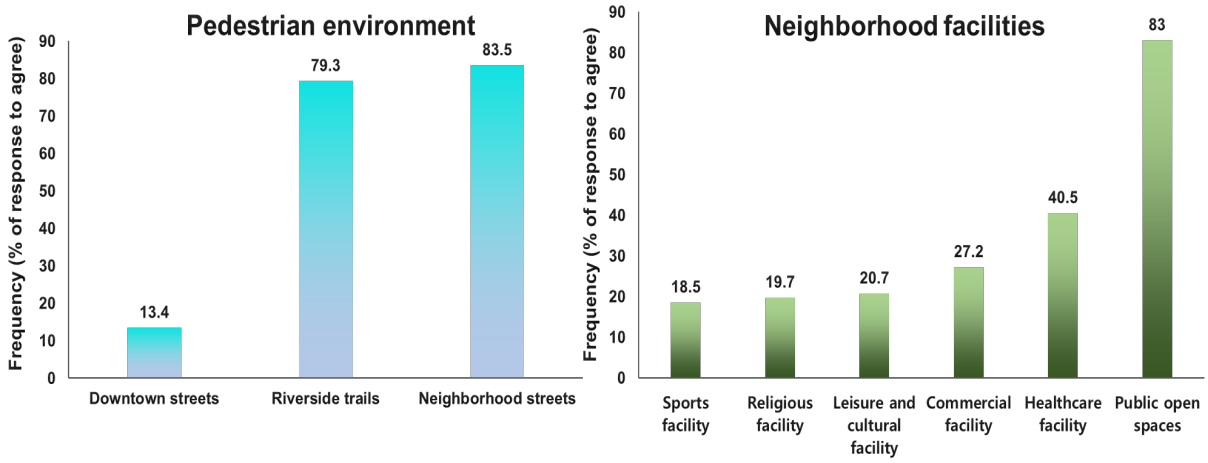


Environmental preferences for walking

On the Likert scale, we categorized the responses to agree and strongly agree as a "preference". Compared to the pre-COVID-19 era, the preferences for the pedestrian environment in the neighborhood tended to increase, while the preferences for the pedestrian environment in the urban center tended to decrease, as seen in Figure 2. The responses to preferences for the riverside trails and neighborhood streets as walking places were 79.3% and 83.5%, respectively. However, preferences for downtown streets as walking places was much lower at 13.4%.

In neighborhood facilities, such as walking places, preferences tended to decrease overall, except for public open spaces, as seen in Figure 2. The responses to preferences for sports, religious, leisure and cultural, commercial, and healthcare facilities were respectively 18.5%, 19.7%, 20.7%, 27.2%, and 40.5%, showing a decreasing trend than before the pandemic. Overall, the response to preferences for public open spaces was 83.0%, which was higher than all other neighborhood facilities.

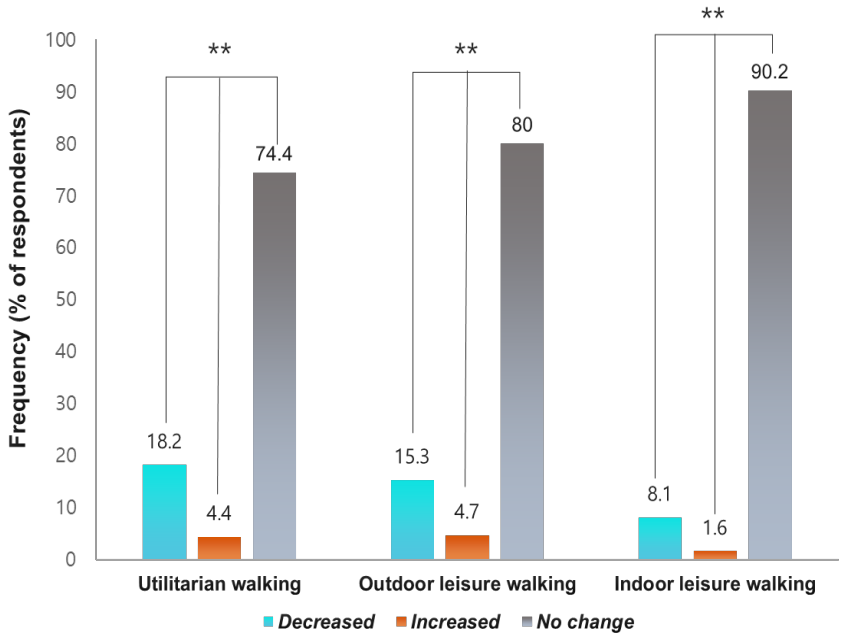
Figure 2. Changes in environmental preferences for walking before and during the COVID-19 pandemic



