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Original Article

Mexico's failure to address the true toll of the COVID-19 pandemic

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Abstract

This study retrospectively analyzes the organizational handling of the COVID-19 pandemic by Mexico's health authorities, from its outbreak in February 2020 to the final phase of the pandemic. The analysis begins with the undercounting of infected persons and deaths, which led to distorted figures and an abnormally high case fatality rate. The underestimation is examined separately for infections, deaths, and case fatality rates. The number of infected persons was affected by insufficient COVID-19 testing and restrictions on hospitalization. Death figures were evaluated by comparing mortality trends observed during the five years preceding the outbreak with the post-pandemic data disaggregated by cause of death. These data were first collected by health authorities, reviewed by the Interinstitutional Group for the Estimation of Excess Mortality (GIEM, in Spanish), and later consolidated by the National Institute of Statistics and Geography (INEGI, in Spanish). The case fatality rate was calculated as the relationship between both variables on the basis of the original figures published by health authorities. After different calculation methods were explored, a more plausible estimate of the real COVID-19 death toll was established. Despite the need to correct the initial figures, the official database has not been updated. This lack of correction misinforms the public about the real impact of COVID-19 and risks leading the health system to repeat the statistical and organizational failures observed during the pandemic, potentially underestimating future health emergencies.

Keywords

COVID-19; Fatality rate; Undercounting; Excess mortality

1. Introduction

The COVID-19 pandemic has severely tested the accuracy, transparency, and responsiveness of national health information systems worldwide. In Mexico, the recording and reporting of COVID-19 deaths and infections has become a particularly controversial issue. During the pandemic, day-to-day information on cases and deaths was compiled to form an official database that remained largely unchanged even after methodological issues related to how infections and causes of death were captured were identified. These inconsistencies contributed to widespread concerns that the official figures substantially underestimated the true scale of the pandemic in the country.

During the pandemic, Mexico had almost 128 million inhabitants, making it the tenth most populous country in the world [1]. The nation's public health system was undergoing major restructuring following the change in the government in December 2018. The new administration implemented budgetary reforms that significantly affected the quality and efficiency of health services. This context likely compounded the challenges of accurate disease surveillance and reporting during the crisis.

The underreporting of both infections and deaths resulted in an unusually high case fatality rate, suggesting that inaccuracies in data collection were not uniform. Two key institutions were responsible for verifying and correcting health statistics: the National Institute of Statistics and Geography (INEGI, in Spanish), which oversees death certificate verification, and the Interinstitutional Group for the Estimation of Excess Mortality from All Causes during the COVID-19 Emergency (GIEM, in Spanish). The latter included ten national institutions and the Pan American Health Organization (PAHO). Despite their involvement, the official database was not revised, resulting in significant uncertainty regarding the pandemic's real impact.

Understanding this discrepancy is crucial for two main reasons. First, it is essential for citizens and policymakers to know the true death toll of COVID-19 during its most critical phases. Second, it is important to identify the social and health characteristics of populations most vulnerable to SARS-CoV-2 infection to strengthen public health systems, implement effective preventive measures, and avoid similar statistical and institutional failures in future crises.

Therefore, the objective of this study was to analyze the accuracy of Mexico's reported COVID-19 deaths and infections between the outbreak in February 2020 and the end of the pandemic in the second quarter of 2023. The study hypothesizes that there is a significant lack of precision in reported data on COVID-19 deaths, infections, and case fatality rates, despite opportunities for correction through institutional review.

2. Methodology and sources of information

The methodology used to evaluate the three series under consideration was based on longitudinal descriptive statistics and international comparative performance via Pearson's correlation coefficients. The case undercounting was analyzed by comparing the figures each country exhibited regarding the number of tests applied to determine the presence of the virus, with Mexico being one of those lagging, leading to obvious consequences for COVID-19 diagnostics. Excess mortality quantification was carried out by comparing the difference between the total death tendency during the period of analysis (i.e., the mortality that would be expected on the basis of a noncrisis mortality rate) and the observed mortality [2]. Since 2020, the latter, as reported by the INEGI after reviewing the data with the GIEM, includes all confirmed COVID-19 deaths. In this context, the fatality rate was calculated by dividing the number of COVID-19 deaths by the number of COVID-19 cases.

Officially, in addition to COVID-19, other causes of excess mortality include road accidents, unexpected temporary diseases, and fortuitous causes. Specifically, INEGI and GIEM did not explore pneumonia and influenza as masked COVID-19 cases, although they increased significantly during the pandemic period, and the spikes clearly correlated with those from COVID-19 [3]. Even though they represent a small part, this study considers that such excess mortalities should be added to that of COVID-19. Therefore, the excess mortality from COVID-19 is calculated here as the difference between the expected deaths according to their trend from 2015-2019 and those observed from January 2020-December 2022, adding the number of deaths from pneumonia and influenza. Both differences are depicted in Figure 1 and will be referred to at the end of the paper, where an expansion factor (the factor by which the reported COVID-19 cases should be multiplied to have a clearer picture of the total deaths that the pandemic caused in the country) is used.

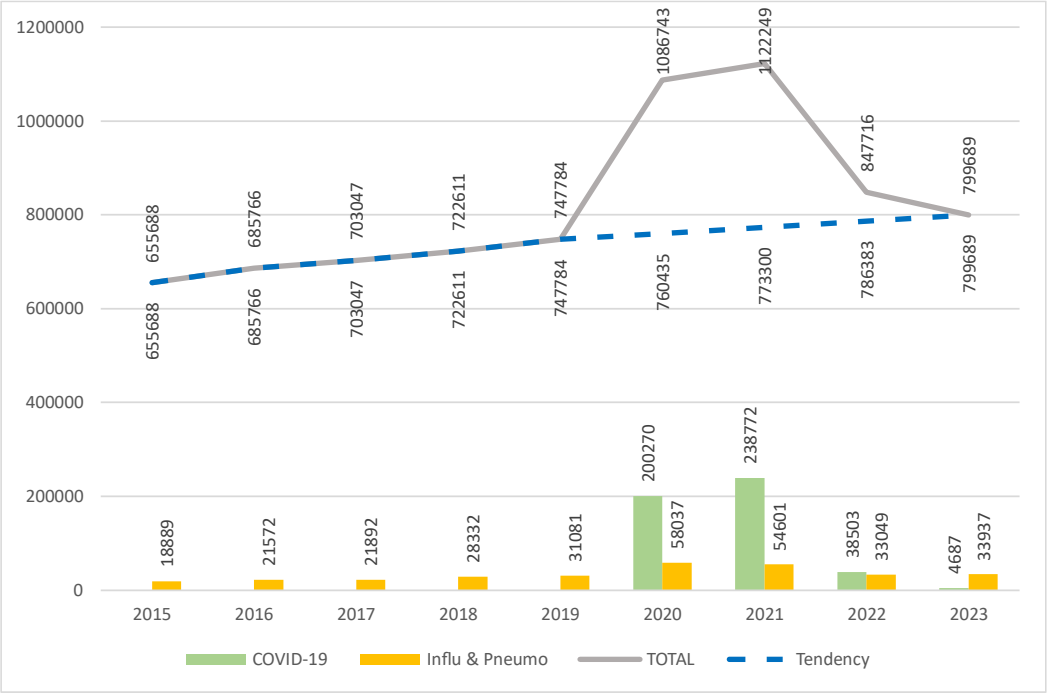

Figure 1. Trends in all-cause mortality and officially reported COVID-19, influenza, and pneumonia deaths in Mexico, 2015–2023 [3].

To make this clear, the figures of the Ministry of Health of Mexico (SSA, in Spanish) [4,5], which are by far the most relevant for COVID-19 purposes, were compared with those of excess mortality presented initially by SSA [6] and GIEM [7], passing finally to INEGI [3,8], where they became official. This is because INEGI has the constitutional mandate to elaborate and disseminate most of the national statistics as part of the National Information System. This means that the longitudinal comparative process carried out here implies a confrontation between the SSA day-to-day COVID-19 statistics and those on excess mortality published by INEGI.

In addition to the SSA [4,5], the day-to-day sources of information are the National Council of Science and Technology [9] for some consolidated data and the World Health Organization (WHO) COVID-19 Dashboard [10] and the Dashboard by the Center for Systems Science Engineering (CSSE) of Johns Hopkins University [11] for international data.

3. Results and discussion

3.1. Evidence of case and mortality undercounting and a distorted relationship between them

This section aims to present evidence suggesting that COVID-19 cases and the death toll were undercounted, recognizing that while it was a generalized problem in many countries [12], particularly developing countries, it was exacerbated in Mexico [13]. Additionally, it intends to demonstrate the circumstances that allowed cases to be less scrutinized than the death toll and shows that Mexico has one of the highest case fatality rates in the world, including both developed and developing countries. Finally, it presents a proposal to estimate what the death toll would have been, along with the underlying expansion factor. This factor departs from the official COVID-19 death toll agreed upon by SSA, GIEM, and INEGI and expands it by incorporating the excess mortality figures related to COVID-19, pneumonia, and influenza from 2020-2023 officially disclosed by INEGI.

3.1.1. Cases

It was evident from the outset that there was a problem of underestimation of both international [11,12] and national cases [9,14,15,16], as well as the death toll. In Mexico, undercounting occurred as health authorities ordered that individuals possibly infected with COVID-19 be registered in a hospital within the national hospital network, which consisted of 475 units throughout the country, known as Viral Respiratory Disease Monitor Health Units (USMERs, in Spanish). However, to be admitted to one of them, the patient's relatives were required to have a positive test issued by a recognized laboratory. Mexico was the country with the fewest number of tests issued in relation to its population out of the 17 countries with more than 100 thousand deaths (sometimes information about China is not available; otherwise, 18) [17]. This was not only due to the administrative process described but also because the tests were costly and had to be covered by the patient's family. As Figure 2 shows, the relationship between the number of tests per 1000 persons in Mexico and the worst period from the beginning of the pandemic until February 15, 2022, was 0.12. The figure was lower than those of Peru (0.86), Argentina (0.78), Brazil (0.34), India (0.55), Iran (0.55), Ukraine (0.51), and South Africa (0.41). When Pearson's correlation coefficient is applied to the variable tests and population, the figure is 0.68547 for the whole sample, implying that as the population of a country increases, so should the number of tests. This simply did not happen in Mexico.

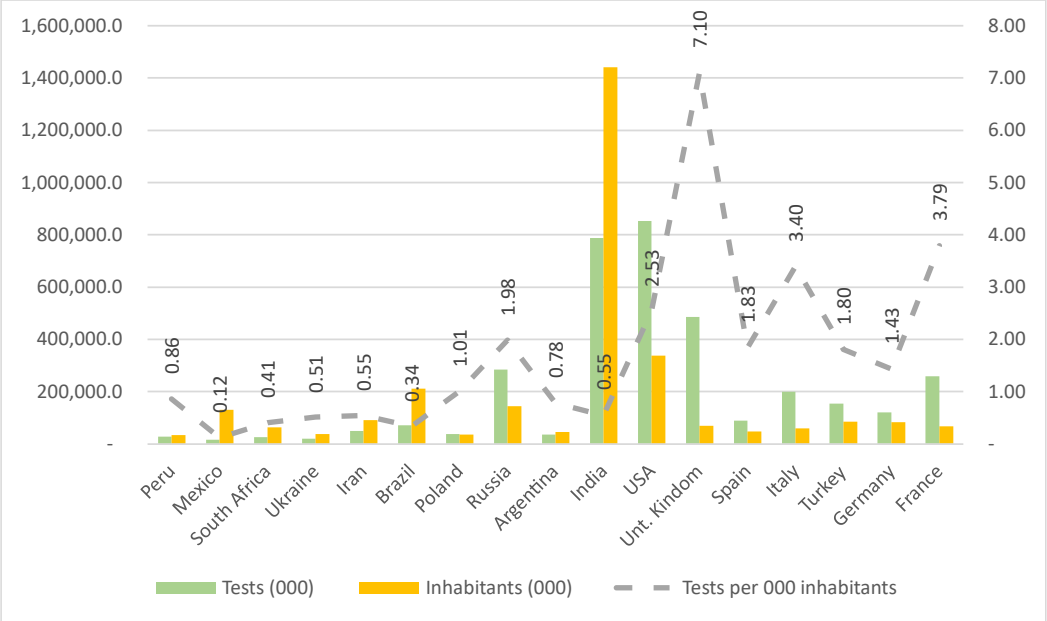

Figure 2. COVID-19 testing intensity measured as tests per 1,000 inhabitants in selected countries during the worst phase of the pandemic, up to February 15, 2022 [1,11].

Transferring patients in precarious conditions at the expense of their own lives and paying for the use of an ambulance during a period when the prices of that service, as well as those of private hospitals and support services, particularly personnel, oxygen, and medicines, had risen extraordinarily owing to the acute phases of the pandemic (April 2020-March 2022), was almost impossible for most families in Mexico [18]. Of course, the patients and their families who sought in-home attendance without registration in the hospital system and then without an official document did not leave traces about their condition. Globally, this period coincided with four well-documented waves of COVID-19, characterized by successive surges in transmission linked to new viral variants and changing containment measures [19]. The fourth wave, beginning in late 2021,

represented the most intense increase in global case numbers, placing renewed pressure on already weakened national health systems, including Mexico's [20]. To reinforce their inertial view on this issue, the sanitary authorities calculated that, in the absence of a vaccine, 80% of Mexicans would develop the disease but not to the point of becoming sick, i.e., they would reach natural "herd immunity". On the other hand, 15% would be infected and develop symptoms, 5% would become sick, 1.5% would enter a hospital, 0.4% would be intubated, of which half would not survive—and 0.15% would die [13,21].

3.1.2. The death toll and fatality rate

Owing to de facto restrictions on attending public hospitals, most families choose to follow the instructions of the official telephone support line and, ultimately, those of their family doctor, who generally keep the patient at home under total isolation, take extreme care and use an oxygen appliance [22]. If a person died, the death certificate was established as the cause of "atypical pneumonia," "acute respiratory disease," or "possible COVID-19." There was no certainty that when the death certificate was released, COVID-19 was the cause of death [23]. The official protocol states that if a person is admitted to a USMER, a clinical diagnosis would be carried out to classify the case as either acute ambulatory respiratory infection (ARI) or severe acute respiratory infection (SARI), and only in the latter case would the person be hospitalized [4,5].

By early 2025, Mexico ranked 19th in reported cases and 13th in the sample shown in Figure 3, lagging countries with smaller populations such as Germany, France, Spain, Italy, the United Kingdom, Iran, and Argentina. However, Mexico is the 5th country in terms of deaths, following the USA, Brazil, India, and Russia. Generally, as the number of cases increases, so do the number of deaths. For the sample, the Pearson's correlation coefficient is 0.85079. However, when only the less developed countries of the sample are considered, excluding Brazil, the correlation coefficient decreases to 0.176609, although not necessarily for the same reason.

