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RESEARCH ARTICLE

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Impact of both socioeconomic level and occupation on antibody prevalence to SARS-CoV-2 in an Egyptian cohort: The first episode

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Abstract

We studied the impact of socioeconomic level on the anti-SARS-CoV-2-antibodies prevalence in an Egyptian cohort. The low socioeconomic standard group (LSS) included 51 humans, 30 females (F) and 21 males (M). The high socioeconomic standard group (HSS) included 55 subjects, 24 F and 31 M. Of the 30 LSSF, 6 were immunoglobulin M (IgM), 21 immunoglobulin G (IgG), and 6 double positive. Of the 21 LSSM, 5 were IgM, 12 IgG, and 5 double positive. Of the 24 HSSF, 6 were IgM, 11 IgG, and 5 double positive. Of the 31 HSSM, 6 were IgM, 14 IgG, and 4 double positive. Of the 51 LSS humans, 26 were symptomatic (S) and 25 asymptomatic (AS). Of the 26 S, 20 were IgG and 8 IgM/IgG double positive. Of the 25 AS, 13 were IgG and 3 IgM/IgG double positive. Of the 55 HSS humans, 38 were S and 17 AS. Of the 38S, 24 were IgG and 11 IgM positive of whom, 9 were double positive. Of the 17 AS, one was IgG and one IgM positive. The IgM prevalence was higher among the HSS humans. The IgG prevalence was significantly higher among the LSS humans. In the two different socioeconomic standards, the prevalence of either IgM or IgG was higher among F. An inverse correlation was observed between age and the anti-SARS-CoV-2-antibodies prevalence except for LSSF-IgG and LSSM-IgM. In conclusion, socioeconomic standard, gender, and age impact humoral responses to SARS-CoV-2 with a clear heterogeneity in individualized responses to the infection in terms of symptoms.

KEYWORDS

anti-SARS-CoV-2-IgM/IgG prevalence, Egyptian cohort, occupational nature, socioeconomic impact

1 | INTRODUCTION

Identifying social determinants, raising public health awareness, and increasing health precautions and safety measures are generally key issues in minimizing or preventing transmission of infection and in particular the devastating novel coronavirus known as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).[1–3] Of course, both socioeconomic and education levels as well as the nature of occupation will have an impact on public health awareness, practicing safety measures, preventive precautions, and eventually infection outcome and disease severity.[4]

On the other hand, heterogeneity in the symptoms and disease severity due to acquiring SARS-CoV-2 infection is quite broad and ranges from mild or no symptoms to severe illness with uncontrollable health eterioration[5] that ends up with case fatality rates ranging from 4.2%[6] to >6.7%.[7]

In fact, the problem does not lie in the clearly symptomatic patients, but rather in those who develop mild or no symptoms[8] but are carriers for the virus and represent a reservoir for spreading SARS-CoV-2 infection. We strongly believe that identifying those individuals and isolating them till the infection is cleared will dramatically contribute to reduction of disease transmission.

The first-line indication of exposure to infection is the humoral immune responses to the SARS-CoV-2.[9,10] Since the emergence of the SARS-CoV-2 outbreak, several biotech companies have entered the race to develop both qualitative and quantitative detection assays for both primary (Immunoglobulin M [IgM]) and secondary (Immunoglobulin G [IgG]) responses against the virus. Of these, the AMP rapid test SARS-CoV-2 IgG/IgM (AMEDALabordiagnostik GmbH) has shown 95.7% and 97.3% sensitivity and specificity for IgM with an overall agreement of 96.8% and the corresponding values for IgG were 91.8%, 96.4% and 95.0%, respectively. The ultimate goal of the present work is to study the impact of both socioeconomic level and occupational nature on the antibody prevalence to SARS-CoV-2 in an Egyptian cohort using the rapid anti-SARS-CoV-2 IgM/IgG detection assay as an indicator.

2 | MATERIALS AND METHODS

In the present work, we used the AMP rapid SARS-CoV-2 IgG/IgM test (AMEDA Labordiagnostik GmbH) to test the presence of SARS-CoV-2 IgM/IgG in sera collected from comparable sample sizes of two groups of Egyptian humans of different socioeconomic levels and occupational nature who are working at the National Research Centre of Egypt with the aim of studying if both socioeconomic level and occupational nature will or will not have an impact on the prevalence rates of the SARS-CoV-2 infection.