Walking practice by purpose

As seen in Figure 3, there was a significant difference in walking practices by purpose before and during the pandemic. Furthermore, the decrease in walking practices by purpose before and during the pandemic was more than four times the increase. The percentage of participants who changed their practice from engaging to non-engaging in walking was respectively 18.2%, 15.3%, and 8.1% in utilitarian, outdoor leisure, and indoor exercise walking ($p < 2.2e\text{-}16$). On the other hand, the percentage of participants who changed their practice from non-engaging to engaging in walking was respectively 4.4%, 4.7%, and 1.6% for utilitarian, outdoor leisure, and indoor exercise walking ($p < 2.2e\text{-}16$).

Figure 3. Changes in the walking practice by purpose before and during the COVID-19 pandemic



Decreased : participants who changed their walking practice from engaging in walking to non-engaging walking before and during the COVID-19 pandemic

Increased: participants who changed their walking practice from non-engaging in walking to engaging walking before and during the COVID-19 pandemic

Engaging in walking: a person who walked for 30 min or more (at least 10 min at a time) for at least five days during a week

**** : $p < 0.01$**

More specifically, walking time decreased between before and during the pandemic, as seen in Table 2. Compared to the pre-COVID-19 period, the average walking time per day during the pandemic decreased respectively by 11.1, 13.9, and 10.8 minutes for utilitarian ($t = 7.22$, $p < 0.001$), outdoor leisure ($t = 8.86$, $p < 0.001$), and indoor exercise walking ($t = 9.32$, $p < 0.001$).

Table 2. Changes in the average walking time per day by purpose before and during the COVID-19 pandemic

Purpose	Time	Average walking time per day (minutes) (min-max)	SD	t	p-values
Utilitarian walking	Before COVID-19	72.5 (0-420)	53.8	7.22	<0.001
	During COVID-19	61.4 (0-330)	46.1		
Outdoor leisure walking	Before COVID-19	67.4 (0-366)	53.0	8.86	<0.001
	During COVID-19	53.5 (0-363)	48.2		
Indoor exercise walking	Before COVID-19	27.5 (0-330)	40.9	9.32	<0.001
	During COVID-19	16.7 (0-330)	34.1		

Discussion

This study provides timely information on changes in urban walking among adults during the COVID-19 pandemic in Seoul, a metropolitan city. The major findings of this study indicate that SDM due to COVID-19 negatively impact walking-based urban lifestyles. This study illustrated a significant decrease in walking practice for various purposes, including transportation, social activities, indoor exercise, and outdoor leisure. In addition, SDM have also been shown to influence the choice of transportation modes and environmental preferences for walking.

The study revealed a sharp drop in the number of participants choosing public transportation as the main mode of transportation during the pandemic. This can be interpreted as the psychological tendency to choose transportation in a way that minimizes human contact during the pandemic and the effect of SDM encouraging telecommuting (Park & Cho, 2021; Kim, 2020). The problem is that prolonged COVID-19 is causing enormous economic damage to the operation of the public transportation system in Seoul, and traffic congestion, which had decreased in the early stages of COVID-19, is changing back to an increasing trend (Lim, 2021; Seoul Transport Operation and Information Service, 2021). Urban transportation systems need to be readjusted for sustainable and active mobility in a COVID-19 context. Recently, the city government of Milan, Italy has begun to make agreements with the police department to implement an ambitious project to reallocate road space from cars to walking and cycling in response to the prolonged COVID-19 crisis (Scorrano & Danielis, 2021). Their strategies include reduction of expenses for bicycle lanes, improvement of street environment, restriction of vehicle speed, and designation of pedestrian-only streets. This transformation can create enormous value for promoting urban health by fostering active transportation choices, encouraging daily physical activity, and minimizing close contact on travel behavior.