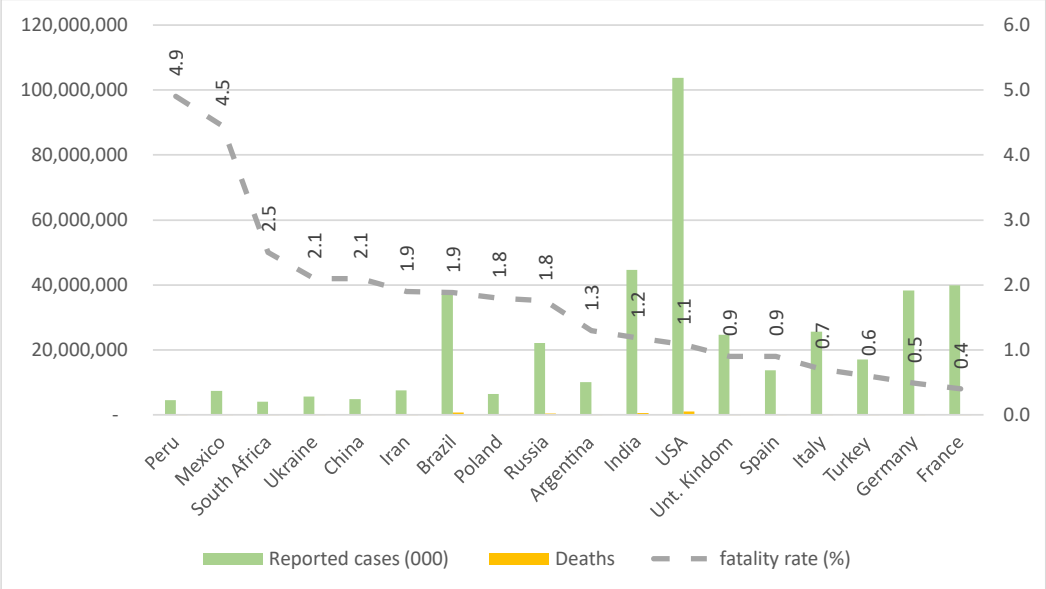

Figure 3. Reported COVID-19 cases, deaths, and cumulative case fatality rates in selected countries as of March 10, 2023 [11].

If population is considered, the countries with the lowest ratios of reported cases to the population are Mexico, South Africa, and India, as shown in Figure 4. The main reasons for this are undercounting of cases, overcounting of deaths, or a combination of

both. For Mexico, the main issue is undercounting of cases in a greater proportion than deaths, as undercounting was less regulated for people who had contracted the disease and were kept outside the sanitary system than for those who died. The cause of death may still be reclassified as COVID-19 [24].

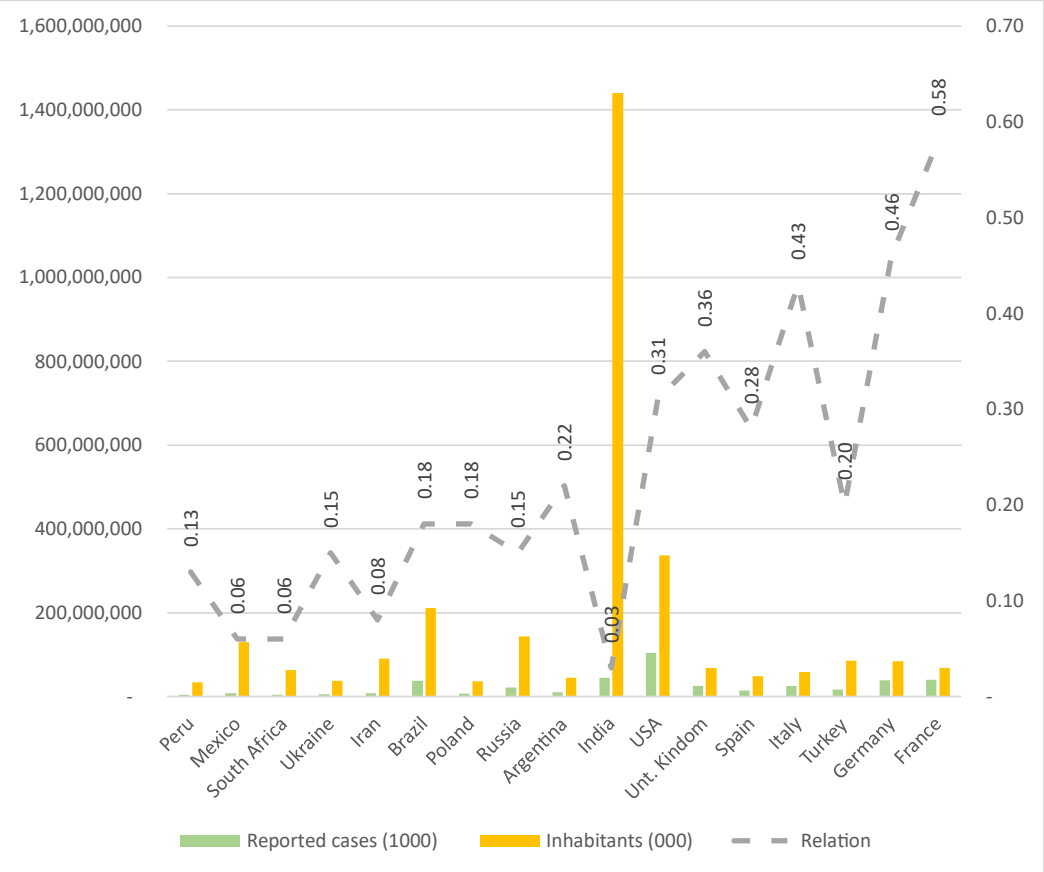

Figure 4. Reported COVID-19 cases relative to population size in selected countries (%) [1,11].

3.2. The counting of excess mortality

By July 2020, six months after the COVID-19 pandemic outbreak in Mexico, when database integration was crucial, most less developed countries faced problems that had accumulated over time. By then, the sanitary authorities of Mexico were under serious pressure from different experts and researchers due to evident discrepancies between the daily figures on deaths released by the SSA and those reported between the first half of 2015 and the end of 2019 in the regions with the highest contagion rates in the country, particularly Mexico City. Consequently, the SSA released the results of an exercise in which excess mortality was counted in 20 of the country's 32 states of the Republic [6]. As shown in the first four numerical columns of Table 1, there was a difference of 71,687 persons considering those who died from January 1 to July 19, 2020, and the historical figures recorded in the same months from 2015--2019 (the table makes its own calculations adjustment to include people aged 19 and under, who were missing in the original SSA figures for the 32 states), implying an expansion factor of 1.55 (national deaths revised over national deaths officially reported).

Table 1. Excess mortality in Mexico from January 1 to July 19, 2020, compared with average mortality during the previous five years, by sex and age group.

Level	Expected	Observed	Excess Deaths *	Obs/Exp Ratio	32 States (Obs/Exp) **	Participation (%)
National	130,763	202,077	71,687	1.55	89,609 (1.68)	100.0
Gender						
Men	73,041	121,085	48,044	1.66	60,055 (1.82)	67.0
Women	57,349	80,992	23,643	1.41	29,554 (1.34)	33.0
Age group (years)						
0–19	n.a.	n.a.	334	n.a.	418 (n.a.)	0.5
20–44	18,121	25,907	7,786	1.43	9,733 (1.54)	10.9
45–64	32,301	63,548	31,247	1.96	39,059 (2.21)	43.5
65 +	72,127	104,447	32,320	1.44	40,400 (1.56)	45.1

* The original states included by the Secretaría de Salud (SSA) were 22: Aguascalientes, Baja California, Baja California Sur, Campeche, Chihuahua, Coahuila, Colima, Mexico City, Guanajuato, Hidalgo, State of Mexico, Morelos, Nuevo León, Puebla, Querétaro, Quintana Roo, San Luis Potosí, Sonora, Veracruz and Zacatecas. ** To include the remaining 10 states, the 1.55 expansion factor reported by SSA for the previous 22 states (Observed/Expected) was applied, considering their share of national COVID-19 deaths (≈ 20 %). *** Obs/Exp = Observed deaths / Expected deaths. n.a. = Not available at this level of analysis. **** Author's elaboration based on publicly available SSA data.

If the missing states of the country are added—some of them are large and are seriously affected by COVID-19, such as Jalisco, Sinaloa, Tabasco, Tamaulipas, Guerrero, Oaxaca, and Chiapas—and the congruence between COVID-19 and the populations of the 22 previous states is maintained, the excess mortality figure increases to 89,609. This number is 2.25 times greater than the number of accumulated deaths from COVID-19 reported until July 19, 2020, by the SSA (39,184), although it could be accepted that, even as mobility was seriously reduced in the country, some people in the excess mortality group died for reasons other than COVID-19. For this reason, when the SSA methodology is adopted and expanded to the countries' whole population, the expansion factor becomes 1.68. Two-thirds of the deaths were men, one-third were women, 45.1% were 65 years and older, and 43.5% were between 45 and 64 years old. The 11.4% difference corresponds to people aged 0 (unborn) to 44 years. This corroborates the difficulties faced by Mexico's health system, since in other countries, the number of people who died in the early years was proportionally lower and exceptional for those younger than 20 years.

Six months later, INEGI published the document "Characteristics of deaths registered in Mexico from January to August 2020", which stated that "In the period spanning from 2012 to 2019, 488,343 deaths were expected, and from January to August 2020, 673,260 occurred". Therefore, they calculated an excess mortality from all causes of 184,917, equivalent to 37.9% [8]. Dividing the excess by the number of months relevant to COVID-19 in that period (4.4), a monthly average excess mortality of 41,093 was obtained, which was 2.8 times higher than the 14,640 officially declared COVID-19 deaths, but of course, it refers to all kinds of excess mortality [4]. This figure is substantially higher than the monthly averages recorded between January and August 2020 due to heart disease (17,734), diabetes mellitus (12,467), and malignant tumors (7,553) [8]. Since the worst part of the COVID-19 pandemic was not the first wave (16,626 official deaths average monthly) but the second wave (26,737 official deaths average monthly), the pandemic continued to be the main cause of death.

In March 2021, the media began to disseminate figures from the World Mortality Dataset on excess mortality [25], expressed as the relationship presented in Figure 5, which shows the 30 most affected countries. The estimated excess mortality was divided by the official number of deaths from COVID-19. Although Peru, Bulgaria, Mexico, and

Ecuador had the highest death tolls per 10,000 inhabitants, represented by the bars (560, 437, 382, and 380, respectively), those with the highest excess mortality multiplier (total mortality/mortality determined by the trend), represented by the line and graduated on the right axis, corresponded to Russia (4.8), Ecuador (3), Peru (2.7), South Africa (2.6), Ukraine (2.6), Iran (2.4), and Mexico (2.2).

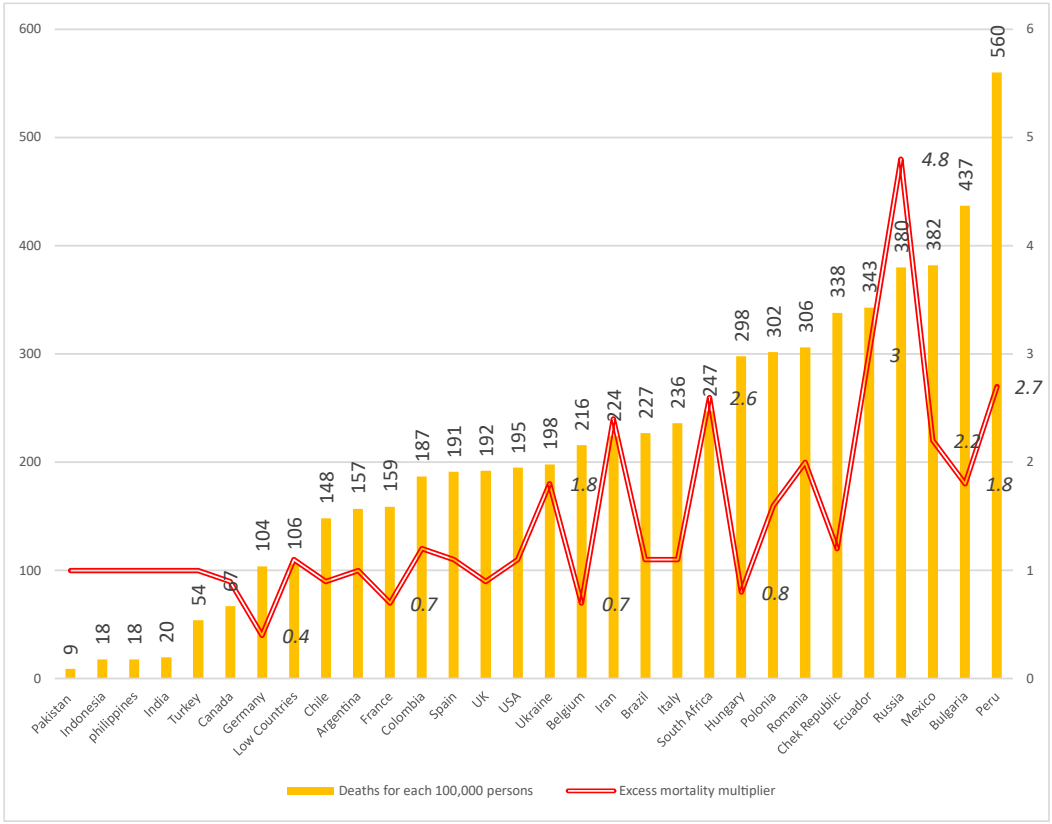

Figure 5. Excess mortality multipliers and COVID-19 deaths per 100,000 inhabitants across the most affected countries as of May 16, 2021 [25].

In a document dated March 2021, the GIEM announced that the statistics on excess mortality for Mexico were updated as of February 13, 2021, starting on December 19, 2019, leading to the following results:

The number of cumulative deaths through February 13, 2021, totaled 1,263,501, and the total number of excess deaths was 417,002.

The total number of deaths associated with COVID-19, according to death certificates, reached 294,287. Therefore, 70.57% of the excess mortality was explained by COVID-19. Importantly, mortality from this cause did not begin on December 19, 2019, but occurred three months later, on March 18, 2020. Therefore, the previous coefficient should have been established by the GIEM at approximately 75%.

This excess was 56.4% for men and 39.7% for women, which is equivalent to a ratio of 1.42 between the two percentages [7].

The range of multipliers calculated at different moments from July 2020 to March 2021 spans from 1.38 (INEGI, August 2020) to 2.2 (WMD, March 2021). These calculations refer to specific periods of time, with national estimates considering only excess mortality for COVID-19 and international estimates including all causes of excess mortality.

