



OPEN Impact of coronavirus (COVID-19) pandemic on physical activity levels in different sub-populations of Iranians: a national survey

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During the COVID-19 pandemic, the level of physical activity (PA) has been reported to decrease worldwide. A sedentary lifestyle is widely recognized as a significant risk factor for various diseases, necessitating extensive big data analysis to uncover the diverse aspects linked to the COVID-19 pandemic. Therefore, the aim of this study was to investigate the impact of the COVID-19 pandemic on PA levels across diverse population subsets in Iran and to identify the barriers to PA during the fifth wave of COVID-19 outbreak. Data from 7810 individuals (50.8% male, 54.8% married, 69.6% 18–49 years) were collected using a standardized questionnaire comprising demographic details, levels of high, moderate, and low PA, daily sedentary time, PA at home, and barriers to PA. The questionnaire was distributed online via social platforms such as Telegram, WhatsApp, and Instagram. The obtained data were analyzed using the Chi-Square goodness-of-fit test and the Chi-Square test at a significance level of $\alpha < 0.05$. During the COVID-19 pandemic, there was a significant decrease in the number of days/week dedicated to high, moderate, and low PA, as well as a reduction in the duration of each PA session compared to pre-pandemic levels ($p < 0.001$). Conversely, the duration of daily sedentary time, particularly exceeding 5 h, significantly increased post-outbreak ($p < 0.001$). Notably, lack of appropriate space and time constraints were identified as the primary barriers to PA during the COVID-19 pandemic ($p < 0.001$). In this nationally representative study, the findings underscore a substantial decline in PA levels across diverse sub-populations in Iran and an increase in sedentary behaviors during the COVID-19 crisis.

Keywords Corona virus, Quarantine, Exercise training, Sports participation, Sedentary behaviors

Since the end of 2019, the world has faced a global outbreak of coronavirus disease 2019 (COVID-19), which has disrupted the working, living, and learning conditions across different sub-populations worldwide due to its highly contagious nature^{1,2}. The rapid spread of COVID-19 has posed unforeseen challenges and taken a significant toll on people, affecting most aspects of human lifestyle, specifically physical activity (PA)^{3–5}. In this regard, Tison et al. investigated the worldwide impact of the COVID-19 pandemic on daily step counts and found a 5.5% and 27.3% decrease in mean steps within 10 days and 30 days of the pandemic declaration, respectively⁶. The reductions varied across different countries. For instance, Italy experienced a 48.7% reduction due to a nationwide lockdown, while Sweden, which advocated for limitations on gatherings and social distancing, experienced a 6.9% decrease⁶. Other studies have also documented reduced PA during the pandemic^{7–9}. Iran has been one of the countries most affected by COVID-19, with one of the highest rates of infection in the world and the highest rate of mortality in the Middle East¹⁰.

To mitigate the spread of infection, Iran has implemented a stringent package of preventive health measures, which have negatively impacted the PA of people. Consequently, the level of PA has been shown to decrease among Iranian population across different provinces in various research studies^{10–15}. However, PA has been found to be associated with decreased hospitalization, ICU admissions, and mortality rates of patients with COVID-19. Additionally, COVID-19 patients with a history of resistance and endurance exercises experience a lower rate of hospitalization and mortality, respectively¹⁶.

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Sedentary lifestyle is a well-established risk factor for chronic non-communicable diseases, including obesity, cardiovascular disease, cancer, and diabetes mellitus. Regular exercise training, on the other hand, is considered an important and effective strategy for improving immune function and preventing and managing these chronic diseases^{17,18}. Current recommendations suggest that children and adolescents (ages 5 to 17) engage in moderate to vigorous PA for at least 1 h per day, while adults and the elderly (18 years and older) should aim for 75 min per week of vigorous PA or 150 min per week of moderate PA to attain the health benefits¹⁹. Indeed, regular exercise training, when combined with appropriate nutritional strategies, enhances the body's immune system function^{20–22}. In general, each session of moderate-intensity exercise for a suitable duration supports the immune system and, when performed regularly, elicits anti-inflammatory and antioxidant effects that can reduce mortality and the occurrence of chronic diseases, as well as reduce the risk of influenza, systemic infection, and upper respiratory tract infection (URTI)^{20,22,23}. This suggests that maintaining a physically active lifestyle may play a protective role in the context of COVID-19, potentially reducing the severity of the disease and its impact on individuals. Therefore, it is important to examine the reasons and different aspects related to the reduction of PA. In this regard, gym closures, social distancing measures, and stay-at-home orders may be among the most important reasons limiting people's ability to engage in PA programs^{18,24}.

The published reports on the COVID-19 pandemic have highlighted the need for additional epidemiological research and big data analysis to identify various aspects and specific factors that have contributed to the decline in PA among different populations. Understanding these factors is crucial for developing effective interventions to promote PA during possible similar pandemics in the future. Therefore, this national survey was designed to investigate the impact of the COVID-19 pandemic on PA levels across different sub-populations of the Iranian population.