SDM have contributed to the rediscovery of the importance of public open spaces and pedestrian environments in neighborhood areas for active living. Compared to the pre-COVID-19 era, the study participants preferred to walk within the neighborhood rather than the urban center, especially in neighborhood public open spaces. Since the 1960s, Seoul has focused on developing urban cores based on rapid industrialization, high access to public transportation, and increased demand for public services (Lee & Kim, 2001). This has led most Seoul residents to revolve around several urban centers away from their neighborhoods, and there had been little interest in their neighborhoods (Lee & Choi, 2015). Additionally, most Seoul residents have restrictions on exercise at home. This is because high-rise apartments, which are advantageous in accommodating the overcrowded population but are vulnerable to noise between floors, are common housing types in Seoul (Kim & Han, 2012). Therefore, in Seoul, it has established as a social norm to exercise in indoor or outdoor facilities, not home exercise exercise (Ha et al., 2015). However, with the COVID-19 pandemic, SDM discouraged long-distance travel and the use of indoor facilities, and may have served as an opportunity to reflect on the value of the neighborhood as a walking place. In this sense, in the post-COVID-19 era, there is a need to review and modify urban planning and design to meet the increased demand for public open spaces and pedestrian environments in the neighborhood during the pandemic. Particularly, considering the tendency of high-quality public open spaces in metropolitan cities to be distributed mainly to high socioeconomic levels of neighborhoods, we should first focus on the development of public open spaces in vulnerable neighborhoods (Oh & Jeong, 2007). This approach can contribute to the achievement of equity in urban health and the strengthening of attachment to neighborhoods.

Walking practices in Seoul decreased between before and during the pandemic, particularly in utilitarian walking. Before the COVID-19, the SMG had emphasized utilitarian walking by inducing residents to go out for various purposes in dense urban environments (Kim et al., 2018; Lee, Kim, & Yoo, 2020). However, as the COVID-19 response has emerged as a top priority, Seoul is rapidly integrating non-contact technology and online services into urban systems, including the retail, education, finance, and administration sectors, to enable daily life without going out (Korea Internet and Security Agency, 2020). These changes in the urban system can be expected to increase sedentary behavior across the overall lifestyle of urban residents during the pandemic. Hall et al. (2021) also predicted that the urban systems that accelerated physical inactivity patterns and sedentary behavior could continue to operate after the pandemic. Hence, the practice of utilitarian walking in a metropolitan city may not recover to pre-pandemic levels, unlike walking for other purposes, and the realization of active life may be hindered at the urban system level. Therefore, a public health approach is needed to break the physical inactivity habits that permeate the daily lives of urban residents during the COVID-19 pandemic. Recently, there has been a paradigm shift in the guidelines for promoting physical activity. The 2018 U.S. Physical Activity Guidelines officially abolished minimum standards for physical activity, acknowledging the benefits of all physical movements to reduce sedentary behavior and increase physical activity in life (U.S. Department of Health and Human Services, 2018). This stance suggests a direction for public health interventions to increase walking practices. Rather than focusing on the amount of walking practice, the new guidelines and message framing for promoting walking should focus on increasing the frequency of walking practice in everyday life.

Limitations

Several limitations of this study need to be acknowledged. First, the sample of this study is unlikely to represent the general population of Seoul, given that only those who can conduct online surveys participated. Therefore, the generalizability of our findings is limited. Second, self-reported questionnaire surveys have the potential to cause respondent bias. For example, the walking practices that participants responded to might be inconsistent with the facts, which could affect the reliability of the results. Third, the responses to pre-COVID-19 situations may have a recall bias. Finally, the variables in this study were measured using a single-item questionnaire, and the results did not cover all the

characteristics of urban walking. However, despite all the limitations, this study can be used as evidence for identifying the impact of SDM, indispensable strategies to control the spread of disease, and the active lives of urban residents.