Figure 1 presented in the introduction established that the all-cause excess mortality was 736,590 during the entire pandemic. Specifically, 24.62% of the patients had COVID-19, and 3.65% had influenza or pneumonia. Together, these three causes represent

28.27% of excess mortality, as shown in Table 2. In the absence of the COVID-19 pandemic, the all-cause death toll would have reached 2,637,070 from January 2020-December 2022 (column one, row five), the period responsible for 89.2% of the death toll accumulated up to the official end of the pandemic (May 2023: 333,188 deaths) [11]. When COVID-19 is added to the figure (column three), including influenza and pneumonia, excess mortality increases to 3,056,708. The revised death toll, which includes excess mortality, increased to 3,793,298. Under these conditions, the expansion factor for COVID-19 plus those associated with it and masked during the pandemic, influenza and pneumonia, is 1.50. On the other hand, the expansion factor for other causes is only 1.20, indicating that, proportionally, most of the all-cause excess mortality comes from COVID-19, where deaths are most undercounted.

Table 2. All-cause and COVID-19–related excess mortality in Mexico, January 2020–December 2022.

Cause of Death	Officially Reported Deaths	Excess Mortality (2020–2022) *	Revised Death Toll	Expansion Factor **	Share of Total Excess Mortality (%)
All causes	3,056,708	736,590	3,793,298	1.24	100.00
COVID-19	300,912	181,320	482,232	1.60	24.62
Influenza & Pneumonia (I&P)	118,726	26,884	145,610	1.23	3.65
COVID-19 + I&P	419,638	208,204	627,842	1.50	28.27
Other causes	2,637,070	528,386	3,165,456	1.20	71.73

* Excess mortality = difference between total observed deaths (2020 – 2022) and the number expected based on 2016 – 2019 trends. ** Expansion factor = Revised death toll / Officially reported deaths. *** Data source: Secretaría de Salud (SSA, 2025) [11,26]. **** Author's elaboration based on publicly available SSA data.

3.3. Why were the death toll and the number of infections so high?

The figures reported by the WHO and SSA allow us to infer that during the first six months of the pandemic, the average age of people who died from COVID-19 in Mexico was just over 60 years, whereas it was almost 80 years in countries such as the United Kingdom. Similarly, in Mexico, seven out of 10 deaths were associated with comorbid factors (hypertension, diabetes mellitus, overweight, smoking, chronic obstructive pulmonary disease), whereas the average number of deaths worldwide is eight. This means that some factors other than comorbidities accounted for 14% more deaths in Mexico than in other countries, with the main factors being the following:

The Popular Health Insurance (Seguro Popular), which was in operation from the beginning of the 21st century to 2018, was dismantled, but the body designed to replace it, the Institute of Health for Welfare (INSABI, in Spanish), was by no means positioned. In addition, demographic dynamics and a lack of investment contributed to the population without access to health services increasing from 16.2% in 2018 to 28.2% in 2020 [27] and 40% in 2022 [28].

A complete transformation of the bidding process of medicines for health public sector institutions was carried out, shifting it from them to the Office of the Chief of Staff of the Ministry of Finance and Public Credit (SHCP, in Spanish), with no health sector experience. This is done to combat alleged vices of the past, obtain better prices owing to the volume of purchases, and reduce the excess profits of pharmaceutical companies. This leads to frictions and prolonged periods of shortages [29].

The decision was made not to conclude that a part of the regional hospital infrastructure was pending by the previous administration, which was supposedly associated with corruption.

With few exceptions, the hospitals of the public health system had insufficient and even obsolete medical equipment to meet the challenge of the pandemic and faced strikes and sporadic demonstrations by staff due to inadequate protocols and a lack of work equipment, including professional masks and gloves [30]. At the same time, private hospital personnel spent five months in claims after the first batches of vaccines arrived in Mexico to allow the federal government to authorize the full course of preventive COVID-19 vaccination [31].

The new administration chose to question, as had never happened before, the work and integrity of the scientific community in general, especially that of the health sector, where some staff members were fired at all levels: administrative, nurses, resident doctors and high-level specialists.

There was great slowness in the care of some groups of beneficiaries in critical health conditions who required expensive medicines, particularly those suffering from cancer, HIV-AIDS and heart disease, frequently with fatal consequences.

Although great efforts have been made to increase the number of intensive care beds, as of August 3, 2020, there were only 10,562 beds, which was lower than the number reported in countries with much lower populations and fewer affected by COVID-19, such as Canada, where more than 18,000 beds were reported. Even so, not all of them were ever used, given the practice of maintaining a conservative number of people hospitalized and intubated.

The participation of the scientific community in the solution of the problem was by no means stimulated: in addition to the lack of success of the project in manufacturing Mexican ventilators, the process of the Mexican Patria vaccine to prevent COVID-19, which sought to "promote significant savings in resources for the Treasury" [9], was not consolidated. In contrast, after ensuring massive purchases of vaccines from laboratories recognized by the USA and European governments and having a Swedish British vaccine packed in Mexican territory, supply agreements were sought with India and Cuba, and an agreement was signed with Russia to package them in Mexico. This action did not consider the difficulties for vaccinated Mexican citizens who were about to travel to the USA and Europe.

Financially, the above problems converge to a single point: excessive control of public health sector spending, which was reduced in 2019 and proved insufficient in 2020 to cope with the pandemic. Likewise, considerable and systematic downward deviations were recorded between the budget authorized and that exercised in the areas of purchase of medicines and allocation of resources to INSABI [32].

Faced with the above, by the end of 2020, Mexico was the country in the world with the highest number of health personnel (doctors, paramedics, and administrative staff) who died from COVID-19; something similar happened to domestic workers and public sector oil industry personnel. In the Mexican Institute of Social Security (IMSS), which accounts for the largest number of COVID-19-infected people, seven out of 10 intubated people died as of September 2021. Additionally, for every 100 deaths from COVID-19, 90 children had lost their primary or secondary caregivers who lived with them (244,000 infants in total): mothers, fathers, both, or grandparents. The figure of 90 substantially exceeded those of other countries: India, 87; Colombia, 67; Peru, 60; Russia, 47; Brazil, 46; the USA, 23; the United Kingdom, 9; Indonesia, 56; and Italy, 5 [33].

Given the need for more personnel, as of August 2020, the public health system had temporarily hired approximately 50,000 retired professionals in the field. The first group of approximately 17,000 people began their functions in April under contract with the IMSS; although they were not specialists in respiratory diseases, they were vulnerable to COVID-19 due to age and comorbidities. Temporary contracts were also used to bring 585

physicians from Cuba to the country, who specialized in general medicine, nursing, critical medicine, biomedicine, and epidemiology [34].

3.4. Summary of comparative performance and national outcomes

In March 2023, Mexico established itself as the world's number 10 in population terms [1], the 19th in terms of accumulated official COVID-19 cases (7,483,444 million) and the 5th in terms of the death toll (333,118) [35]. On this basis, the case fatality rate was 4.5%, which is five times higher than the world average (0.9%) and only less than Peru's 4.9% in the 18 countries most affected by the COVID-19 pandemic, all with death tolls exceeding 100,000. Obviously, this reflects serious inconsistencies for Mexico, particularly in terms of the denominator (accumulated COVID-19 cases), which was easier to mask by the public health system sending people back home when they were seriously sick. For people dying from COVID-19, the registration process was somewhat more transparent, and even if it was not, the excess mortality count would make evident some of the failures.

During the most critical period of the COVID-19 pandemic, from January 2020–December 2022, when 89.4% of accumulated deaths were registered, excess mortality from all causes rose significantly, as shown in Figure 1. Table 2 shows that 24.6% of this figure was explained by COVID-19, and if excess mortality from influenza and pneumonia was added, because many COVID-19 cases and deaths were masked by them, the figure increased to 28.3%. This implies that the official death toll for COVID-19, including influenza and pneumonia, should be expanded by a factor of 1.5. Similarly, the table shows that if only the partial row of excess mortality for COVID-19 was considered, the expansion factor would be 1.6.

The insufficiency of COVID-19 testing in the public health system was due, first, to a lack of a policy regarding this issue, such as the specialized institution recon [11]; second, to budgetary reasons, such as the government having other priorities; third, to a lack of personnel and infrastructure; and last, to the way in which the system organized itself to attend patients during the pandemic. Importantly, many symptomatic patients were not considered COVID-19 cases; they were sent back home without being followed and attended by public institution personnel, and many of them died there. Others managed to recuperate by isolation from the rest of their family and using a medicine kit provided at a certain cost by most private physicians.

Under these circumstances, from the beginning of the pandemic, the last-resort policy carried out by the government was massive COVID-19 vaccination, which started in January 2021. As of March 2023, 225 million vaccines have been administered, an average of 1.75 vaccines per person, although not all the population but 77.5% of it has received at least one dose [11].

4. Conclusions

The lack of precision in the figures on infections and deaths released daily by the country's health authorities is evident and was not corrected until the intervention of INEGI, which verified death certificates, and the reconciliation carried out by the GIEM. Once undercounting is recognized, both for ethical and statistical reasons, the entire series of case fatality rates should be reviewed, as it is clear that the underestimation of infections (the denominator) is greater than that of deaths (the numerator).

Although approximately 25% of the excess mortality from January 2020 to December 2022 was officially attributed to COVID-19—whereas initial studies in 2021 estimated a figure of 70% considering the reduced mobility imposed by the pandemic—the official

series on cases, deaths, and case fatality rates have remained unchanged, with only minor daily adjustments.

These figures should be corrected for at least two key reasons. First, they misinform the public about the real outcomes of the pandemic, hindering social understanding of its impact. Second, they risk leading the health system to underestimate the potential magnitude of future sanitary crises.

Finally, restructuring of the public health sector must be completed as soon as possible. The federal budget allocated to health must be significantly increased, and the resources originally assigned to the healthcare system must be used fully for that purpose rather than redirected to other institutions.

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Original Article

Association between premenstrual syndrome severity and academic performance among adolescent girls in Bara Kahu, Islamabad

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Abstract

Premenstrual syndrome (PMS) affects many adolescent girls in terms of physique, behavior, and psychology. However, evidence regarding the association between PMS severity and academic performance among adolescents in peri-urban areas of Pakistan remains limited. This cross-sectional analytical study was conducted from May to September 2024 among 270 adolescent girls enrolled in secondary and higher secondary schools in Bara Kahu, Islamabad, using multistage cluster sampling. This study determined the frequency and severity of PMS and examined its association with academic performance. Overall, 85.93% of the participants reported PMS symptoms, with 35.19% experiencing mild, 30.00% moderate, 12.59% severe, and 8.15% very severe symptoms. For inferential analysis, PMS severity was categorized into mild, moderate, and severe levels. A statistically significant association was observed between PMS severity and academic performance ($\chi^2 = 34.565$; $p < 0.001$). Spearman's rank correlation further demonstrated a significant negative correlation between PMS severity and academic performance ($\rho = -0.356$, $p < 0.01$), indicating poorer academic performance with increasing symptom severity. These findings suggest that greater PMS severity is associated with reduced academic performance among adolescent girls in peri-urban Islamabad. While causality cannot be inferred because of the cross-sectional design, the results highlight the relevance of menstrual health in educational contexts during adolescence.

Keywords

Premenstrual syndrome; Adolescent girls; Academic performance; Peri-urban area

1. Introduction

The menstrual cycle in females often causes psychological and physiological symptoms that affect daily life and routines, with approximately 80% of women worldwide experiencing at least one symptom before menstruation [1]. Premenstrual syndrome (PMS) is a group of clinically important physical and psychological symptoms among females that begins around day 14 of the cycle and continues until seven days after the start of menstruation [2]. These symptoms range widely from bloating, pain, and headaches to mood swings, anxiety, and social withdrawal. In severe cases, premenstrual dysphoric disorder (PMDD), a recognized mental health condition, can occur and requires appropriate clinical attention [3]. Major risk factors for PMS include demographic aspects, psychological stress, menstrual cycle characteristics, and lifestyle habits such as smoking, alcohol consumption and caffeine intake, exercise, and diet [4].

PMS is a prevalent condition, with studies reporting a pooled prevalence of 47.8% worldwide. Its prevalence appears to be higher in Asian countries than in Western nations [5]. Studies around the world have revealed a substantial relationship between PMS

and academic performance. A Nigerian study concluded that this disorder had a negative effect on reading comprehension and homework completion for the majority of students and that a considerable number of students reported a high negative effect on their academic performance due to PMS [6]. Similarly, one study in Thailand reported significant differences in academic scores between the PMS and non-PMS groups. PMSs are associated with various challenges, including a lack of concentration and motivation, poor individual and collaborative work performance, and low scores. [7].

In a study among adolescents in Bangladesh, 65.85% of participants reported a loss of concentration during educational activities due to PMS, which subsequently led to decreased academic performance [8]. Moreover, in Indian studies among adolescents, PMS is more likely to cause poor academic performance among students, as PMS is among the most common problems among high school students, and regular screening of PMS in school-aged girls has been suggested to improve their academic performance [9].

Various studies in Pakistan have also indicated that PMS is associated with academic performance among young girls. For example, in a cross-sectional survey of adolescents in Arif Wala city, Punjab, the prevalence of PMS was found to be 75%, and this study revealed that PMS was distressing and that females experiencing these symptoms reported impairment in their school activities [10]. Another study conducted in Islamabad reported a prevalence of PMS among adolescent students of 81% and reported associations between PMS symptoms and academic life as well as emotional well-being, highlighting the need for increased awareness and support regarding menstrual health education [11].

Although various studies have highlighted the prevalence of PMS across the globe, quantitative scientific evidence on its frequency, severity, and association with academic performance among adolescent girls in Pakistan, particularly in peri-urban regions, remains limited. Compared with urban areas, the peri-urban areas of Islamabad are a specific focus because of disparities in access to healthcare services, educational support, and increased cultural stigma. Therefore, this study investigates the frequency, severity, and association of PMS severity levels with academic performance among adolescent girls in Bara Kahu Islamabad, which is a mixture of urban and rural communities that represents the demographic diversity of Islamabad.

2. Methodology

2.1. Study design, setting and population

A cross-sectional analytical study was conducted among adolescent female students (aged 13–19) enrolled in secondary and higher secondary schools in Bara Kahu, the largest peri-urban settlement in Islamabad.

2.2. Study duration

The study was conducted for a period of approximately 5 months from May to September 2024.

2.3. Selection criteria

2.3.1. Inclusion criteria

The study included female secondary school students aged 13–19 years who had reached menarche and were willing to participate in the study.