Results

Demographic characteristics of the participants are reported in Table 1. The proportion of male and female respondents was nearly equal, and almost half of the respondents fell within the age range of 30 to 49 years. Furthermore, most respondents resided in urban areas.

The number of people who engaged in PA 2–3 days and more than 3 days per week decreased significantly. Meanwhile, the number of people who did not engage in PA or did it only one day a week increased (Fig. 1). The duration of weekly PA significantly decreased across all three intensities (high, moderate, and low PA), with fewer respondents engaging in 30–60 min and more than 60 min of daily PA. Conversely, the number of people performing less than 30 min of PA per day increased significantly. Additionally, during the COVID-19 pandemic, there was a significant increase in the number of people sitting for 5–8 and more h/day compared to before the pandemic.

The frequency and duration of PA during the COVID-19 pandemic were compared between men and women, as well as urban and rural/suburban populations, as shown in Fig. 2. It appears that a greater proportion of men engaged in PA 2–3 days or more per week compared to women. Moreover, the urban population exhibited higher levels of both the frequency and duration of PA in comparison to the rural/suburban population.

A higher proportion of respondents in the age groups of under 18 and 18 to 29 years, with education levels of elementary/high school, and diploma and associate degrees, engage in high-intensity PA more than 3 times a week (Fig. 3).

Figure 4 illustrates barriers to participating in PA during the COVID-19 pandemic. Lack of appropriate space and lack of time were identified as the primary barriers by 57.4% and 64.3% of respondents, respectively. However, other proposed barriers received less agreement.

Discussion

To the best of our knowledge, no research has been conducted regarding the effects of the COVID-19 pandemic on the amount of PA among the Iranian people at the national level. Since the COVID-19 pandemic is considered the biggest global crisis after the Second World War, causing a significant change in people's lifestyle by closing public centers, especially sports venues, the results of the current research are of great importance. This issue can be clearly observed from the present findings, so that based on the self-declaration of the respondents, the number of days per week of vigorous, moderate, and light PA, and the duration of PA in each session during the period of the COVID-19 outbreak had decreased significantly among the Iranian people compared to before the outbreak ($p < 0.001$). In fact, the percentage of people who normally did two or more days of PA per week before the outbreak (the application of home quarantine rules) has decreased. In contrast, the percentage of those who did zero or one day of PA per week has increased. Moreover, the percentage of people who did half an hour to more than one hour of PA in each session has decreased significantly. On the other hand, the percentage of those who did zero to half an hour of PA in each session has increased. Meanwhile, the daily sitting time, as a sedentary behavior, among different sub-populations of Iranian people showed a significant increase compared to before the COVID-19 outbreak ($p < 0.001$). Therefore, our results confirm that PA levels among Iranian people were reduced, and the daily sitting time was generally increased during the lockdowns compared to the previous situation.

Based on the current body of literature, the present findings are in agreement with previous studies conducted in Iran^{10–14}. Saemi et al. (2022) showed significant decreases in Iranian's PA levels from before to during the pandemic, regardless of their gender¹³. Similarly, Charkazi et al. (2022) reported a decrease in the amount of PA after the COVID-19 outbreak among 2710 Iranians from all over the country¹². Additionally, similar results have been observed in various studies involving Iranian adults¹⁰, college students¹⁴, and individuals from specific cities in the country¹¹.

Variable		N (%)
Gender	Male	3970 (50.8)
	Female	3840 (49.2)
Marital status	Single	3530 (45.2)
	Married	4280 (54.8)
Age (years)	< 18	1291 (16.5)
	18 to 29	1906 (24.4)
	30 to 49	3533 (45.2)
	50 ≤	1080 (13.8)
Body mass (kg)	< 50	430 (5.5)
	50 to 60	1379 (17.7)
	61 to 70	2151 (27.5)
	70 to 80	1984 (25.4)
	81 to 90	1049 (13.4)
	91 to 100	490 (6.3)
	100 <	327 (4.2)
Height (cm)	< 150	149 (1.9)
	151 to 160	1810 (23.2)
	161 to 170	2674 (34.2)
	171 to 180	2174 (27.8)
	181 to 190	908 (11.6)
	191 to 200	88 (1.1)
	200 <	7 (0.1)
Educational stages	Elementary and high school	1380 (17.7)
	Diploma and associate	1348 (17.3)
	Bachelor	2889 (37)
	Master	1718 (22)
	Doctorate and upper	475 (6.1)
Employment status	Civil servant	3342 (42.8)
	Private employee	703 (9)
	Student	2126 (27.2)
	Self employed	1106 (14.2)
	Unemployed	533 (6.8)
Type of work during the COVID-19 pandemic	Remote work or work at home	1637 (21)
	Work at office	3018 (38.7)
	Legal restrictions of the government do not allow me to work	232 (3)
	I am retired/sick	136 (1.7)
	I am a student	2254 (28.9)
	I am unemployed	533 (6.7)
Geographic areas	Urban	6681 (85.5)
	Rural/Suburban	1129 (14.5)
Living space	Apartment, < 50 m	146 (1.9)
	Apartment, 50 to 100 m	2994 (38.3)
	Apartment, 100 to 200 m	1655 (21.2)
	Apartment, 200 m <	252 (3.2)
	House, < 50 m	73 (0.9)
	House, 50 to 100 m	797 (10.2)
	House, 100 to 200 m	1148 (14.7)
	House, 200 m <	745 (9.5)
Outdoor space for physical activity	Yes	5928 (75.9)
	No	1882 (24.1)