Conclusion

In this study, we provided novel evidence on the changes in urban walking before and during the COVID-19 pandemic in Seoul, a metropolitan city. During the pandemic, active life based on walking among urban residents was severely disrupted. Additionally, the perceived environment for walking places and the choice of transportation modes changed to a different pattern than before the pandemic. Given that the pandemic is still ongoing, these findings may have crucial and timely urban health implications and provide information for the development of public health intervention research in the post-COVID-19 era.

Correspondence should be addressed to

Seunghyun Yoo, Ph.D.
Department of Public Health Sciences
Graduate School of Public Health
Seoul National University
Seoul 08826, Korea.
syoo@snu.ac.kr
+82-02-880-2725

- Dong Ha Kim: 0000-0003-0444-0479
- Seunghyun Yoo: 0000-0002-6719-7632

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Conflicts of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization, D.H.K. and S.Y.; Methodology, D.H.K. and S.Y.; Data curation, D.H.K.; Data interpretation, D.H.K. and S.Y.; Writing – Original Draft, D.H.K.; Writing – Review & Editing, S.Y.; Funding acquisition, S.Y.; Supervision, S.Y.

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References

Caputo, E. L., & Reichert, F. F. (2020). Studies of physical activity and COVID-19 during the pandemic: A scoping review. *Journal of Physical Activity and Health*, *1*(AOP), 1-10.

Choe, Y. J., & Lee, J. K. (2020). The impact of social distancing on the transmission of influenza virus, South Korea, 2020. *Osong Public Health and Research Perspectives*, *11*(3), 91-92.

Chomistek, A. K., Manson, J. E., Stefanick, M. L., Lu, B., Sands-Lincoln, M., Going, S. B., ... & Eaton, C. B. (2013). Relationship of sedentary behavior and physical activity to incident cardiovascular disease: Results from the Women's Health Initiative. *Journal of the American College of Cardiology*, *61*(23), 2346-2354.

Fong, M. W., Gao, H., Wong, J. Y., Xiao, J., Shiu, E. Y., Ryu, S., & Cowling, B. J. (2020). Nonpharmaceutical measures for pandemic influenza in nonhealthcare settings--social distancing measures. *Emerging Infectious Diseases*, *26*(5), 976-985.

Ha, J., Lee, T., & Shin, E. (2015). Social Inter-Floor Noiseproof Measures According to Experiences of Conflict in Multi-Family Housing. *Journal of the Korean housing association*, *26*(6), 1-8.

Hall, G., Laddu, D. R., Phillips, S. A., Lavie, C. J., & Arena, R. (2021). A tale of two pandemics: How will COVID-19 and global trends in physical inactivity and sedentary behavior affect one another?. *Progress in cardiovascular diseases*, *64*, 108.

Kim, E. A. (2020). Social distancing and public health guidelines at workplaces in Korea: responses to Coronavirus disease-19. *Safety and Health at Work*, *11*(3), 275-283.

Kim, D. H., Chung, C. K., Lee, J., Kim, K. K., JeKarl, J., & Yoo, S. (2018). A systems thinking approach to explore the structure of urban walking and health promotion in Seoul. *Korean Journal of Health Education and Promotion, 35*(5), 1-16. (Korean)

Kim, H. M., & Han, S. S. (2012). Seoul. *Cities*, *29*(2), 142-154.

Korea Disease Control and Prevention Agency. (2020). *2019 Community health survey questionnaire.* Osong, Korea: Author. (Korean)

Korea Internet and Security Agency. (2020). *2020 KISA report.* Naju, Korea: Author. (Korean)

Lee, E., & Choi, H. (2015). Urban community formation process in the city of Seoul: Case of Seodaemun-gu community building project. *The Korea Spatial Planning Review, 84*, 75-94. (Korean)

Lee, J., Kim, D. H., & Yoo, S. (2020). Factors associated with Seoul citizen's utilitarian and leisure walking. *Seoul Studies, 21*(4), 233-253. (Korean)

Lee, W. H., & Kim, Y. U. (2001). A study on the transformation of spatial morphology of Seoul -the analysis of spatial configuration using space syntax. *Journal of the Urban Design Institute of Korea Urban Design, 3*(1), 41-57. (Korean)

Lim, H. (2021). Public transportation passengers in Seoul plunged last year due to Corona. Retrieved June 05, 2021, from https://www.yna.co.kr/view/AKR20210209157351004

Lim, S., Lim, H., & Després, J. P. (2020). Collateral damage of the COVID-19 pandemic on nutritional quality and physical activity: Perspective from South Korea. *Obesity*, *28*(10), 1788-1790.