2.3.2. Exclusion criteria

Female secondary and higher secondary school students with a known history of gynecological, endocrine, or chronic medical conditions (e.g., polycystic ovary syndrome (PCOS), endometriosis, pelvic inflammatory disease (PID), and thyroid disorders) that could independently influence menstrual symptoms or academic functioning were excluded from the study on the basis of self-reported medical history.

2.4. Sample size calculation

Sample size for detecting a correlation of r = 0.40 was calculated using the Fisher z-transform formula with a two-sided α = 0.05 and 80% power. The initial required sample size was 47. After applying a design effect of 4.3 (ICC = 0.05, mean cluster size ≈ 67), the required sample increased to 203 participants (≈ 4 clusters) [12]. In order to account for potential dropouts, absenteeism, and incomplete questionnaires, the sample size was further increased by 35%, resulting in a final sample size of 275 participants.

2.5. Sampling technique

The sampling technique used in this study was multistage cluster sampling, where schools served as clusters. In the first stage, four public educational institutions at the secondary and higher secondary levels were randomly selected via the balloting method from the list of educational institutions in Bara Kahu under the Federal Directorate of Education, Islamabad. Schools were selected to reflect variation in school level (secondary and higher secondary) and student enrollment size, thereby ensuring coverage of the adolescent female school-going population. The four randomly selected schools were Islamabad Model School for Girls, Lakhwal (I–XII) (n = 121); Islamabad Model College for Girls, Bara Kahu (XI–XII) (n = 40); Islamabad Model School for Girls, Mera Bhagwal (I–X) (n = 77); and Islamabad Model School for Girls, Malot (I–X) (n = 32).

In the second stage, class attendance registers served as the sampling frame, and systematic random sampling was applied. A random starting point was selected, after which every third eligible student was included, regardless of their PMS status. Eligible students who declined participation were excluded. Classes from the sixth to intermediate level were purposively included to encompass the 13–19-year age range, the target population for assessing PMS frequency during adolescence.

PMS status was not used as a screening criterion at the sampling stage; rather, all selected participants were included and subsequently assessed for self-reported PMS symptoms via the Premenstrual Syndrome Scale (PMSS) during data analysis [13].

2.6. Data collection tool

Structured questionnaires were administered to assess PMS symptoms and academic performance. The PMS was self-reported via the PMSS, and a one-time questionnaire is not a diagnostic tool; therefore, PMSS scores are described as self-reported PMS symptoms rather than a clinical diagnosis. To differentiate PMS from normal menstrual symptoms, the functional impact of symptoms on daily activities and academic performance were considered.

The first part of the questionnaire included participants' sociodemographic information and menstrual data, and the second part included an assessment of PMS-related physical, psychological, and behavioral symptoms via the PMSS [13], which is based on the Diagnostic and Statistical Manual of Mental Disorders (DSM) criteria and was designed for South Asian adolescent populations [14]. The internal consistency of the PMSS was excellent, with a Cronbach's alpha of 0.944 across 40 items. The participants self-

reported symptom presence and severity on the basis of their recall of their previous three menstrual cycles. The third part included an assessment of academic performance via the academic performance score (APS) [15]. The APS, an eight-point scale tool, determines study habits, class participation, concentration, interest in academics, effort in academics, and problem-solving ability among respondents. The APS also showed strong internal consistency, with a Cronbach's alpha of 0.912 across the eight items. Scores were calculated by summing item responses; higher scores indicate better academic performance.

Back translation of the questionnaire was conducted by experts to ensure the accuracy and cultural appropriateness of the questionnaire.

2.7. Study measures

Premenstrual symptoms were assessed via the PMSS, a 40-item standardized self-report questionnaire designed to assess the physiological, psychological, and behavioral symptoms of PMS among females. Each item on the scale was rated on a 5-point Likert scale ranging from 1 ("never") to 5 ("always"), resulting in a total score between 40 and 200, with higher scores indicating greater severity of premenstrual symptoms. The total scores of the PMSS were further classified into five domains on the basis of symptom severity: no PMS symptoms (≤ 40), mild (41–80), moderate (81–120), severe (121–160), and extremely severe (161–200) [13].

Academic performance was determined via the APS, which consists of eight items, each rated on a 5-point Likert scale; each individual item score was summed to obtain a total APS score ranging from 8–40, with higher scores revealing better academic performance. The APS scores were categorized into five domains of academic performance by employing a percentile-based approach, and the responses were graded as very poor (≤ 20th percentile), poor (21st–40th percentile), average (41st–60th percentile), good (61st–80th percentile), or excellent (> 80th percentile).

For inferential analysis, PMS severity categories were collapsed from five levels (i.e., no PMS, mild, moderate, severe, and very severe) into three levels (mild, moderate, and severe) by excluding participants without PMS and merging very severe cases into the severe category. Similarly, academic performance categories were consolidated from five levels into three ordered groups (poor, average, and good) by combining related categories to achieve an adequate cell distribution for chi-square analysis.

2.8. Statistical analysis

Descriptive statistics were used to summarize sociodemographic characteristics, the distribution of PMS severity, and academic performance categories. The association between PMS severity (mild, moderate, or severe) and academic performance (poor, average, or good) was assessed using the chi-square test. Spearman's rank correlation was also used to determine the associations between PMS severity, academic performance, age, academic level, and school absenteeism. A p value equal to or < 0.05 was considered to indicate statistical significance. All analyses were performed using SPSS version 27.0.

2.9. Ethical considerations

Ethical approval for the study was obtained from the Institutional Review Board of Health Services Academy (No. 000443/HSA/MSPH-2022). Furthermore, permission for data collection was obtained from targeted school principals, and participants were completely informed about the study's purpose and were assured that voluntary participation and the right to withdraw at any time were clearly conveyed. Moreover, written paren-

tal/guardian consent and adolescent assent were obtained prior to the study. The data collected was not used for any purpose other than this research, and the confidentiality and privacy of the participants were maintained throughout the study.

3. Results

Among the 275 participants, 270 completed the questionnaire, resulting in a response rate of 98.18%. The mean patient age was 14.87 ± 1.88 years. The majority of the participants (82.22%) were aged 13–16 years, whereas 17.78% were aged 17–19 years (Table 1). Most participants were from a lower socioeconomic background (59.26%). The mean duration since menarche was 27 ± 1.65 months, and the mean duration of menstruation was 6 ± 1.32 days.

Table 1. Sociodemographic and menstrual characteristics of adolescent girls in Bara Kahu, Islamabad (N = 270).

Characteristics		Frequency (%)
Age (years), Mean ± SD		14.870 ± 1.878
Socioeconomic status	Lower	160 (59.26)
	Middle	84 (31.11)
	Upper	26 (9.63)
Age of menarche (years)	11-12	110 (40.74)
	13-14	146 (54.07)
	15-16	14 (5.19)
Time since menstruation (months)	0-12	112 (41.48)
	13-24	61 (22.59)
	25-36	37 (13.70)
	37-48	30 (11.11)
	> 48	30 (11.11)

The distribution of PMS severity among adolescent girls is shown in Figure 1. The majority of participants reported mild PMS symptoms (35.19%), followed by moderate PMS symptoms (30.00%). Nearly one-eighth of the participants experienced severe PMS symptoms (12.59%), whereas a small proportion reported no PMS symptoms (14.07%). Very severe PMS was observed in only 8.15% of the participants.

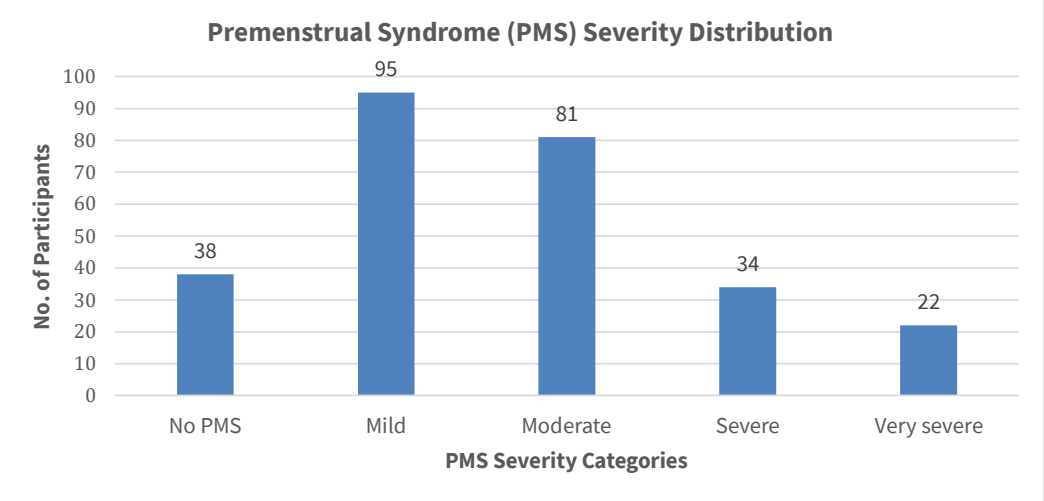

Figure 1. Distribution of PMS severity among adolescent girls in Bara Kahu, Islamabad.

Table 2 shows a statistically significant association between PMS severity and academic performance among symptomatic adolescent girls ($p < 0.001$). Academic performance deteriorated as PMS severity increased: compared with mild (17.9%) and moderate (22.2%) PMS, 51.6% of girls with mild PMS had good performance, whereas 17.9% of those with severe PMS had poor performance, while poor performance was highest among the severe PMS group (58.9%).

Table 2. Association between PMS severity and academic performance among adolescent girls in Bara Kahu, Islamabad (N = 232).

Variables		Academic Performance			Chi-Square Value	Degree of Freedom (df)	*p* Value
		Poor	Average	Good			
		Frequency (%)	Frequency (%)	Frequency (%)			
PMS severity	Mild	17 (17.9)	29 (30.5)	49 (51.6)	34.565	4	< 0.001 **
	Moderate	18 (22.2)	30 (37.0)	33 (40.7)			
	Severe	33 (58.9)	13 (23.2)	10 (17.9)			

* Chi-square test of association. ** $p < 0.05$ was considered to indicate statistical significance.

The data in Table 3 indicate a significant negative correlation between PMS severity and academic performance (ρ = -0.356, $p < 0.01$). Academic performance is also significantly negatively correlated with school absenteeism (ρ = -0.266, $p < 0.01$), indicating poorer performance with increasing absenteeism. Moreover, PMS severity was not significantly correlated with age ($p = 0.204$) or academic level ($p = 0.197$).

Table 3. Correlations between PMS severity, academic performance, age, academic level, and school absenteeism among adolescent girls in Bara Kahu, Islamabad (n = 270).

Variables	Age (years)	Academic Level	School Absenteeism	PMS Severity	Academic Performance
Age (years)	1.00	-	-	-	-
Academic level	0.758 **	1.00	-	-	-
School absenteeism	−0.094	−0.115	1.00	-	-
PMS severity	0.077	0.079	0.086	1.00	-
Academic performance	0.069	0.090	−0.266 **	−0.356 **	1.00

* Spearman's rho (ρ) coefficients are presented. ** Correlations are significant at $p < 0.01$ (two-tailed).

4. Discussion

This study examined the association between PMS severity and academic performance among adolescent girls in the peri-urban setting of Islamabad and suggested that increasing the severity of premenstrual symptoms is associated with poor academic performance among symptomatic students. Moreover, academic performance was found to be related to school absenteeism, whereas PMS severity did not vary meaningfully with age or academic level in this population. These findings highlight the functional implications of menstrual health during adolescence and emphasize the importance of considering symptom severity when educational outcomes are being examined.

The results of this study, highlighting the high frequency of PMS among adolescent girls, are consistent with those of another Pakistani study, which reported that the prevalence of PMS in the country is 52% [16]. Other scientific literature from Pakistan also supports the same findings of the study and records higher percentages of PMS in the country [17,18]. Moreover, national studies also support the level of severity of the disease reported in the current study [19,20]. According to the national literature, this can be attributed to the lifestyle, low calcium and vitamin D intake and limited exposure to

sunlight among Pakistani females; furthermore, working in high-stress environments can also be a contributing factor to the disease [21,22]. However, the level of awareness regarding PMS among Pakistani females was consistently high [23].

The results of the current study revealed an association between PMS severity and academic performance, which is supported by an Arabian study that highlighted that PMS symptoms negatively influence academic performance among adolescent girls, affecting mainly concentration in the classroom [24]. Another Arabian study conducted among college girls supports the findings of the current study that show that PMSs influence academic performance to a moderate degree [12]. A study conducted in the UAE highlighted the same increase in annual absenteeism among girls due to PMS symptoms [25]. This can be attributed to the fact that PMS influences academic functioning through cognitive and emotional difficulties, as well as the diet of adolescent girls, which impacts their PMS and academic performance [26,27,28].

With respect to age and academic level and PMS symptoms, the findings of the current study align with those of previous similar studies conducted in India [11,29]. However, importantly, an increase in age is linked to higher academic levels, resulting in greater concentration and more academic inputs, which may confound age and academic performance, separating the individual effects of age and educational level on PMS among adolescent girls. Similar findings have been reported by other studies, highlighting that adolescent girls may continue attending school with appropriate academic performance despite experiencing PMS symptoms, mainly because of academic pressure or sociocultural expectations of peers and society [30,31].

Despite these limitations, this study contributes valuable evidence by documenting the experiences of peri-urban Pakistani adolescents, a population that remains underrepresented in menstrual health research. In light of the observed associations between PMS severity and academic performance, the introduction of age-appropriate menstrual health education into school curricula may help improve symptom recognition and self-management among adolescent girls. Customized academic and psychosocial support systems for female students from lower socioeconomic strata may also reduce the combined effects of PMS and educational disadvantage. Furthermore, flexible, supportive school policies that acknowledge menstruation-related challenges among adolescent females may further promote academic engagement, whereas community-based awareness initiatives focused on nutrition, physical activity, and help-seeking behaviors may contribute to improved menstrual health and overall well-being among adolescent females.

5. Conclusions

The study revealed statistically significant associations between PMS severity and academic performance among adolescent girls in the peri-urban setting of Islamabad. Increased severity of premenstrual symptoms was associated with poor academic performance, highlighting the functional relevance of menstrual health during adolescence. Although these findings are based on cross-sectional data and do not imply causality, they suggest that attention to menstrual health and supportive educational environments may be important considerations in promoting academic engagement among adolescent girls.

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Data availability: The data supporting this study's findings are available from the corresponding author, Alia Ibrahim, upon reasonable request.