Table 1. Frequency distribution of demographic characteristics among the participants.

Our results also confirm findings from various other countries worldwide. Maugeri et al. (2020) reported that PA levels had decreased significantly between before and during the COVID-19 pandemic in all age groups, particularly among Italian men⁴. In an international study, Ammar et al. (2020) demonstrated that the pandemic negatively impacted all intensities of PA levels (i.e., vigorous, moderate, and walking) in people across Asia,

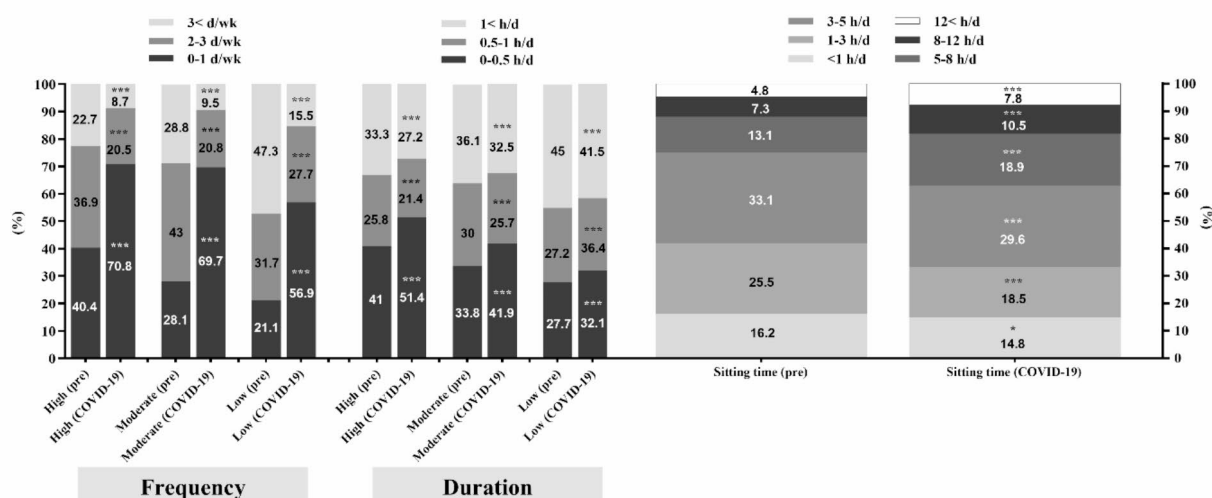


Fig. 1. Comparison of the frequency and duration of physical activity at high, moderate, and low intensities (left), and the daily sitting time (right) among Iranian people before (pre) and during the COVID-19 pandemic. * $p < 0.05$, *** $p < 0.001$.

