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Original Article

Impact of the COVID-19 Pandemic on Objectively Measured Physical Activity and Sedentary Behavior in Female Adolescents: A Longitudinal Study

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Abstract

Introduction: Numerous studies employing self-reported questionnaires and cross-sectional methodologies have demonstrated that social isolation resulting from the COVID-19 pandemic has markedly influenced the physical activity (PA) levels of youth.
Objective: This study utilized modern accelerometers to assess the impact of the pandemic-related lockdown on PA levels of female adolescents, acknowledging the intrinsic limitations associated with the objectivity of self-reported PA.
Methods: A cohort of 29 Iranian female students, aged between 15 and 18 years, utilized accelerometers for a duration of seven consecutive days, both prior to and during the pandemic. The analysis of PA levels of these students was conducted using descriptive statistics and paired t-tests.
Results: The mean daily engagement in moderate-to-vigorous PA (MVPA) was documented at 46.8 minutes prior to the pandemic. However, this figure saw a significant reduction to 20.7 minutes during the pandemic, a level that is below the recommended international guidelines.
Conclusion: This observation highlights the significant influence of lockdown measures on PA levels of female adolescents. It underscores the necessity for tailored strategies and initiatives that cater to the specific needs and preferences of young individuals, aimed at fostering an appropriate level of PA during periods of social restrictions, such as those experienced during the pandemic.

Keywords: COVID-19, Exercise, Sedentary Behavior, Adolescents, Device

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1. Introduction

COVID-19, a new strain of coronavirus, was first identified in December 2019 in Wuhan, China, and has since spread swiftly to almost every country around the world. On March 11, 2020, the World Health Organization (WHO) officially classified COVID-19 as a pandemic (1). In response to the swift transmission of the virus, various governments implemented stringent measures aimed at curbing its spread. These measures included home confinement, quarantine, and social isolation (2), which inadvertently and negatively impacted individuals' lifestyles. For instance, youth encountered the abrupt closure of schools and recreational facilities, resulting in a significant reduction in their daily activities. Rather than engaging in educational settings and social interactions or participating in sports, they were compelled to remain at home for extended periods. This scenario likely contributed to an increase in sedentary behavior (SB) among youth, a factor recognized as a significant risk for both physical and mental health (3-6). Reversely, it is widely recognized that consistent engagement in physical activity (PA) contributes to enhancements in cardiorespiratory and muscular fitness, the development of strong bones, improvements in memory and cognitive control, as well as a decrease in depressive symptoms and obesity among youth (e.g., 7-9). Additionally, research indicates that participation in PA during childhood is a predictor of PA levels in adulthood, thereby influencing public health outcomes (10,11). Nevertheless, numerous investigations have revealed that even before the onset of the pandemic, a significant number of youths failed to meet international guidelines (e.g., 12-14). It is reasonable to propose that the limitations enacted during the pandemic have contributed to a further decline in PA levels among this population.

In fact, a multitude of studies conducted across various nations has investigated the alterations in PA among youth as a result of the quarantine measures implemented during the pandemic (15-23). For instance, utilizing a parent-reported methodology, Dunton et al. (15) demonstrated that in the United States, there was a notable decline in children's PA alongside an increase in SB from the pre-pandemic

phase to the early stages of pandemic. Similarly, Elnaggar et al. (16) observed a significant reduction in the PA of adolescent boys in Saudi Arabia during the pandemic, while girls did not exhibit a significant decrease, likely due to their already low levels of PA. Gilic et al. (18) reported a marked decline in adolescents' PA in Bosnia and Herzegovina when comparing pre-pandemic levels to those during the pandemic, with only 24% of adolescents meeting international guidelines. Moore et al. (19) corroborated these findings in Canada, noting a significant drop in PA among youth, with only 24% adhering to the international guidelines. Comparable results have been documented in other countries, including Australia (20), Germany (22), and China (23). A comprehensive review conducted by Yomoda and Kurita (24) of various studies examining children's PA prior to and throughout the pandemic indicated an overall reduction in PA levels. The effects of the pandemic were significantly more significant among boys and older youth. In contrast, younger children, as well as those living in detached homes with greater space, in rural settings, or within larger family structures, exhibited a lesser decrease in their PA levels.\.