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Original Article

Effect of racecadotril as an adjunct to standard therapy and standard therapy alone on the duration of hospital stay in children aged 6–60 months with acute watery diarrhea

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Abstract

Acute watery diarrhea (AWD) is a significant contributor to morbidity as well as mortality among underfive children, predominantly in resource-limited settings. Although rehydration therapy is the cornerstone of management, it has a limited role in reducing the duration and severity of diarrhea. This study compared the duration of hospital stay in children aged 6–60 months with AWD and some or severe dehydration, with or without acute malnutrition, who received racecadotril as an adjunct to standard therapy versus standard therapy alone. This comparative interventional study was conducted in the Pediatric Medicine Department, Mayo Hospital, Lahore. A total of 208 children fulfilling the selection criteria were enrolled and allocated into two groups (104 participants per group) using a random number table. All participants received standard treatment for AWD. Children in Group A received three divided doses of racecadotril (1.5 mg/kg/day) in addition to the standard treatment, whereas children in Group B were administered only the standard treatment. The duration of hospital stay and reduction in loose stool frequency were recorded for all participants. Our results revealed that the median hospital stay duration was significantly shorter in Group A [22.75 hours (IQR = 11.00) versus 61.00 hours (IQR = 24.00) in Group B; $p < 0.001$]. Similarly, the median decrease in the frequency of loose stools during hospitalization was significantly greater in Group A [9.00 (IQR = 2.00) versus 5.00 (IQR = 2.00) in Group B; $p < 0.001$]. Among children with moderate acute malnutrition (MAM), the median hospital stay duration was significantly shorter in Group A [40.00 hours (IQR = 35.00)] than in Group B [65.00 hours (IQR = 29.00)] ($p = 0.003$). Similarly, among children with varying degrees of dehydration (some or severe) classified according to the WHO criteria, the median duration of hospital stay remained significantly lower in Group A ($p < 0.001$) than in Group B ($p = 0.013$). Racecadotril as an adjunct to standard therapy significantly reduced the duration of hospital stay in children aged 6–60 months with AWD, including those with MAM and some or severe dehydration.

Keywords

Acute diarrhea; Child; Dehydration; Hospitalization; Racecadotril

1. Introduction

Three or more episodes of loose stools over 24 hours for less than 14 days are termed acute watery diarrhea (AWD) [1]. In developing countries, it is a frequently occurring condition that causes morbidity as well as mortality in children, particularly those younger than five years [2]. In developed countries, AWD is generally mild; however, with some exceptions, it contributes to hospital admissions and substantial healthcare costs [3,4]. AWD is a global health issue linked to approximately 1.3 million child deaths annually, especially in low-income countries [5]. According to the UNICEF, AWD led to

38,706 deaths among the underfive population in Pakistan, accounting for approximately 20% of the total number of underfive deaths in 2015 [6].

Depletion of fluids and electrolytes (sodium concentration of 55 mEq/L, potassium concentration of 25 mEq/L, and bicarbonate concentration of 15 mEq/L in diarrheal fluid) occurs as a result of AWD. Oral or intravenous rehydration therapy, encouragement for breastfeeding, utilization of probiotics, zinc therapy, and, in selected patients, the administration of antibiotics are recommended for the management of AWD [7]. Notwithstanding the broad use of oral rehydration therapy (ORT) has resulted in substantial decreases in both the morbidity as well as mortality caused by diarrhea, rehydration has minimal effects on the duration and intensity of diarrhea [8]. Racecadotril is a newer addition to the collection of drugs used for the management of AWD in children [9]. Racecadotril exerts its effect through the inhibition of enkephalinase, which increases the antisecretory effect of enkephalin in submucosal enteric neurons. Once absorbed following oral administration, it is transformed into its active metabolite (thiorphan), which prolongs the action of methionine-enkephalin [10]. Racecadotril has an appreciable safety profile and tolerability with no serious adverse effects [5,11].

The administration of racecadotril has also been recommended for the management of AWD, but the recommendation is weak and based on moderate-quality evidence [3,12,13]. However, there is conflicting evidence demonstrating the effectiveness of racecadotril in severe AWD. In 2017, Gharial J et al. studied the effectiveness of racecadotril for the management of severe AWD and reported no remarkable decrease in the frequency of stools, duration of hospital stay or occurrence of diarrhea in the study group [14]. By excluding patients with severe dehydration, Sreenivas S K et al. studied the effectiveness of racecadotril combined with ORT for AWD in children and reported a decrease in the mean frequency of loose stools within 48 hours (34.1%), mean recovery time within 48 hours (79.24%) and mean volume of ORS consumed (30.1%) in the study group [15]. Nevertheless, few studies have compared the average hospital stay duration in children aged 6–60 months with AWD who have some or severe dehydration with or without acute malnutrition and who are treated with racecadotril as an adjunct to standard therapy. AWD is related to considerable hospitalization rates and substantial healthcare costs in our country, which not only increase financial costs to the family but also increase the bed occupancy rate and health care cost in hospitals. Considering these factors, we designed this study to compare the duration of hospital stay in children aged 6–60 months with AWD, some or severe dehydration, and with or without acute malnutrition who received racecadotril as an adjunct to standard therapy versus standard therapy alone; if it is proven efficacious, its use may reduce not only the financial burden on families but also hospital bed occupancy and healthcare costs, particularly during peak diarrheal seasons.

2. Methods

2.1. Study design, duration, and settings

This comparative interventional study was conducted for six months from October 2024 to March 2025 in the Pediatric Medicine Department, Mayo Hospital, Lahore, Pakistan, one of the largest and oldest public healthcare facilities in the country with 2,400 beds, providing general and specialized healthcare services since its inception.

2.2. Ethics considerations

The study received approval from the Board of Studies in Pediatric Medicine (No. Prof/Paeds/BOS/KE/MH/U-1-505-509), Project Evaluation Committee (No. 1159/PEC/RC/KEMU), Institutional Review Board (No. 13725/REG/KEMU/2020) and Advanced Studies &

Research Board (No. 2078/KEMU/2020) of King Edward Medical University, Lahore, Pakistan, which is affiliated with Mayo Hospital, Lahore. Written informed consent was obtained from the parents or caregivers of all the recruited children before enrollment.

2.3. Sample size and sampling technique

Sample size was calculated on the basis of the comparison of two independent groups (racecadotril + standard therapy versus standard therapy alone) using a two-sided t test with α = 0.05 and power = 90%. Expected means and standard deviations were taken from a prior study: racecadotril group mean = 92.40 (SD = 38.99) and placebo group mean = 76.40 (SD = 31.09). Using the pooled variance approach, the pooled variance was σ2 = 1243.40 (pooled SD = 35.26), and the mean difference Δ = 16.0 [16]. The required sample size per group was calculated with the following formula:

$$n = \frac{2\,(Z_{1-\alpha/2} + Z_{1-\beta})^2\,\sigma^2}{\Delta^2} \quad (1)$$

which yielded n ≈ 102.1 per group using G*Power version 3.1. We rounded up to 104 participants per group to allow a small margin for loss to follow-up, resulting in the enrollment of 208 participants (104 per group). Simple random probability sampling was used for participant recruitment.

2.4. Participant selection

Children aged 6–60 months who presented with AWD, defined as the passage of ≥ 3 loose stools/day for < 14 days, and children with some or severe dehydration and either no acute malnutrition or moderate acute malnutrition (MAM) were enrolled, and those with severe acute malnutrition were excluded. Furthermore, children with diarrhea secondary to any local or systemic infection other than gastroenteritis, those with a history of receiving antidiarrheal medications, those who had used probiotics or antibiotics within 24 hours before presentation to the hospital, those with blood in the stools, and those with persistent vomiting were not included in the study.

2.5. Intervention

After enrollment, demographic information, including age, sex, and weight, was recorded for each participant. A detailed clinical history was obtained from parents or caregivers using a predesigned data collection proforma. Clinical examination was performed by the investigator, and the degree of dehydration at registration was assessed clinically according to WHO criteria and categorized as having some degree of dehydration or severe dehydration. Nutritional status was assessed using a WHO weight-for-height Z score chart and categorized as no acute malnutrition or MAM. All the enrolled children received standard treatment for AWD according to the departmental management protocol. Standard treatment included oral or intravenous rehydration therapy as indicated by the degree of dehydration, zinc supplementation, continued feeding, breastfeeding support, and other supportive measures as needed. Body weight was measured at enrollment using a calibrated digital weighing scale and recorded in kilograms (kg).

Children were allocated to two groups, i.e., Group A and Group B, using a random number table. Children in Group A received racecadotril in addition to the standard treatment. Racecadotril was administered at a dosage of 1.5 mg/kg/day in three split doses. For administration, a 10 mg sachet of racecadotril was mixed with 10 mL of plain water, yielding a concentration of 1 mg/mL. The medication was administered for five days or until hospital discharge, whichever occurred earlier. Children in Group B received standard treatment alone and did not receive racecadotril. No placebo was administered to

participants in Group B. All participants were monitored throughout their hospital stay. Patients were discharged when they passed fewer than three stools per day or had two consecutive formed stools, whichever occurred first. The study outcomes included length of hospital stay (hours from admission to discharge) and a decrease in the frequency of loose stools during hospitalization.

2.6. Data analysis

The data were analyzed using SPSS version 26.0. Quantitative variables are summarized using medians, interquartile ranges (IQR), while categorical variables, including sex, degree of dehydration, and nutritional status, are described as frequencies and percentages. The distribution of continuous variables was assessed before analysis; age, weight, length of hospital stay, and reduction in stool frequency were nonnormally distributed. Thus, the Mann–Whitney U test and chi-square test was employed to achieve study objectives. Statistical significance was set at $p < 0.05$.

3. Results

Table 1 delineates that a total of 208 children were enrolled in the study, with 104 participants in each group. The median age was 13 months (IQR = 14.00) in Group A and 16 months (IQR = 20.00) in Group B, with similar distributions across the groups (p = 0.148). Similarly, median weight did not differ significantly between Group A [12 kg (IQR = 5.00)] and Group B [12 kg (IQR = 5.00)] (p = 0.430). The proportions of children with MAM and severe dehydration were also comparable between the two groups ($p > 0.05$), indicating baseline similarity of the study groups.

Table 1. Baseline characteristics of the study participants.

Characteristics		Group A (n = 104)	Group B (n = 104)	Z Statistic/χ^2	*p* Value
		Median (IQR)	Median (IQR)		
Age (months)		13.00 (14.00)	16.00 (20.00)	-1.450	0.148
Weight (in kg)		12.00 (5.00)	12.00 (5.00)	-0.789	0.430
Sex, n (%)	Male	62 (59.62)	57 (54.81)	0.491	0.483
	Female	42 (40.38)	47 (45.19)		
Degree of malnutrition, n (%)	Moderate acute malnutrition	14 (13.46)	20 (19.23)	1.260	0.261
	No acute malnutrition	90 (86.54)	84 (80.77)		
Degree of dehydration, n (%)	Some dehydration	90 (86.54)	96 (92.31)	1.830	0.176
	Severe dehydration	14 (13.46)	8 (7.69)		

The average length of hospital stay was significantly shorter in Group A [22.75 hours (IQR = 11.00)] than in Group B [61.00 hours (IQR = 24.00)] ($p < 0.001$) (Table 2). Similarly, the median decrease in the frequency of loose stools during hospitalization was significantly greater in Group A [9.00 (IQR = 2.00)] than in Group B [5.00 (IQR = 2.00)] ($p < 0.001$).

Table 2. Comparison of study outcomes between the two study groups.

Outcome	Group A	Group B	Z Statistic	*p* Value
	Median (IQR)	Median (IQR)		
Duration of hospital stay (hours)	22.75 (11.00)	61.00 (24.00)	-10.74	< 0.001
Reduction in number of loose stools during hospital stay	9.00 (2.00)	5.00 (2.00)	12.440	< 0.001

Table 3 demonstrates that among the children with MAM, the average duration of hospital stay was significantly shorter in Group A [40.00 hours (IQR = 35.00) versus 65.00 hours (IQR = 29.00) in Group B; $p = 0.003$]. Similarly, among children without acute malnutrition, the median hospital stay was significantly shorter in Group A [22.00 hours (IQR = 10.60)] than in Group B [60.50 hours (IQR = 24.00)] ($p < 0.001$). Among children with some degree of dehydration, the median length of hospital stay was shorter in Group A [22.00 hours (IQR = 10.10) versus 59.50 hours (IQR = 23.50) in Group B, $p < 0.001$]. Similar results were observed among children with severe dehydration, where the median hospital stay was significantly shorter in Group A [41.50 hours (IQR = 41.40)] than in Group B [73.00 hours (IQR = 30.50)] ($p = 0.013$).

Table 3. Comparison of duration of hospital stay by nutritional status and degree of dehydration.

Variables		Duration of Hospital Stay (Hours)		Z Statistic	*p* Value
		Group A	Group B		
		Median (IQR)	Median (IQR)		
Degree of malnutrition	Moderate acute malnutrition	40.00 (35.00)	65.00 (29.00)	-3.011	0.003
	No acute malnutrition	22.00 (10.60)	60.50 (24.00)	-10.240	< 0.001
Degree of dehydration	Some dehydration	22.00 (10.10)	59.50 (23.50)	-10.760	< 0.001
	Severe dehydration	41.50 (41.40)	73.00 (30.50)	-2.490	0.013

4. Discussion

Diarrhea remains among the prominent causes of morbidity as well as mortality among children under 5 years of age, particularly in developing countries. Even though the death toll owing to diarrhea has substantively decreased, it is still responsible for a sizeable proportion of under five deaths. The treatment of choice is oral or intravenous rehydration therapy. Nevertheless, although it is effective in most cases of mild to moderate illness, it does not substantially reduce the frequency, volume, or diarrhea duration [17]. Therefore, adjunctive therapies that can shorten the course of illness, reduce the course of illness and reduce hospitalization remain of clinical interest [18].

Given that local evidence regarding the effectiveness of racecadotril in AWD is limited, this study was conducted to evaluate its role as an adjunct to standard therapy. The findings of the present study suggest that racecadotril may be beneficial for reducing the duration of hospitalization among children with AWD. This finding aligns with those reported by Lehert et al., who conducted a meta-analysis evaluating racecadotril use as an adjunct to oral rehydration solution in children with acute gastroenteritis [19,20]. The authors concluded that racecadotril provided favorable outcomes in reducing diarrheal episodes irrespective of age, rotavirus status, dehydration status, treatment setting, or geographic region. Similarly, Sultana et al reported a significantly shorter duration of hospitalization among children receiving racecadotril than among those receiving placebo [21]. Another study also demonstrated superior outcomes with racecadotril compared with conventional treatment, with a significant reduction in recovery time among both outpatient and hospitalized children [22]. These findings corroborate those of our study, which supports the potential role of racecadotril as an effective adjunctive treatment in children with AWD.