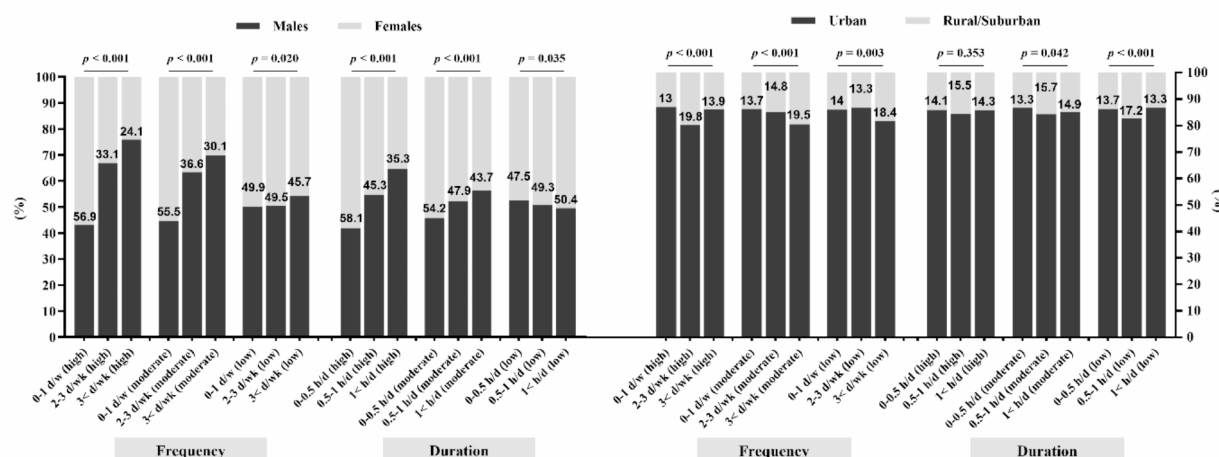


Fig. 2. Comparison of the frequency and duration of physical activity at high, moderate, and low intensities during the COVID-19 pandemic among Iranian men and women (left), and urban and rural/suburban people (right).

Africa, and Europe. In contrast, daily sitting time had increased from five to eight hours per day⁵. The findings of Castañeda-Babarro et al. (2020) revealed a significant decrease in PA levels during the pandemic period, with a 17% reduction in intense PA and a 58% reduction in walking time. Conversely, the sedentary time had increased by 24% in the Spanish adult population²⁵. Moreover, Wang et al. (2021) showed that during the outbreak, the level of walking, moderate- and high-intensity exercise had significantly decreased among Chinese adults²⁶.

The decrease in the amount of intense and moderate PA among Iranian people can be attributed to a fundamental change in their daily routines and habits. People who stay at home spend more time on light activities such as housework (e.g., cooking, washing dishes, or gardening). On the other hand, the increase in sedentary behaviors such as daily sitting time during the COVID-19 outbreak can be attributed to the increase in remote work and online businesses in virtual social networks. It seems that with the spread of COVID-19, social isolation, and the need for alternative forms of communication and entertainment, different sub-populations of people have increasingly turned to social networks for information about COVID-19, online education, earning money from home, and entertainment to make isolation more bearable²⁷.

Considering the significance of regular PA as an effective strategy for enhancing immune function and preventing systemic infections^{17,18,20}, the decrease in PA levels observed among different sub-populations of

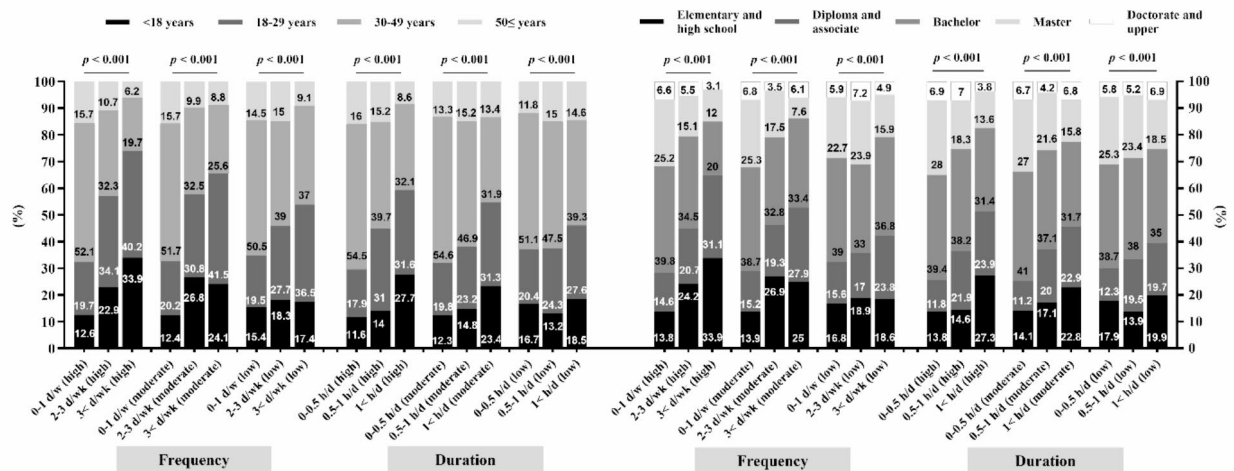


Fig. 3. Comparison of the frequency and duration of physical activity at high, moderate, and low intensities during the COVID-19 pandemic among different age groups (left), and educational levels (right) of Iranian people.

Iranian people during the COVID-19 outbreak can lead to serious complications and risks. This includes a reduction in immune system function and an increased risk of developing non-communicable chronic diseases such as obesity, diabetes, and various cardiovascular diseases.

The present findings showed that during the COVID-19 epidemic period, Iranian men engaged in different intensities of PA with higher duration per session and weekly frequency compared to women ($p < 0.05$). Women's lower amounts of PA may be due to the demands of their government jobs and household responsibilities. For instance, 55% of the female respondents were married, and 43% of them had government jobs, requiring them to work during office hours or remotely. Additionally, they had to manage household duties such as caring for children, which could contribute to their limited time for physical activity. Therefore, the lack of time for Iranian women seems to be one of the main reasons in this regard. In corroboration of this statement, Wang et al. (2021) found that Chinese women increased their home cooking and takeout orders during the COVID-19 pandemic²⁶, a trend that may also be relevant to Iranian women.