While previous research has enhanced our comprehension of the impact of the pandemic on PA of youth, these studies exhibit several limitations. Primarily, a significant number of these investigations rely on subjective self-reported questionnaires, which raise concerns regarding their accuracy, particularly when applied to younger populations (25-27). Additionally, the cross-sectional design employed in these studies restricts their ability to evaluate changes in PA among youth over time (15,16,18,19,20-23). The current study seeks to overcome these limitations by utilizing accelerometers for the objective measurement of PA and adopting a longitudinal research design. Unlike questionnaires, accelerometers provide a more objective assessment of PA, free from subjective bias, while the longitudinal framework facilitates the observation of potential changes in PA over time. Consequently, the objective of our study was to compare the levels of objectively measured PA and SB among female adolescents in Iran prior to and during the lockdown imposed by the COVID-19 pandemic.

2. Methods

2.1. Participants

The study involved 29 Iranian female students, aged between 15 and 18 years (mean age 15.96 years, SD = 0.42), enrolled in the tenth and eleventh grades at regular high schools. These students participated in the PAIR project (Physical Activity of Children and Adolescents in Iran), with data collection occurring from October 2019 to January 2020. Due to organizational constraints, only female students were available during this period. The project was interrupted by the onset of the COVID-19 pandemic in Iran in February 2020 and resumed a year later, with a second round of measurements conducted from October 2020 to March 2021, amidst the ongoing pandemic. At both measurement points, all participants were in good health and free from any acute physical conditions. The criteria for inclusion specified that participants must be female high school students who willingly agreed to take part in the study, with written consent secured from both the students and their parents. In contrast, those who did not complete the accelerometer protocol were excluded from participation. The research complied with the Declaration of Helsinki, and the study protocol was approved by the Ethics Committee of the Islamic Azad University. Both parents and students received comprehensive information regarding the study procedures, and written informed consent was obtained from the parents. The data collected were anonymized and used solely for the purposes of the study, with no sharing of information with third parties.

2.2. Measurement of Physical Activity

PA was assessed utilizing the ActiGraph wGT3X-BT accelerometer. These accelerometers are compact, non-invasive, and user-friendly devices designed to quantify the frequency, duration, and intensity of PA in terms of energy expenditure. The intensity of PA is categorized into four classifications— SB, light PA, moderate PA, and vigorous PA—based on established cut-off points proposed by a previous study (28,29). Prior to distribution to participants, each accelerometer was set to a recording frequency of 30 Hz. In recent years, accelerometers have emerged as the predominant devices in research settings, demonstrating robust validity and reliability across numerous studies (e.g., 30,31)

2.3. Procedure

Prior to the commencement of each data collection phase, meetings were convened at the school for the first survey and conducted online for the second survey. During these meetings, participants were briefed on the objectives of the study and the methodology involved. They received comprehensive instructions regarding the accelerometer, including guidance on its proper usage. Participants were specifically directed to affix the device to their right hip for a duration of seven consecutive days while awake, removing it only for showering, engaging in water-related activities, or during sleep. One day prior to the initiation of the individual data collection period, the accelerometer was activated and provided to the participant along with a standardized protocol sheet, which required them to document the times and reasons for any periods of non-wear. After a week, the accelerometer was retrieved from the student, and the collected data was downloaded. The device was then prepared for the subsequent participant, which involved a thorough disinfection process for both the accelerometer and the hip belt. Data collection prior to the pandemic occurred between October 2019 and January 2020, a period during which the coronavirus had not yet been identified in Iran, allowing schools and sports clubs to operate without restrictions. The official declaration of the pandemic in Iran occurred in February 2020. Data collection during the pandemic took place from October 2020 to March 2021, during which time schools, sports clubs, and recreational facilities such as parks and gyms - common venues for student PA - were closed to the public.

2.4. Data Analysis

Data analysis was conducted using SPSS Statistics

(version 26), where means and standard deviations (SD) were computed to summarize the data, and paired t-tests were performed to assess changes in PA among participants from the pre-pandemic period to during the pandemic. The significance level was established at $P < .05$.