Furthermore, another study reported that the average diarrhea duration was considerably shorter among children treated with racecadotril than among those receiving a placebo [23]. However, not all studies have demonstrated similar benefits. Gharial et al evaluated the efficacy of racecadotril in severe AWD and reported no significant reduction in the stool frequency, duration of diarrhea, or length of hospital stay [14]. Conversely, the findings of our study indicate that racecadotril may still provide clinical ben-

efit even among children who present with dehydration [24]. Differences in our populations, severity of illness, inclusion criteria, treatment protocols, and outcome assessment methods may account for the variation in findings across studies [25].

Our study has several limitations. First, it was conducted at a single tertiary care center, and the target population was limited. In addition, infants younger than six months and children older than five years were excluded. Therefore, our study findings cannot be generalized to the whole pediatric population. Bias could have been introduced because of nonblinding. Therefore, larger multicenter, blinded, randomized clinical trials are needed before the regular use of racecadotril in AWD is recommended. These results may have been affected by recall bias because the stool frequency was reported by parents or caregivers. Assessment of mortality and complication rates was also not included in this study.

5. Conclusions

Racecadotril as an adjunct to standard therapy significantly reduces the length of hospital stay in children aged 6–60 months with AWD, including those with MAM and some or severe dehydration.

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Original Article

Parental knowledge of mobile applications for improving literacy among children with hearing impairment

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Abstract

Mobile phone applications have increasingly been used as tools for literacy development in children with hearing impairment. This cross-sectional study determined parental knowledge of mobile applications and explored how demographic factors relate to that knowledge; and included 376 parents of children with hearing impairment. The study used a structured questionnaire and a purposive sampling technique for data collection. Results of the study highlighted that most parents showed a moderate level of knowledge (67.55%), while 21.81% had high knowledge and 10.64% had low knowledge. Many parents felt that mobile applications helped their children's learning activities, including communication, vocabulary development, problem solving, and understanding of educational content. Parental knowledge was significantly associated with parent or guardian gender ($\chi^2 = 7.605$; $p = 0.022$), parent or guardian education ($\chi^2 = 20.572$; $p = 0.008$), and child's academic grade ($\chi^2 = 39.361$; $p < 0.001$). Our study found that parents or guardians generally had a moderate level of knowledge about using mobile applications to support literacy which varies by gender, educational level, and child's academic grade suggesting digital awareness is not evenly distributed across different parent groups. These findings suggest a need for targeted educational intervention in order to strengthen digital literacy, especially among parents with lower educational attainment. Such interventions could help these parents better support their children's literacy development.

Keywords

Assistive mobile technology; Digital literacy; Literacy development; Mobile applications, Children with hearing impairment

1. Introduction

Literacy development is a major challenge among children with hearing impairment, and they usually struggle with phonemic awareness and acquisition of language [1,2]. Limited access to auditory cues can affect their reading and writing abilities, making alternative learning strategies compulsory [3]. Mobile phone technology has become a favorable tool in special education of children in recent years, with assistive applications that offers features including but not limited to sign language support, speech-to-text conversion, and interactive learning for people with special needs [4,5].

Scientific evidence has highlighted those digital tools, like word prediction software, mobile dictionaries, and sign language translation applications, can improve vocabulary

and reading proficiency in children with hearing impairment [6,7]. These advances in mobile technology have led to a range of assistive soft tools with an aim to address educational needs of special population [8]. Moreover, mobile phone applications that combine speech-to-text capabilities, interactive visual aids, and gamified literacy exercises usually are engaging, and an accessible way to build reading and writing skills [9].

These mobile phone applications have demonstrated to improve comprehension, support acquisition of vocabulary, and contribute to overall language development in special needs children [10]. However, use of these soft tools in an effective and efficient manner depends on active parental engagement and support [11]. Parents who understand mobile applications well and integrate them into their educational routine of children to help to address gaps in language comprehension, which in turn supports their communication and literacy skills among special needs children [12,13,14,15]. Attitudes, beliefs, and level of engagement of parents also play an important role in shaping learning outcomes; those parents who recognize the educational value of these mobile applications are more likely to use and incorporate them as part of daily learning of special needs children [16,17,18].

Despite these advancements of mobile phone applications for learning, many parents may not be aware of available resources or may not fully understand their potential benefits [19]. Moreover, disparities in parental knowledge and adoption of mobile applications may exist, especially in communities with limited access to technology or inadequate digital literacy training [20,21,22]. Understanding the extent of parental awareness and knowledge regarding mobile applications for literacy development is essential for optimizing their use in special education [23,24]. Therefore, this study was conducted to assess parental knowledge of mobile applications for improving literacy among children with hearing impairment and to explore the association between demographic factors and the level of knowledge regarding these applications.

2. Methodology

2.1. Study design and duration

This cross-sectional study was conducted for a period of six months between February and July 2024.

2.2. Ethical considerations

Ethical approval was obtained from the Research and Ethics Committee of Riphah International University (No. REC/RCR&AHS/23/0631). Written informed consent was obtained from the parents or legal guardians of the children with hearing impairment who participated in the study.

2.3. Study settings

Data were collected from various educational and rehabilitation institutions serving children with hearing impairment in Lahore, Punjab, Pakistan, including the Hamza Foundation Academy for the Deaf, Deaf Reach School, Innayat Foundation Academy for the Deaf, Badar Care School, Lahore Residency and Rehabilitation Center, and Riphah Rehabilitation Center.

2.4. Participant recruitment

The study targeted parents of children aged 9 to 15 years who had been diagnosed with moderate to profound hearing impairment and were actively utilizing mobile applications for literacy improvement. However, parents of children with additional co-mor-

bid conditions such as intellectual disabilities, autism spectrum disorder, or neurological impairments were not included in the study.

2.5. Sample size and sampling technique

The sample size was calculated using OpenEpi (version 3.00) by taking the expected proportion of parental knowledge about educational applications as 60.4% on the basis of a previous study, with a 95% confidence level and a 5% margin of error [25]. The calculated sample size was 368, which was further increased to 400 to account for potential nonresponse and incomplete questionnaires. A purposive sampling technique was used for the selection of participants.

2.6. Study tool development

A structured questionnaire was adopted from previous studies conducted by Achouche et al. and Cheadle [26,27]. The final questionnaire was sent to two field experts for review, including a PhD-qualified medical educationist and a senior special childcare professional with over 10 years of clinical experience, to assess its content validity regarding relevance, clarity, as well as appropriateness of the items. The revised questionnaire was subsequently pretested on five study participants to assess its face validity and comprehensibility. The reliability of the questionnaire was tested using Cronbach's alpha. The internal consistency of the Likert-scale items used to assess parental knowledge was high, with a Cronbach's alpha value of 0.897. The results of the pretest survey were not included in the final analysis of the study.

2.7. Study measures

The questionnaire consisted of two sections. The first section included demographic information, such as the parent's or guardian's sex, their qualifications, monthly income, and the child's age, sex, and academic grade. The second section consisted of sixteen questions answered on a 5-point Likert scale (ranging from strongly disagree to strongly agree, scored from 1 to 5), which were designed to assess parents' knowledge as operationalized through their awareness, familiarity, perceived educational value, and reported use of mobile applications that support literacy development among children with hearing impairment. The overall minimum score was 16, and the maximum score was 80; parents' knowledge was categorized as low for scores from 16 to less than 40 points (< 50%), moderate for scores from 40 to < 64 points (50– < 80%), and high for scores from 64 to 80 points (80–100%) using the modified Bloom's cutoff points [28].

2.8. Data collection

Permission for data collection was obtained from the concerned authorities of the targeted institutions prior to conducting face-to-face interviews in local languages with study participants in a separate room designated by the administration, with each interview lasting between 10 and 15 minutes.

2.9. Data analysis

Data was analyzed using SPSS version 25.00, and descriptive statistics were calculated for the study variables. Furthermore, the chi-square test was used to assess the association between parents' level of knowledge and sociodemographic characteristics.

3. Results

Of 400 parents/guardians approached, 376 completed the interview, yielding a response rate of 94.0%. More than half of the parents/guardians were male (57.71%), whereas 42.29% were female (Table 1). Most parents/guardians had a bachelor's degree (34.31%), followed by a master's degree or above (22.07%). The mean age of the children was 11.87 ± 1.92 years, with a slightly greater percentage of male children (52.66%). Most of the children were in grades 4–5 (36.20%), followed by grades 6–8 (33.80%).

Table 1. Sociodemographic characteristics of the study participants and their children with hearing impairment.

Variables		Frequency (%)
Parent/guardian gender	Male	217 (57.71)
	Female	159 (42.29)
Parent/guardian education	Illiterate	41 (10.90)
	Matriculation	51 (13.56)
	Intermediate	72 (19.15)
	Bachelor's degree	129 (34.31)
	Master's degree or above	83 (22.07)
Monthly household income (in PKR)	≤ 20,000 PKR	30 (7.98)
	20,001–40,000 PKR	86 (22.87)
	40,001–60,000 PKR	73 (19.41)
	60,001–80,000 PKR	94 (25.00)
	> 80,000 PKR	93 (24.73)
Child's age (in years), Mean ± SD		11.870 ± 1.919
Child's gender	Male	198 (52.66)
	Female	178 (47.34)
Child's academic grade	Grades 1–3 (primary)	75 (19.90)
	Grades 4–5 (upper primary)	136 (36.20)
	Grades 6–8 (middle school)	127 (33.80)
	Grades 9–10 (matriculation level)	38 (10.10)

As shown in Table 2, a considerable proportion of parents/guardians agreed that their children used mobile applications for educational and literacy-related purposes. In particular, many respondents reported that mobile applications supported study activities, problem solving, vocabulary improvement, and understanding of learning content.

Table 2. Parental responses to statements regarding the use of mobile applications for literacy development among children with hearing impairment.

Variables	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	N (%)	N (%)	N (%)	N (%)	N (%)
Daily use of a mobile device	53 (14.10)	31 (8.24)	49 (13.03)	182 (48.40)	61 (16.22)
Use of mobile applications for study	20 (5.30)	52 (13.80)	59 (15.70)	180 (47.90)	65 (17.30)
Mobile applications help solve study problems	28 (7.40)	36 (9.60)	88 (23.40)	182 (48.40)	42 (11.20)
Use of Google Live Transcribe to convert speech into text	22 (5.90)	90 (23.90)	126 (33.50)	106 (28.20)	32 (8.50)
Use of sign language translation applications	26 (6.90)	48 (12.80)	105 (27.90)	178 (47.30)	19 (5.10)
Use of social media to connect with friends	21 (5.60)	49 (13.00)	52 (13.80)	196 (52.10)	58 (15.40)
Texting with friends helps improve vocabulary	18 (4.80)	58 (15.40)	56 (14.90)	220 (58.50)	24 (6.40)
Understands social media content without sign language	8 (2.10)	43 (11.40)	84 (22.30)	197 (52.40)	44 (11.70)
Use of a word prediction tool on the keyboard	19 (5.10)	52 (13.80)	78 (20.70)	193 (51.30)	34 (9.00)

Variables	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	N (%)	N (%)	N (%)	N (%)	N (%)
Word prediction tools help memorize or learn new words	11 (2.90)	47 (12.50)	69 (18.40)	172 (45.70)	77 (20.50)
Use of mobile dictionaries to search for meanings of new words	35 (9.30)	58 (15.40)	49 (13.00)	158 (42.00)	76 (20.20)
Parental support in mobile application use for academic purposes	17 (4.50)	25 (6.60)	57 (15.20)	222 (59.00)	55 (14.60)
Asks about new applications or games to enhance literacy	9 (2.40)	95 (25.30)	46 (12.20)	212 (56.40)	14 (3.70)
Mobile applications have improved the child's learning	10 (2.70)	53 (14.10)	43 (11.40)	216 (57.40)	54 (14.40)
Searches difficult study topics using a mobile device	20 (5.32)	55 (14.63)	39 (10.37)	228 (60.64)	34 (9.04)
Videos with subtitles help understand content more quickly	14 (3.70)	45 (12.00)	68 (18.10)	174 (46.30)	75 (19.90)

The majority of the parents/guardians had a moderate level of knowledge (67.55%) regarding mobile applications for improving literacy among children with hearing impairment (Table 3). In contrast, 21.81% had high knowledge, while 10.64% had low knowledge.

Table 3. Distribution of parents according to the level of knowledge regarding mobile applications for improving literacy among children with hearing impairment.

Variables		Frequency (%)
Level of parental knowledge	Low knowledge (< 50%)	40 (10.64)
	Moderate knowledge (50– < 80%)	254 (67.55)
	High knowledge (80–100%)	82 (21.81)

As shown in Table 4, parent/guardian gender was significantly associated with the level of parental knowledge ($\chi^2 = 7.605$, $p = 0.022$). A statistically significant association was also found between parent/guardian education and the level of parental knowledge ($\chi^2 = 20.572$, $p = 0.008$). Similarly, the child's academic grade was significantly associated with the level of parental knowledge ($\chi^2 = 39.361$, $p < 0.001$).

Table 4. Association between sociodemographic factors of parents and their level of knowledge regarding mobile applications for improving literacy among children with hearing impairment.

Variables		Level of Parental Knowledge			Chi-Square Value	Degree of Freedom (df)	*p* Value
		Low Knowledge	Moderate Knowledge	High Knowledge			
		Frequency (%)	Frequency (%)	Frequency (%)			
Parent/guardian gender	Male	15 (37.50)	154 (60.63)	48 (58.54)	7.605	2	0.022 *
	Female	25 (62.50)	100 (39.37)	34 (41.46)			
Parent/guardian education	Illiterate	8 (20.00)	28 (11.02)	5 (6.10)	20.572	8	0.008 *
	Matriculation	10 (25.00)	34 (13.39)	7 (8.54)			
	Intermediate	11 (27.50)	47 (18.50)	14 (17.07)			
	Bachelor's degree	6 (15.00)	91 (35.83)	32 (39.02)			
	Master's degree or above	5 (12.50)	54 (21.26)	24 (29.27)			
Child's academic grade	Grades 1–3	6 (15.00)	61 (24.02)	8 (9.76)	39.361	6	< 0.001 *
	Grades 4–5	5 (12.50)	107 (42.13)	24 (29.27)			
	Grades 6–8	19 (47.50)	69 (27.17)	39 (47.56)			
	Grades 9–10	10 (25.00)	17 (6.69)	11 (13.41)			

* Chi-square test of association. ** Significance at $p < 0.05$.

4. Discussion

The present study examined parental knowledge regarding the use of mobile applications for improving literacy among children with hearing impairment and assessed its

association with selected sociodemographic factors. The findings showed that most parents demonstrated a moderate level of knowledge regarding the use of mobile applications for literacy development. Parents reported various forms of mobile application use by their children for learning-related activities, including communication, vocabulary development, and access to educational content. In addition, significant associations were observed between the level of parental knowledge and certain sociodemographic characteristics, including parent/guardian gender, parent/guardian education, and the child's academic grade, with higher levels of knowledge more common among male parents/guardians, those with higher educational attainment, and parents of children in higher academic grades.