Our results revealed that the weekly frequency of PA across all intensities was higher among residents of rural areas and the outskirts of the city during the pandemic, compared to those in urban areas ($p < 0.05$). In contrast to the present findings, a study by Beck et al. (2021) reported that residents of non-rural areas engaged in higher levels of intense, moderate, and recreational PA compared to rural participants²⁸. The study involved 278 participants from 25 US states, with 50% from rural and 50% from non-rural areas, who completed an online questionnaire to describe their PA levels during the COVID-19 pandemic. However, the researchers noted that half of the respondents who identified as rural were actually considered non-rural based on their zip code, which may partially explain the contradiction in the results.

The current research found that men and women aged 18 to 49 had more weekly sessions with longer durations than those under 18 and over 49 ($p < 0.001$), and that people with education levels ranging from "below diploma" to "postgraduate level" had higher weekly frequency and duration of PA than other education levels ($p < 0.001$). On the other hand, respondents identified "lack of appropriate space" and "lack of time" as the main barriers to PA during the COVID-19 pandemic ($p < 0.001$). These findings are consistent with previous studies. Khalidifard et al. (2017) demonstrated that "lack of time", "lack of sports facilities", and "lack of motivation" were the most prevalent barriers to participation in PA among 3000 Iranians from 14 provinces²⁹. Moreover, in another study conducted by Farah et al. (2021) on Brazilian adults, the main barriers to regular participation in PA during the COVID-19 outbreak were reported as "Laziness and fatigue", "lack of motivation", "lack of appropriate facilities/equipment/space", and "lack of time"³⁰.

Conclusions

In the present research, for the first time since the spread of the COVID-19 in the world, the effects of this epidemic on PA levels (duration, frequency, and across different intensities) and barriers to PA were investigated among different sub-populations of Iranian people at the national level. As expected, the weekly frequency of PA and the duration in each session significantly decreased during the COVID-19 outbreak compared to before pandemic. Conversely, the amount of sitting time during the day (as a sedentary behavior) increased significantly. Furthermore, analysis of different sub-populations revealed that during the COVID-19 pandemic, men compared to women, residents of rural areas and the outskirts of the city compared to urban areas, people 18 to 49 years old compared to under 18 years and older 49 years old, and people below diploma to post-diploma compared to other education levels had engaged in more PA per week. Additionally, "lack of appropriate space"