3. Results

Table 1 presents the personal characteristics of the female adolescents involved in this research. There was a modest rise in height and weight from the pre-pandemic period to the pandemic phase, primarily attributed to typical physical growth. Notably, the body mass index (BMI) exhibited a significant increase ($t = 2.437$, $P = 0.020$), escalating from 20.82 prior to the pandemic to 22.86 during the pandemic, which may serve as an initial indication of the potential effects of the lockdown measures implemented during this period.

Table 1. Personal Variables of the Participants.

Variables	Before the Pandemic		During the Pandemic	
	Mean	SD	Mean	SD
Age (year)	15.96	0.42	16.55	0.50
Height (cm)	165.00	4.44	166.37	6.77
Weight (kg)	58.96	11.24	61.93	8.84
BMI (kg/m^2)	20.82	2.98	22.86	3.15

Table 2 illustrates the mean and SD of PA pattern, along with the outcomes of the paired t-tests. The accelerometer data demonstrate that prior to the pandemic, participants engaged in SB for 67.71% of their total time. However, during the pandemic, this figure rose significantly to 71.00% (P=0.03). The proportions of light and moderate PA remained consistent before and during the pandemic, with P-values of 0.864 and 0.711, respectively. In contrast, there was a marked decline in vigorous PA, which decreased from an average of 3.99% to 1.32% (P=0.001), and MVPA fell from 8.08% to 5.18% (P=0.001). In terms of absolute values, the total time allocated to MVPA diminished from an average of 328 minutes to 144 minutes (P=0.001), while daily MVPA decreased from 46 minutes to 20 minutes (P=0.001). These figures are significantly below international guideline. Notably, even before the pandemic, only 21% of female participants met the recommended MVPA levels; during the pandemic, this number dropped to zero. Consequently, daily energy expenditure also saw a significant reduction, falling from 547 kcal to 319 kcal (P=0.001).

Table 2. Mean and Standard Deviation of PA Variables.

Variables	Before		During		Paired t-Test
	Mean	SD	Mean	SD	
Sedentary Behavior (%)	67.71	2.93	71.00	4.07	t = 2.291 P=0.030*
Light PA (%)	24.21	2.68	23.82	2.67	t = 0.287 P=0.864
Moderate PA %	4.09	1.13	3.86	0.93	t = 0.337 P=0.711
Vigorous PA %	3.99	1.42	1.32	0.99	t=5.720 P<0.001***
MVPA %	8.08	2.34	5.18	1.83	t=-8.760 P<0.001***
Total MVPA	328.09	142.84	144.97	51.98	t= 24.550 P<0.001***
Daily MVPA (minutes)	46.87	19.52	20.71	7.81	t=7.158 P<0.001***
Energy Expenditure (Kcal per day)	547.71	227.64	319.26	70.34	t=4.365 P<0.001***

*P<0.05; ***P<0.001

4. Discussion

This study employed contemporary accelerometers and a longitudinal study design to objectively assess PA levels of female adolescents over time, from pre to after the COVID-19 pandemic. Initially, our analysis revealed a significant rise in both weight and BMI among female adolescents from the pre-pandemic period to the duration of the pandemic. This observation aligns with findings from previous research (e.g., 32,33) and may serve as an initial indication of the potential effects of social isolation measures. However, it is important to recognize that the observed increase in weight and BMI may also be attributed to the typical physical development associated with this age group.

The primary aim of the research was to examine the PA patterns of adolescents before and during the pandemic. The results indicate a pronounced negative impact of social isolation measures on these behaviors. Specifically, there was a significant increase in SB from the pre-pandemic period to the pandemic phase, while levels of vigorous PA and MVPA experienced a significant decline. For instance, prior to the onset of the pandemic, female adolescents engaged in an average of approximately 46 minutes of MVPA daily, which is already below international recommendations. However, during the pandemic, this average was reduced to merely 20 minutes per day. It is noteworthy that no significant alterations were observed in light and moderate PA, which represent the less intense categories of PA.