The results of our study are in line with those of a mixed-method study conducted on school children and highlight that parents moderately agree that mobile phone applications are helpful in improving children's literacy [29]. Furthermore, in support of the results of the current study, the scientific literature highlights that the use of mobile applications for learning improves children's world learning, language learning and communication capabilities [30]. Another study highlighted mobile applications as effective tools for improving children's knowledge [31].

A Greek study reported better awareness among parents of the use of mobile phone applications to enhance learning among children. Parents usually have better knowledge and prefer mobile applications for learning because they are economical, easily accessible and convenient to use [32,33]. Although parental knowledge about mobile applications for learning depends upon several factors, it can also vary based on the scientific scale used for measurement [34]. Furthermore, the language of the application and user interface may hinder the use of mobile applications in learning [35,36].

Parents' sociodemographic characteristics, mainly age and level of education, play a vital role in obtaining the true benefits of the applications for children's learning and literacy development. However, the choice of mobile application may hamper learning among children [37]. Another study conducted in Greece highlighted the association of the use of mobile applications for children's learning with the age of parents, number of children at home, knowledge of the application and frequency of usage [38]. A French qualitative study also revealed that the literacy level of parents and culture may impact the learning of children through the use of digital tools [39]. Another study revealed that the digital literacy of parents also positively influences the digital learning of children and vocabulary enhancement [40]. However, a study conducted in the Philippines revealed that learning among children through the use of digital media is not related to parental level of education, the environment at home or the use of electronic devices at home, suggesting that all children can benefit positively from digital learning tools [41].

Studies have shown that mobile devices and applications are effective at learning children with special needs but are influenced by the mobile phone usage behaviors of parents [42,43]. Furthermore, parents with higher levels of education and technical background and with frequent use of electronic gadgets are more inclined to use mobile applications for children's learning [44,45]. Marketing of mobile phone applications may influence the knowledge of parents, and it may impact their choices for the selection of applications as well among different cultural settings [46].

The study used a standardized tool, furnished scientific evidence from the local context and gathered samples from a diverse range of sociodemographic parameters, highlighting the strengths of the study. However, the study did not take into consideration the qualitative factors responsible for parental attributes in the use of mobile applications for special needs children's learning. Furthermore, knowledge was self-reported and may contain bias, and findings of the study cannot be generalized, which remains a weak-

ness of the study. Although questionnaire was designed to capture knowledge of parents through awareness and self-reported engagement with mobile applications, some items also reflected practices and perceptions, which should be considered when interpreting the findings.

5. Conclusions

The study highlighted that parents or guardians generally had a moderate level of knowledge about use of mobile phone applications to support literacy, which varies by gender, educational level, and academic grade of children. These findings suggest a need for targeted educational intervention to strengthen digital literacy, especially among parents with lower education.

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Original Article

Differences in anxiety and subjective sleep among medical students in two curricular models: a crosssectional comparative study

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Abstract

Anxiety and poor quality of sleep are common among medical students, and they are affected by exhaustive academic schedules as well as different curricular models at teaching institutions. This study examined differences in the levels of anxiety and sleep experiences among medical students who were registered in two different types of curricula at a private medical college, determined whether curriculum type is related to differences in anxiety and sleep patterns, as well as explored the relationships between anxiety and sleep features among students for each type of curriculum. This cross-sectional comparative study was conducted for six months at Niazi Medical & Dental College (NMDC) and included 184 students, with 92 participants in each curriculum group. A nonprobability quota sampling technique with equal distribution was used, and anxiety and quality of sleep were determined by using the Hamilton Anxiety Rating Scale (HAM-A) and Pittsburgh Sleep Quality Index (PSQI), respectively. The results of the study revealed that most participants were from the 4th year (n = 66, 35.9%), the median HAM-A score was 23.00, and the median PSQI score was 7.00. No statistically significant difference was observed in the levels of anxiety between the two curriculum groups ($p = 0.137$). However, students in the modular curriculum reported significantly poorer quality of sleep ($p = 0.036$) and shorter sleep duration ($p = 0.009$). Anxiety was significantly positively correlated with overall PSQI scores in both the annual ($p < 0.001$) and the modular ($p < 0.001$) curricula. In the modular group, anxiety was significantly associated with overall quality of sleep, sleep latency, sleep disturbance, reduced sleep efficiency, and fewer hours in bed (all $p < 0.05$). The study concluded that anxiety levels did not differ significantly between the two curriculum types. However, students in the modular curriculum experienced poor quality and shorter durations of sleep. Furthermore, anxiety was significantly associated with adverse sleep outcomes.

Keywords

Anxiety; HAM-A; PSQI; Quality of sleep; Medical education; Medical students; Medical curriculum; Healthcare academia

1. Introduction

Medical education is globally recognized as a highly demanding, challenging, and high-pressure process with significant psychological and physiological strain on students [1,2]. Medical students have been reported to experience greater psychological distress (30.6%), with anxiety being among the most prevalent, when compared with general population [3,4]. Performance expectations, a competitive environment, continuous assess-

ments, and early exposure to straining clinical scenarios all contribute to increased vulnerability [5]. Along with psychological effects, anxiety can damage the cognitive abilities of students, decision-making processes, academic performance, and long-term professional development [6].

Poor quality of sleep among students has become an important concern in medical and healthcare education [7]. The rigorous, demanding, and challenging structure of medical training often disrupts the sleep patterns of students, resulting in sleep deprivation and reduced quality of sleep, affecting medical students more than nonmedical students do [8]. Sleep disturbances in such situations are linked to stress, which also contributes independently to worsening anxiety and other mental health issues [9]. This cyclic bidirectional relationship among medical students negatively affects memory consolidation, learning ability, and academic and clinical performance [10]. Furthermore, chronic anxiety and poor quality of sleep are linked to burnout, depression, and diminished empathy, which increase the potential risks to patient safety in clinical settings [11]. Since medical students are considered future healthcare professionals and future experts in the field, their mental and physical health is important not only for themselves but also for patients and for maintaining the integrity of future healthcare services [12].

Scientific evidence suggests that the curriculum structure in medical sciences affects student well-being [13,14]. Traditional, lecture-based academic programs heavily rely on memorization, high-stakes summative assessments, and extensive written examinations, which increase academic stress [15]. In contrast, integrated or problem-based learning (PBL) programs encourage self-directed learning, critical thinking, and formative assessment, which may foster a more conducive academic environment for professional learning [16]. However, in the context of South Asia, limited scientific evidence is available to highlight the differences in educational approaches that impact medical students' anxiety and sleep patterns in terms of external stressors.

The present study is based on the transactional model of stress and coping proposed by Lazarus and Folkman, in which it is suggested that psychological stress results from a person's appraisal of environmental needs relative to their available coping resources [17]. Within medical education, the structure of the curriculum represents an important academic demand that may affect students' perceptions of workload, the frequency of assessments, and learning expectations. These cognitive appraisals may contribute to anxiety, which can ultimately affect behavioral and physiological outcomes, including but not limited to the quality as well as duration of sleep among medical students. Moreover, this framework provides a theoretical basis for observing whether differences in the organization of the curriculum are associated with differences in anxiety and subjective sleep experiences among medical students [17]. Particularly, it compares medical students enrolled in two distinct curricular models—traditional and integrated—in a private medical college in Pakistan [18]. By exploring these relationships, this study aims to contribute to the development of more student-centered medical education models that support psychological strength and academic performance [19]. Therefore, this study explores differences in anxiety levels and sleep experiences, including perceived quality and duration of sleep, among medical students enrolled in two different models of the curriculum at a private medical college. It also aims to determine whether curriculum type is associated with differences in anxiety and sleep patterns. Finally, it explores the relationships between anxiety and sleep characteristics for each curriculum type.

2. Methods

2.1. Study design and setting

This study was a comparative cross-sectional in nature, and was conducted over a six-month period at Niazi Medical and Dental College (NMDC), Sargodha.

2.2. Sample size and sampling technique

In total, 184 participants were enrolled, with 92 students selected from each curriculum group, namely, annual and modular [20]. The sample size was determined pragmatically on the basis of the total number of eligible students available during the study period and the feasibility of data collection within the NMDC. Given the reachable student population, which was registered in both curriculum types, an equal distribution of students between groups was adopted for balanced comparison and to enhance the internal validity of the between-group analyses. A nonprobability quota sampling technique was used, with an equal distribution of students across the annual and modular curriculum groups.

2.3. Eligibility criteria

Students who were currently enrolled in the specific academic year of either the annual or the modular curriculum type, who were able to understand the study instrument, and who provided verbal as well as written informed consent to participate were included in the study. Students who self-reported a previous diagnosis of sleep disorders or severe mental health problems; who used medications for anxiety or sleep; or who had experienced major emotional or psychological events within the past three months were excluded from the study.

2.4. Study instruments

The study employed two validated instruments for data collection. The Hamilton Anxiety Rating Scale (HAM-A), which is a clinician-rated 14-item scale for determining both the physical and the somatic symptoms of anxiety among participants [21], was converted into an online self-administered tool because of the Google Form data collection approach adopted by the study [22]. Furthermore, the Pittsburgh Sleep Quality Index (PSQI), which is a self-reported 19-item questionnaire used to determine subjective sleep quality over the previous month, was used [23]. English versions of the HAM-A and PSQI were used in this study, as English is the official medium of instruction in Pakistani medical colleges, and it was assumed that all participants were proficient in English and were able to comprehend the questionnaire items without requiring translation.

2.5. Study measures

The HAM-A was used to measure mental stress, psychological distress, and physical symptoms associated with anxiety among the participants. Each item on the instrument was scored on a 5-point Likert scale ranging from 0 (not present) to 4 (severe), with total scores ranging from 0–56 points; higher scores indicate greater severity of anxiety. The PSQI measures quality of sleep through seven-element scores, highlighting subjective quality of sleep, habitual sleep efficiency, sleep latency, sleep disturbances, sleep duration, daytime dysfunction, and use of sleep medication. These element scores, when summed, ranged from 0–21 points, with higher scores highlighting poorer quality of sleep.

2.6. Data collection procedure

Ethical approval for the purpose of the study was obtained from the Institutional Research Advisory Board (IRAB) [No. DRC/0261/04/ERC-(25)], and permission to collect data and gain access to students was obtained from the concerned heads and offices of the institution. Students were equally divided into two groups: those registered in curriculum type A (annual) and those registered in curriculum type B (modular). Furthermore, for the purpose of data collection, students were contacted through official channels of the institution during regular academic sessions to avoid academic assessment or examination-related stress.

An online survey was distributed among the eligible students via Google Forms, along with informed consent and instructions for the participants to record their responses on Google Forms. The responses obtained were continuously monitored to identify any incomplete submissions. After the data collection was completed, the responses obtained from Google Forms were exported to Microsoft Excel for final data analysis.

2.7. Data analysis

Data analysis employed SPSS version 29.0 and used descriptive statistics for demographic characteristics, anxiety scores, and sleep metrics, which are reported as medians, IQRs and ranges. The Mann–Whitney U test was used to compare anxiety, quality of sleep, and duration of sleep among medical students registered in two different types of curricula (annual and modular), where effect sizes (r) were calculated and interpreted according to Cohen's criteria; multiple linear regression was used to examine the association of the two different types of curricula (annual and modular) with the study outcome variables. Spearman's correlation was used to determine the relationships between the anxiety and sleep characteristics of medical students in each curriculum group. A significance level of $p \leq 0.05$ was used.

3. Results

The study included 184 medical students across five academic years at an institution. Most of the participants were from the 4th year (n = 66, 35.9%), followed by the 2nd year (n = 46, 25.0%), 3rd year (n = 32, 17.4%), 5th year (13.0%) (n = 24, 13.0%), and 1st year (n = 16, 8.7%).

The median HAM-A anxiety score (23.00) and median PSQI score (7.00) are shown in Table 1. Furthermore, the HAM-A demonstrated excellent internal consistency (α = 0.93), and the PSQI showed acceptable reliability (α = 0.74). Self-reported sleep duration was 5.3 hours.

Table 1. Descriptive analysis of anxiety and sleep-related measures.

Variables	Median (IQR)	Range (Min – Max)	Cronbach Alpha (α)
Overall Hamilton Anxiety Scale score	23.00 (18.00)	0-56	0.93
Overall PSQI score	7.00 (5.00)	0-21	0.74
Bed time	02:00 am (4:00 hours)	-	-
Minimum time taken to fall asleep (in minutes)	20.00 (28.00)	-	-
Wake-up time	07:00 am (1:00 hour)	-	-
Subjective quality of sleep	1.00 (1.00)	0-3	-
Sleep latency	2.00 (2.00)	0-6	-
Sleep duration (in hours)	5.33 (2.46)	-	-
Hours in bed (in hours)	6.00 (2.50)	-	-

Variables	Median (IQR)	Range (Min – Max)	Cronbach Alpha (α)
Sleep efficiency, N (%)	93.51 (9.24)	0-100	-
Sleep disturbance	6.00 (9.75)	0-27	-
Use of sleep medication	0.00 (1.00)	0-3	-
Daytime dysfunction	2.00 (2.00)	0-6	-

Table 2 shows the comparisons of anxiety levels, quality of sleep, and sleep duration among students enrolled in the annual and modular curricula. No significant difference was observed in anxiety scores between the two groups (U = 3694.00; $p = 0.137$). However, students in the modular curriculum reported significantly poorer quality of sleep than did those in the annual system did (U = 3487.50, $p = 0.036$). Additionally, sleep duration was significantly shorter among students following the modular curriculum (U = 3313.00, $p = 0.009$). Table 2 further delineates that all effect sizes were small (r = 0.11–0.19).

Table 2. Comparisons of anxiety levels, quality and duration of sleep among medical students across curriculum types (N = 184).

Indicators	Curriculum Type	n	Mean Rank	U Value	*p* Value	Effect Size	Magnitude
Anxiety	Annual	92	86.65	3694.0	0.137	0.11	Small
	Modular	92	98.35				
Quality of sleep	Annual	92	84.41	3487.5	0.036 *	0.15	Small
	Modular	92	100.59				
Sleep duration	Annual	92	102.49	3313.0	0.009 **	0.19	Small
	Modular	92	82.51				

* $p \leq 0.05$, ** $p \leq 0.01$.