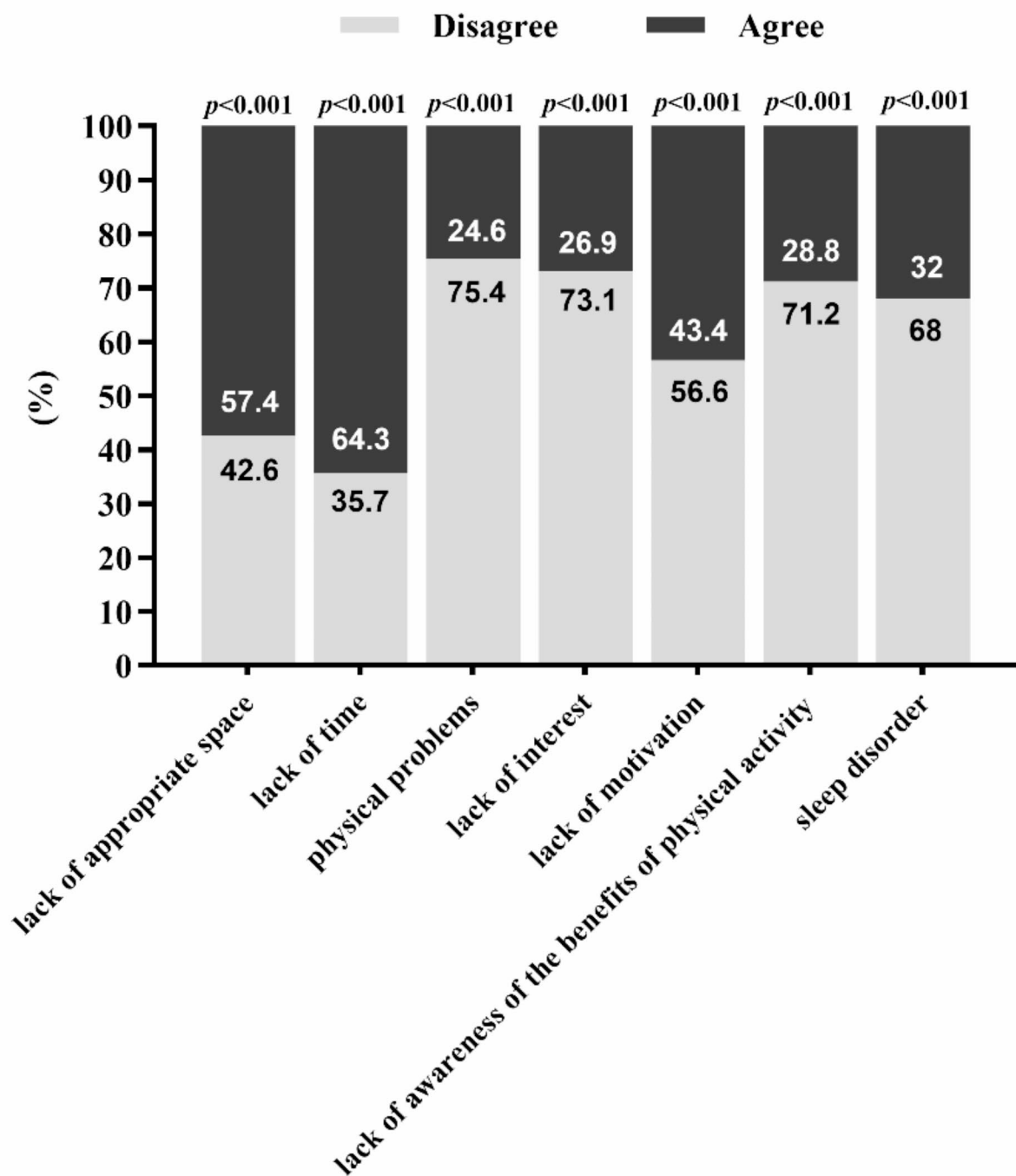


Fig. 4. Primary barriers hindering the engagement of Iranians in physical activity during the COVID-19 pandemic. Note: The percentage of individuals with physical problems is based on the initial total of 10,358 respondents, whereas the other percentages are reported from the 7810 individuals included in the final analysis.

and “lack of time” were the main barriers to participation in PA during the fifth wave of COVID-19 outbreak in Iran.

Methods

Participants

The current cross-sectional study was carried out in Iran from June 22 to September 22, 2021, during the fifth wave of COVID-19 outbreak. Based on the 2016 census of the Statistical Center of Iran³¹, the entire population

living in Iran was reported to be about 80 million people. Hence, Cochran's equation was used to determine the sample size required for the study. Using the equation, an estimated sample size of 2401 people was necessary to achieve a 2% margin of error with 95% confidence level and a statistical power ($1 - \beta$ error) of 98%.

$$n = Z^2 \cdot \frac{p(1-p)}{e^2}$$

All participants were residents of Iran, were able to operate networks of smart communication devices (e.g., smartphones and computers), were able to read and understand the questions in the questionnaire, were not suffering from COVID-19 at the time of answering or within four weeks before and were able to perform daily activities without the help of people or tools. The informed consent was obtained from all participants. The present study was conducted in compliance with the Declaration of Helsinki and received approval from the Review Board of Iranian Sport Sciences Research Institute (IR.SSRC.REC.1400.091).

Study procedure

Initially, the country was divided into five regions: North, South, Center, East, and West. Specific provinces were then selected to represent each region: Gilan and Mazandaran for Northern, Tehran and Isfahan for Central, Fars and Hormozgan for Southern, Razavi and South Khorasan for Eastern, and Kurdistan and Ilam for Western. With the exception of Gilan province, the other provinces were chosen randomly. To collect data, a virtual questionnaire was designed, incorporating Telegram, WhatsApp, and Instagram, and was published in various groups and channels with a high number of members. Due to the online nature of the questionnaire and the presence of members from other provinces in the selected virtual spaces, a total of 10,358 respondents initially completed the questionnaire. However, responses from 2548 individuals were excluded from further analysis due to physical problems. Consequently, the data from 7810 individuals, representing all 31 provinces of the country, were included in the final analysis.

Questionnaire

A three-part standard questionnaire was used in this study. The first part consisted of demographic information, including gender, marital status, education level, employment status, age, body weight, height, province of residence, type of home, amount of income, and type of work during the COVID-19 outbreak period. The second part involved determining the amount of PA using the questionnaire provided by Maugeri et al.⁴, which was an adapted version of the International Physical Activity Questionnaire (IPAQ) questionnaire. The third part aimed to identify the factors that inhibit the participation of Iranian people in PA throughout the COVID-19 pandemic by using the standard tool, namely, the Barriers to Being Active Quiz (BBAQ)³².