In accordance with international recommendation, our findings indicate that prior to the onset of the pandemic, only 21% of adolescents met this guideline. Conversely, a significant majority, comprising 79%, engaged in PA for less than 60 minutes, with 14% participating for fewer than 30 minutes. During the pandemic, none of the participants managed to achieve 60 minutes or more of MVPA; only 14% of female adolescents reported engaging in at least 30 minutes of MVPA, while the majority remained largely inactive. Overall, these observations reveal a marked decline in health-related PA levels.

Recent research has indicated a significant decrease in PA among youth as a result of the social isolation measures implemented during the pandemic (15-23). However, to our knowledge, no studies have employed objective methodologies to quantify PA and present results in terms of precise minutes of MVPA. Some investigations have assessed MVPA among adolescents during the pandemic through self-reported surveys. For instance, findings revealed that Greek adolescents (34) and children in the United States (35) engaged in only 24 and 34 minutes of MVPA per day, respectively. In our study, we observed an even lower average of 20 minutes of MVPA among participants, which may be attributed to several factors. First, self-reporting methods typically yield inflated PA estimates compared to objective measures like accelerometry, as individuals often overrate their activity levels (25-27). Second, unlike the aforementioned studies, our research focused solely on female adolescents, and existing literature consistently indicates that girls are generally less physically active than boys (12,13,36). Finally, it is plausible that cultural and socioeconomic disparities between Iranian youth and their counterparts in Western nations contribute to this observation. In Iran and other predominantly Muslim countries, young women often encounter various regulations that limit their options for sports and PA.

In conclusion, consistent with earlier research, our results indicate a significant adverse effect of social isolation measures on the PA behaviors of adolescents. Notably, the more vigorous and health-promoting forms of PA experienced a substantial decline, with reductions exceeding fifty percent in this study. Additionally, our findings suggest that PA levels of female Muslim adolescents may be disproportionately impacted by the pandemic-related restrictions compared to those of other youth demographics.

From a methodological perspective, the current study exhibits both advantages and limitations. Unlike earlier research, PA was assessed objectively using accelerometers, thereby minimizing the potential for bias stemming from subjective inaccuracies. Additionally, the longitudinal design of the study represents another significant strength. By measuring the PA of the same group of adolescents both before and during the pandemic, the study effectively captures changes in their daily PA, allowing for an evaluation of the effects of pandemic-related interventions.

The study's limitations stem from the organizational constraints that permitted only female youth to be included, resulting in a relatively small sample size. Prior to the pandemic, a larger cohort of students was surveyed; however, due to various concerns and apprehensions, only 29 students and their parents consented to participate during the pandemic. Additionally, the lack of control over the participants' socioeconomic status restricts our ability to assess the potential influence of this variable. Future research should incorporate these factors to adopt a more holistic approach in evaluating the effects of various measures or conditions on adolescents' PA.

4.1. Conclusion

This research represents one of the initial efforts to objectively and longitudinally assess the effects of the COVID-19 pandemic on PA among female adolescents. The results indicated a significant increase in both BMI and SB among participants from the pre- to after the pandemic, while levels of more vigorous PA notably declined during this time. From a health standpoint, it is particularly concerning that prior to the onset of the pandemic, only 20% of female adolescents met the guideline of engaging in 60 minutes or more of MVPA daily, which is essential for their long-term healthy development. Unsurprisingly, none of the participants in our study approached this guideline during the pandemic. Collectively, these findings underscore the susceptibility of young females, particularly regarding their health behaviors during crises. It is crucial that the needs of youth are prioritized during such periods to avert long-term adverse effects on their health, psychological well-being, and social development. Implementing strategies and initiatives to encourage adequate PA among youth, even in challenging circumstances, would be a vital measure in this context.

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Footnotes

Authors' Contribution: This study was carried out solely by the corresponding author.

Conflict of Interests: The researcher confirms that there is no conflict of interests in this study with any participant.

Data Availability: The data that support the findings of this study are openly available upon request from the corresponding author.

Ethical Approval: The author confirms that all steps and requirements of this study comply with ethical guidelines. Participants were informed about the characteristics of the study and gave written informed consent.

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