Louro, A., Franco, P., & Marques da Costa, E. (2021). Determinants of Physical Activity Practices in Metropolitan Context: The Case of Lisbon Metropolitan Area, Portugal. *Sustainability*, *13*(18), 10104.

Ministry of Foreign Affairs in Korea. (2020). *All about Korea's response to COVID-19*. Seoul, Korea: Task Force for Tackling COVID-19, Ministry of Foreign Affairs in Korea.

Madhuripan, N., Cheung, H. M., Cheong, L. H. A., Jawahar, A., Willis, M. H., & Larson, D. B. (2020). Variables influencing radiology volume recovery during the next phase of the coronavirus disease 2019 (COVID-19) pandemic. *Journal of the American College of Radiology*, *17*(7), 855-864.

Min, K. D., Kang, H., Lee, J. Y., Jeon, S., & Cho, S. I. (2020). Estimating the effectiveness of non-pharmaceutical interventions on COVID-19 control in Korea. *Journal of Korean Medical Science*, *35*(35), e321.

Ministry of Land Infrastructure and Transport. (2020). *Public Transportation Investigation (2011~2019).* Sejong city, Korea: Author. (Korean)

Oh, K., & Jeong, S. (2007). Assessing the spatial distribution of urban parks using GIS. *Landscape and urban planning*, *82*(1-2), 25-32.

Park, B., & Cho, J. (2021). Older adults' avoidance of public transportation after the outbreak of COVID-19: Korean subway evidence. *Healthcare (Basel, Switzerland)*, *9*(4), 448.

Park, J. H., Yoo, E., Kim, Y., & Lee, J. M. (2021). What happened pre-and during COVID-19 in South Korea? Comparing physical activity, sleep time, and body weight status. *International Journal of Environmental Research and Public Health*, *18*(11), 5863.

Scorrano, M., & Danielis, R. (2021). Active mobility in an Italian city: Mode choice determinants and attitudes before and during the Covid-19 emergency. *Research in Transportation Economics*, *86*, 101031.

Seong, E. Y., Lee, N. H., & Choi, C. G. (2021). Relationship between land use mix and walking choice in high-density cities: A review of walking in Seoul, South Korea. *Sustainability*, *13*(2), 810.

Seoul Metropolitan Government. (2021). Seoul open data plaza. Retrieved June 08, 2021, from https://data.seoul.go.kr/

Seoul Metropolitan Government. (2018). *Seoul Public Transportation*. Seoul, Korea: Author.

Seoul Transport Operation and Information Service. (2021). Traffic status. Retrieved June 07, 2021, from https://topis.seoul.go.kr/

Shon, C. (2021). The role of cities as the first responder to pandemics: Focusing on the case of the Seoul Metropolitan Government's response to the COVID-19. *Journal for Peace and Nuclear Disarmament*, *4*(sup1), 60-72.

Stockwell, S., Trott, M., Tully, M., Shin, J., Barnett, Y., Butler, L., McDermott, D., Schuch, F., & Smith, L. (2021). Changes in physical activity and sedentary behaviours from before to during the COVID-19 pandemic lockdown: A systematic review. *BMJ Open Sport & Exercise Medicine*, *7*(1), e000960.

U.S. Department of Health and Human Services. (2018). Physical Activity Guidelines for Americans 2nd edition. Washington: Author.

World Health Organization. (2021). WHO coronavirus (COVID-19) dashboard. Retrieved October 01, 2021, from https://covid19.who.int/.

World Health Organization. (2020). *COVID-19 Public Health Emergency of International Concern (PHEIC) global research and innovation forum: Towards a research roadmap.* Geneva, Switzerland: Author.

World Health Organization. (2010). *Global recommendations on physical activity for health.* Geneva, Switzerland: Author.