The second part of the questionnaire consisted of 17 simple questions asking participants to report any changes in their level of PA since the onset of COVID-19 restrictions. The questions were designed to collect information on whether participants' PA remained the same, increased, or decreased. The questions examined light, moderate, and vigorous PA, sitting position, and PA at home. These components were defined as below:

- *Light PA*: An increase in heart rate above the resting state, allowing a person to talk while exercising but not sing.
- *Moderate PA*: An increase in heart rate slightly above the resting state, allowing a person to talk and sing while exercising.
- *Vigorous PA*: An increase in heart rate much higher than the resting state, preventing a person from speaking or singing during the activity.
- *Sitting position*: The amount of time in a normal day that a person is in a sitting position.
- *PA at home*: The type of PA, how to perform it, and the source used to design the movements.

Additionally, the BBAQ questionnaire was used to evaluate barriers to participating in PA, including lack of time, social influence, lack of energy, lack of motivation and will, fear of injury, lack of skills, and lack of resources (such as amenities and sports activity equipment). The questionnaire included 17 questions asking respondents to rate the degree of hindrance effect of each item on participation in PA and sports based on a four-point scale from "zero" for "completely disagree" to "three" for "I completely agree".

Statistical analysis

The statistical software, IBM SPSS[®] 22.0 for Windows[®] was used for data analysis, with an alpha level set at < 0.05 to determine statistical significance and minimize Type I error. Categorical data were reported in frequencies as sample size (n) and percentages. We used the Chi-Square goodness-of-fit test to investigate differences in PA levels and barriers to participation before and during the COVID-19 pandemic. Moreover, the Chi-Square test was used to compare PA levels across age groups, education levels, urban/non-urban areas, and gender.

Data availability

The data presented in this study are available on request from the corresponding author. The data are not publicly available due to restrictions.