Table 3 shows correlation between anxiety and sleep-related parameters among medical students, stratified by curriculum type. In both the annual and modular groups, anxiety levels were significantly positively related to the overall PSQI score ($p < 0.001$), indicating that higher anxiety was associated with poorer overall quality of sleep. Similarly, anxiety was significantly correlated with greater sleep disturbance in both groups. Sleep latency was also more strongly positively associated with anxiety in the annual group ($\rho = 0.411$; $p < 0.001$) than in the modular group ($\rho = 0.241$; $p = 0.020$). In the modular curriculum, anxiety was negatively correlated with hours spent in bed ($\rho = –0.283$; $p = 0.006$) and sleep efficiency ($\rho = –0.272$; $p = 0.009$), whereas these associations were not statistically significant in the annual curriculum.

Table 3. Correlation between anxiety and sleep parameters among medical students by curriculum type (N = 92 per group).

Sleep Variables	Spearman's ρ (Annual)	*p* Value (Annual)	Spearman's ρ (Modular)	*p* Value (Modular)
Overall PSQI score	0.461	< 0.001 **	0.550	< 0.001 **
Sleep latency (minutes)	0.411	< 0.001 **	0.241	0.020 *
Total hours in bed	–0.025	0.813	–0.283	0.006 **
Sleep efficiency (%)	–0.196	0.061	–0.272	0.009 **
Sleep disturbance score	0.582	< 0.001 **	0.579	< 0.001 **

* $p \leq 0.05$, ** $p \leq 0.01$.

The association between sleep outcomes and anxiety scores among students in the annual curriculum is shown in Table 4. Anxiety was significantly associated with overall PSQI score ($p < 0.001$; $R^2 = 0.203$), sleep latency ($p < 0.001$; $R^2 = 0.153$), and sleep disturb-

ance ($p < 0.001$; $R^2 = 0.310$). However, anxiety was not significantly linked to sleep efficiency ($p = 0.239$) or hours in bed ($p = 0.931$).

Table 4. Associations between sleep outcomes and anxiety scores among students in the annual curriculum (N = 92).

Dependent Variable	β (Standardized)	SE	t	*p* Value	R^2
Overall PSQI score	0.460	0.027	4.919	< 0.001 ****	0.203
Sleep latency (minutes)	0.403	0.013	4.176	< 0.001 ****	0.153
Sleep disturbance score	0.564	0.040	6.477	< 0.001 ****	0.310
Sleep efficiency (%)	-0.124	0.071	-1.187	0.239	0.004
Hours in bed	-0.009	0.014	-0.087	0.931	-0.011

* Independent variable for all models: Hamilton Anxiety Total Score. ** Regression coefficients are standardized (β). *** R^2 shows the variance proportion in the dependent variable accounted for by anxiety. **** Significance threshold set at $p < 0.05$.

Table 5 provides multiple regression results for medical students enrolled in the modular curriculum. Anxiety was significantly associated with overall quality of sleep ($p < 0.001$, $R^2 = 0.301$), sleep latency ($p = 0.027$, $R^2 = 0.043$), and sleep disturbance ($p < 0.001$, $R^2 = 0.269$), indicating that higher anxiety scores were related to poorer subjective sleep outcomes. Additionally, anxiety was significantly associated with reduced sleep efficiency ($p = 0.014$; $R^2 = 0.054$) and fewer hours in bed ($p = 0.017$; $R^2 = 0.052$).

Table 5. Associations between sleep outcomes and anxiety scores among students in the modular curriculum (N = 92).

Dependent Variable	β (Standardized)	SE	t	*p* Value	R^2
Overall PSQI score	0.555	0.026	6.334	< 0.001 ****	0.301
Sleep latency (minutes)	0.231	0.014	2.255	0.027 ****	0.043
Sleep disturbance score	0.526	0.042	5.870	< 0.001 ****	0.269
Sleep efficiency (%)	-0.255	0.089	-2.499	0.014 ****	0.054
Hours in bed	-0.249	0.014	-2.439	0.017 ****	0.052

* Independent variable for all models: Hamilton Anxiety Total Score. ** Regression coefficients are standardized (β). *** R^2 shows the variance proportion in the dependent variable accounted for by anxiety. **** $p \leq 0.05$.

4. Discussion

Medical sciences have traditionally been known to be a challenging discipline of study, and the present study highlights that medical students are inclined to have significant levels of anxiety along with disturbed sleep patterns. While anxiety levels did not differ significantly between students registered in annual and modular curricula, significant differences were observed in the sleep parameters of the students; modular curriculum-registered students reported poor quality of sleep and a shorter duration of sleep, demonstrating a potential association between curriculum structure and sleep-related outcomes. These findings highlight the similar nature of psychological burdens among medical students regardless of curriculum type and that variations in academic organization and assessment patterns may unequally affect students' sleep habits and overall well-being.

The results of the current study revealed that most of the participants had mild anxiety, while approximately sixty percent reported symptoms of higher levels of anxiety. These findings are in line with those of a study conducted in Sudan on mental health challenges among medical students [24]. Previous studies have highlighted that the extreme demands of medical studies, anxiety about professional exams, busy study schedules, and difficulties encountered in clinical settings could be the primary sources of

stress among medical students [25,26,27]. Additional contributing factors include insufficient guidance, especially during clinical years, a lack of feedback, peer pressure, limited time for leisure activities, unsuitable learning environments, and disorganized clinical training patterns [28]. These factors make it challenging for medical students to function in an environment that is free from anxiety and stress [25]. These findings are supported by and interpreted through the transactional model of stress and coping, which proposes that individuals experience psychological stress according to their environmental demands rather than the demands themselves [29].

The present study demonstrated relatively better quality of sleep among students, as reflected by below-average PSQI scores. These findings are consistent with previous scientific evidence reporting similar quality of sleep scores among medical students [30]. The average bedtime of these medical students was found to be at 02:00 a.m., and the mean wake-up time was observed to be 07:00 a.m. These findings support the results of another study conducted on undergraduate medical students in India regarding their sleep, stress, and academic performance [31]. The low prevalence of sleep medication use in the current study was also consistent with the results reported in an earlier study [28]. Furthermore, eating habits, culture and male sex can affect the level and frequency of stress among medical students [32,33,34].

The results of the inferential statistics highlighted a nonsignificant difference in the anxiety scores of medical students based on their curriculum type. These findings highlight that, regardless of the curriculum structure, medical students frequently face significant stress and anxiety stemming from the inherent challenges of the medical profession. A study conducted at Helwan University showed that approximately 55% of participants reported experiencing moderate to high levels of anxiety, primarily because of academic, teaching, social, and intrapersonal circumstances, resulting in diminishing potential impact of the type of curriculum [35]. These results were also in line with a study conducted at Karachi Medical College to determine differences in knowledge among students enrolled in annual and modular medical programs and reported no difference in overall knowledge scores, making it inappropriate to state that one type of curriculum model is better than the other [36]. This could be attributed to the familial pressure to pursue a career in medicine, which is a dominant source of stress for medical students in Pakistan, reflecting the tendency of families to amplify stress and anxiety [37]. These findings align with those of another study demonstrating that external stressors, when interacting with inherent vulnerabilities, contribute to psychological outcomes such as anxiety and sleep disturbances [38].

Significant differences in quality of sleep were observed among medical students on the basis of their curriculum type, which may be attributed to the higher academic burden among students enrolled in modular systems because of rigorous class schedules and frequent assessments [39]. Modular academic programs are generally topic focused, with academic content covered over shorter periods of time and frequent quizzes and examinations, which may contribute to sustained academic stress [40]. Research on the effects of the modular medical education system on medical students is relatively scarce. However, the hectic schedule at medical colleges and rising academic demands contribute to the poor quality of sleep experienced by medical students [41].

Quality of sleep may also be affected because medical students frequently experience stress due to clinical rotations, examinations, and overnight work without sufficient rest. This lack of rest can decrease social interactions and personal relations and heighten the likelihood of anxiety and depression, which may lead to extreme fatigue and insomnia. Encountering depressive or stressful situations can activate neuroendocrine and behavioral responses of the body, which can result in alterations to the activities and

functioning of the immune system and hypothalamo-pituitary-adrenal axis of a human being. This can lead to sleep disturbances, disrupt slow-wave sleep, and contribute to poor quality of sleep [42].

A modular curriculum requires a classroom environment in which students are actively engaged in constructing knowledge and shifting the role of a teacher from merely delivering knowledge to facilitating student learning. Additionally, modularization demands the ongoing monitoring and assessment of students' progress throughout the module. It is believed that effective continuous assessment allows instructors to adjust their teaching and learning strategies on the basis of the evidence gathered from assessments [43]. Therefore, the increased responsibility for learning, late-night studying required by modular schedules, hinders consistent bedtime habits and social life [44].

When students need to stay awake at night because of educational demands, they tend to consume caffeine, which raises concerns about their sleep hygiene practices. Research has indicated that individuals with poor sleep patterns report higher levels of caffeine intake than those who sleep well. If caffeine is consumed in large quantities, it can disrupt sleep patterns. Depending on the dosage, it can have both positive and negative effects on behavior and cognitive performance. The intake of caffeinated beverages significantly decreases sleep duration, delays the time it takes to fall asleep, and overall undermines quality of sleep [45].

The study used two validated scales, the HAM-A and the PSQI, and a diathetic-stress model to assess medical students' anxiety and quality of sleep, which strengthened the scientific integrity of the study. In the present study, HAM-A, a clinician-administered instrument, was employed as a self-administered online questionnaire via Google Forms in accordance with previous scientific evidence, which may have introduced measurement bias and should be considered when the findings are interpreted. The data were acquired from only a single healthcare academic institution, highlighting a considerable limitation of the study. Furthermore, the study did not consider objective sleep measures or longitudinal assessments among medical students for targeted healthcare academic institutions. Moreover, regression analyses did not adjust for potential demographic variables (e.g., age, sex, and academic year), which may have affected the observed associations between variables. Therefore, future studies should use multivariable regression models that account for these potential confounding factors.

5. Conclusions

The results revealed that there was no significant difference between the level of anxiety among medical students and the type of curriculum, and medical students who registered in the modular type of curriculum experienced poor quality and duration of sleep. Higher anxiety scores were significantly associated with impaired sleep parameters, especially among medical students who were registered in the modular type of curriculum. These findings highlight the potential effects of the curriculum structure on the mental well-being of medical students.

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Data availability: The data supporting this study's findings are available from Syed Hyder Raza Naqvi upon reasonable request.

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Viewpoint

Modernizing criminal justice in Pakistan: the case for forensic reform

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Extract

The integration of forensic science, legal frameworks, and community health is crucial for achieving peace in developing territories. The judicial systems of countries such as Pakistan often struggle with low conviction rates as well as prolonged trial procedures, mainly owing to outdated fact finding methods and a blind reliance on eyewitness testimony, despite often being unreliable. This emphasizes the dire need to introduce advanced forensic technologies into the local legal system, including but not limited to digital forensics, DNA examination, toxicology screenings, and ballistic studies. To lower the odds of wrongful convictions, expedite legal proceedings, and help deter crime, dependence on objective, as well as scientifically validated evidence, is a pressing need. Therefore, this correspondence highlights that stronger forensic capabilities may build judicial trust and public faith in government institutions, which are key elements of a healthy and stable society.

Keywords

Forensic science; Criminal justice system; Social health; Judicial integrity; Societal peace; Pakistan

1. Introduction: relationship between society, law and justice

Harmony in any society directly correlates with its legal structure. Justice acts as one of the important pillars that contributes to making society healthy. When there are problems related to justice where the guilty go unpunished or the innocents do not become protected, it creates a sense of collective anxiety and fear [1]. The criminal justice system in Pakistan also suffers from several major issues, such as a low number of convictions and a long trial period. One of the most important weaknesses that the system faces is the heavy reliance on witness accounts of events that, according to cognitive science and history, are highly fallible [2]. To have a strong and peaceful society, it is very important for developing countries such as Pakistan to adopt a scientific way of doing things by employing forensic science technologies.

2. Transforming evidence by forensic science

To make a change in the judicial process, moving away from testimony-based evidence to scientifically proven material evidence becomes extremely important [3]. It is important to implement forensics, including 1) DNA profiling, which is a DNA-based analysis that provides extremely accurate means of identifying people by establishing centralized and legally supported DNA banks that would help in solving cases of sexual crimes, murder and mass casualty cases; 2) digital and cyber forensics, which has become extremely necessary to extract and preserve digital data from smartphones, cloud

systems and networks because of the increase in cyber-crimes over the past few decades; 3) forensic toxicology and chemistry, which is a chemical test that provides objective proof in cases of poisoning, drug abuse and crimes related to drug abuse; and 4) ballistics and tool mark analysis, which are automated systems for fingerprinting and ballistic testing that would help in identifying the guns used in crime.

3. Improving Pakistan's legal framework

Adopting scientific approaches within the judiciary has transformative benefits. For example, traditional evidence generally looks to eyewitness accounts that are accompanied by high error rates as well as delays [4]. In contrast, modern forensic approaches depend on scientific evidence and verifications, making the process more objective and supporting accurate prompt justice outcomes [5]. These developments have manifold imperative implications, including but are not limited to 1) reducing judicial bias by limiting influence in legal decision making; 2) fast-tracking case proceedings through clear scientific evidence easing court backlogs; and 3) preventing unlawful convictions by demonstrating that verdicts are made on the basis of objective data, ultimately strengthening human rights and their protection.

4. Societal advantages stemming from forensic science

The amalgamation of forensic science at the systemic level provides long-term societal benefits, including crime prevention, as lawbreakers are more likely to be deterred when they realize the certainty of punishment through scientific investigation, ultimately resulting in a decline in crime rates [6]. Moreover, the restoration of public confidence in the judiciary system strengthens public trust, reduces the likelihood of vigilantism, promotes social harmony and decreases communal discord. Furthermore, the protection of vulnerable members of society is enhanced, as forensic investigation serves as an impartial safeguard for women, children, and other vulnerable groups in cases of societal discrimination.

5. Problems in the forensic sector of Pakistan

Although institutions such as the Punjab Forensic Science Agency have demonstrated advancements in technology, several problems still exist, such as deficiencies in the training of first responders where the police may lack fundamental knowledge regarding the procedures of crime scene investigations and can contaminate the evidence and regional disparities where advanced forensic techniques are limited mostly to the urban population and outdated legislation, which requires regular updating of the legal framework because of the emergence of new forensic technologies globally [7].

6. Suggestions for better forensic integration

To take advantage of the full potential of forensic science in improving the system of justice and bringing about social peace, it is recommended that forensic training skills should be made compulsory in police training programs; the forensic services should be decentralized and established in each province and the legal education of judges and prosecutors should be introduced, with a focus on how to interpret forensic scientific findings, especially probabilistic DNA evidence, and forensic science should be introduced in the legal structure of Pakistan, which would not only be an administrative change but also a necessity for ensuring good social health. Replacing subjectivity with objectivity would enable Pakistan to create a criminal justice system that will effectively deter criminals and protect human rights.

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