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References

1. Moghadam, M. T., Taati, B., Paydar Ardakani, S. M. & Suzuki, K. Ramadan fasting during the COVID-19 pandemic; observance of health, nutrition and exercise criteria for improving the immune system. *Front. Nutr.* <https://doi.org/10.3389/fnut.2020.570235> (2021).
2. Taati, B., Arazi, H. & Kheirikhah, J. Interaction effect of green tea consumption and resistance training on office and ambulatory cardiovascular parameters in women with high-normal/stage 1 hypertension. *J. Clin. Hypertens. (Greenwich Conn)*. **23**, 978–986. <https://doi.org/10.1111/jch.14198> (2021).
3. Park, A. H., Zhong, S., Yang, H., Jeong, J. & Lee, C. Impact of COVID-19 on physical activity: a rapid review. *J. Global Health* **12**, 05003. <https://doi.org/10.7189/jogh.12.05003> (2022).
4. Maugeri, G. et al. The impact of physical activity on psychological health during Covid-19 pandemic in Italy. *Heliyon* **6**, e04315. <https://doi.org/10.1016/j.heliyon.2020.e04315> (2020).
5. Ammar, A. et al. Effects of COVID-19 home confinement on eating behaviour and physical activity: results of the ECLB-COVID19 international online survey. *Nutrients*. <https://doi.org/10.3390/nu12061583> (2020).
6. Tison, G. H. et al. Worldwide effect of COVID-19 on physical activity: a descriptive study. *Ann. Intern. Med.* **173**, 767–770 (2020).
7. Giustino, V. et al. Physical activity levels and related energy expenditure during COVID-19 quarantine among the sicilian active population: a cross-sectional online survey study. *Sustainability* **12**, 4356 (2020).
8. Meyer, J. et al. Changes in physical activity and sedentary behavior in response to COVID-19 and their associations with mental health in 3052 US adults. *Int. J. Environ. Res. Public Health* **17**, 6469 (2020).
9. Mehraeen, E. et al. The impact of COVID-19 pandemic on the levels of physical activity: a systematic review. *Infect. Disord. Drug Targets* **23**, 37–55 (2023).
10. Akbari, H. et al. How physical activity behavior affected well-being, anxiety and sleep quality during COVID-19 restrictions in Iran. *Eur. Rev. Med. Pharmacol. Sci.* **5**, 7847–7857 (2021).
11. Amini, H. et al. Physical activity during COVID-19 pandemic in the Iranian population: a brief report. *Heliyon* **6**, e05411 (2020).
12. Charkazi, A. et al. Effects of the COVID-19 pandemic on lifestyle among Iranian population: a multicenter cross-sectional study. *J. Res. Med. Sci. (Iran)* **27** (2022).
13. Saemi, E. et al. The impact of COVID-19 pandemic restrictions on physical activity and mental health status of Iranian people. *BMC Sports Sci. Med. Rehab.* **14**, 1–9 (2022).
14. Rafrat, M., Molani-Gol, R. & Sahebjam, M. Effect of COVID-19 pandemic on eating habits and lifestyle of college students in Tabriz, Iran: a cross-sectional study. *Front. Public Health*. <https://doi.org/10.3389/fpubh.2023.1185681> (2023).
15. Taheri, M. et al. Mental health, eating habits and physical activity levels of elite Iranian athletes during the COVID-19 pandemic. *Sci. Sports* **38**, 527–533 (2023).
16. Rahmati, M. et al. Baseline physical activity is associated with reduced mortality and disease outcomes in COVID-19: a systematic review and meta-analysis. *Rev. Med. Virol.* **32**, e2349 (2022).
17. Nieman, D. C. & Sakaguchi, C. A. Physical activity lowers the risk for acute respiratory infections: time for recognition. *J. Sport Health Sci.* **11**, 648–655 (2022).
18. Taati, B. et al. Protective roles of exercise and nutritional factors for immune system during delta variant-COVID-19 outbreaks: evidence review and practical recommendations. *Iran. J. Med. Microbiol.* **16**, 178–185. <https://doi.org/10.30699/ijmm.16.3.178> (2022).
19. World Health Organization. *Global Recommendations on Physical Activity for Health*. <https://www.ncbi.nlm.nih.gov/books/NBK305058/> (2010).
20. Nieman, D. C. & Wentz, L. M. The compelling link between physical activity and the body's defense system. *J. Sport Health Sci.* **8**, 201–217 (2019).
21. Arazi, H., Taati, B. & Suzuki, K. A review of the effects of leucine metabolite (β -hydroxy- β -methylbutyrate) supplementation and resistance training on inflammatory markers: a new approach to oxidative stress and cardiovascular risk factors. *Antioxid. (Basel)*. **7**, 148. <https://doi.org/10.3390/antiox7100148> (2018).
22. Suzuki, K. & Hayashida, H. Effect of exercise intensity on cell-mediated immunity. *Sports (Basel)* **9**, 8. <https://doi.org/10.3390/sports9010008> (2021).
23. Suzuki, K. Chronic inflammation as an immunological abnormality and effectiveness of exercise. *Biomolecules* **9**, 223. <https://doi.org/10.3390/biom9060223> (2019).
24. Kaur, H., Singh, T., Arya, Y. K. & Mittal, S. Physical fitness and exercise during the COVID-19 pandemic: a qualitative enquiry. *Front. Psychol.* <https://doi.org/10.3389/fpsyg.2020.590172> (2020).
25. Castañeda-Babarro, A., Arbillaga-Etxarri, A., Gutiérrez-Santamaría, B. & Coca, A. Physical activity change during COVID-19 confinement. *Int. J. Environ. Res. Public Health* **17**, 6878 (2020).
26. Wang, J. et al. Change in eating habits and physical activities before and during the COVID-19 pandemic in Hong Kong: a cross-sectional study via random telephone survey. *J. Int. Soc. Sports Nutr.* **18**, 33. <https://doi.org/10.1186/s12970-021-00431-7> (2021).
27. Tsourgiannis, L., Valsamidis, S., Karagianni, P. & Tassos, K. The use of internet and social networks during COVID-19 in Greece. *KnE Soc. Sci.*, 360–374. <https://doi.org/10.18502/kss.v8i1.12656> (2023).
28. Beck, A. M., Gilbert, A. S., Duncan, D. D. & Wiedenman, E. M. A cross-sectional comparison of physical activity during COVID-19 in a sample of rural and non-rural participants in the US. *Int. J. Environ. Res. Public Health* <https://doi.org/10.3390/ijerph18094991> (2021).
29. Khaledifard, A., Alidoust Ghahfarrokhi, E., Mahmudvand, Z., Aghayi, A. & Kabomier, R. An investigation of factors and barriers to participation in sport for all and recreation sport in Turkish, kurdish and lor provinces of Iran. *New Trends Sport Manag.* **6**, 21–37 (2018).
30. Farah, B. Q. et al. Barriers to physical activity during the COVID-19 pandemic in adults: a cross-sectional study. *Sport Sci. Health* **17**, 441–447 (2021).
31. Statistical Centre of Iran. *Selected Findings of the 2016 National Population and Housing Census*. <https://www.amar.org.ir/english/Population-and-Housing-Censuses> (2018).
32. Centers for Disease Control and Prevention (CDC). *Briersto being active quiz what keeps you from being more active?*. https://www.google.com/url?sa=t&rct=j&q=&resrc=s&source=web&cd=&ved=2ahUKEwj_mvfm4cODAxVu8QIHHanrDPAQFnoECBcQAQ&url=https%3A%2F%2Fwww.cdc.gov%2Fdiabetes%2Fprofessional-info%2Fpdfs%2Ftoolkits%2Froad-to-health-barriers-activity-quiz-p.pdf&usg=AOvVaw1MMHeM_gCm3r4LpRWwglY2&opi=89978449 (2019).

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Author contributions

H.A. designed and supervised the study. B.T. collected and analyzed the data, wrote the first draft of the manuscript. H.A. contributed to conceptualization, validation, rewriting, reviewing, and editing of the manuscript.

Both authors read and approved the final version of the manuscript.

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Declarations

Competing interests

The authors declare no competing interests.

Additional information

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