The group of low socioeconomic standards consisted of 51 humans, who comprised 30 females and 21 males. However, the high socioeconomic standard group included 55 subjects of 24 females and 31 males. Both groups had age ranges of 25–60 years. The low socioeconomic standard group was mainly composed of workers responsible for cleaning laboratories, offices, corridors, stairs, and toilets who are not well educated, not always able to keep a reasonable social distance either due to the fact that they are living in very crowded areas and frequently using very crowded public transportation, not consistently using disinfectants and are pretending to show that they are using but not really using facial masks. Unlikely, the high socioeconomic standard group was mainly composed of academicians and researchers who are ranging in job description from research assistants (master or doctoral students) to full professors who are trying to ideally keep adequate social distance by avoiding being in crowded public transportations or areas, always appropriately using facial masks and frequently using soap to wash hands and disinfectants upon need.

A consent form was filled and signed by all participants of the study, which included their agreement to participate in the study and to use their samples in the work. The questionnaire used included age, gender, suffering from chronic diseases, suffering from other viral diseases, type of received medications if any, developing fever, coughing or any flu-like symptoms during the time of the outbreak, place of living, type, and frequency of using public transportation.

Interviewing participants and withdrawal of blood samples took place in 2 successive days. Noteworthily, although the sampling date and place were announced to both groups on the same day, which was 1 week ahead of the sampling and a reminder was sent to both groups, the turnout of the low socioeconomic standard participants was more obvious in comparison with the high socioeconomic standard ones and the sampling team members sometimes needed to approach the high socioeconomic standard participants in their laboratories and offices to withdraw the blood samples and fill the questionnaires.

Blood collection was carried out in compliance with the relevant laws and institutional guidelines in accordance with the ethical standards of the Declaration of Helsinki and after taking the approval of the Medical Ethics Committee of the National Research Centre (meeting date: November 5, 2020, approval reference number: 20166). Sera were separated from individuals representing the two groups of different socioeconomic standards on the same day of sample collection and were freshly used for rapid detection of SARS-CoV-2 IgM/IgG.

Statistical analysis and plots were done using the GraphPad PRISM version 5 software. Results were expressed as means ± standard deviations (*SD*). Statistical significance was calculated by comparing the differences between means of different studied groups using the Student *t* test. Differences were considered significant when the $p < .05$. Correlation analysis was carried out by calculating the square value of the correlation coefficient (r^2) for nonparametric and non-normally distributed data.

3 | RESULTS

The gender distribution in the studied populations of the low and high socioeconomic standards is presented in Table 1. Of the 30 females of low socioeconomic standard, 6 were IgM positive, 21 were IgG positive, and 6 were positive for both antibody classes (Table 1). However, of the 21 males of low socioeconomic standard, 5 were IgM positive, 12 were IgG positive, and 5 were positive for both (Table 1). Among the 24 females of high socioeconomic standards, 6 were IgM positive, 11 were IgG positive, and 5 were positive for both (Table 1). However, of the 31 males of high socioeconomic standard, 6 were IgM positive, 14 were IgG positive, and 4 were positive for both (Table 1).

Out of the 51 studied human subjects of low socioeconomic standards, 26 were symptomatic and 25 were asymptomatic (Table 2). Of the 26 symptomatic subjects, 20 were IgG positive and 8 were positive for both IgM and IgG (Table 2). However, of the 25 asymptomatic subjects, 13 were IgG positive and 3 were positive for both IgM and IgG (Table 2). Of the 55 high socioeconomic standard studied humans, 38 were symptomatic and 17 were asymptomatic

TABLE 1 Prevalence of anti-SARS-CoV-2 IgM and IgG antibodies among studied human subjects from different socioeconomic standards

Socioeconomic level	Low						High					
Gender	Females (30)			Males (21)			Females (24)			Males (31)		
Antibody	IgM	IgG	Both	IgM	IgG	Both	IgM	IgG	Both	IgM	IgG	Both
Relative ratio	6/30	21/30	6/21	5/21	12/21	5/12	6/24	11/24	5/11	6/31	14/31	4/14

Abbreviations: IgG, immunoglobulin G; IgM, immunoglobulin M; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

TABLE 2 Prevalence of anti-SARS-CoV-2 antibodies in symptomatic and asymptomatic human subjects of different socioeconomic standards

Socioeconomic level	Low (51)						High (55)					
Disease	Symptomatic (26)			Asymptomatic (25)			Symptomatic (38)			Asymptomatic (17)		
Antibody	IgM	IgG	Both	IgM	IgG	Both	IgM	IgG	Both	IgM	IgG	Both
Relative ratio	8/26	20/26	8/26	3/25	13/25	3/25	11/38	24/38	9/38	1/17	1/17	0

Abbreviations: IgG, immunoglobulin G; IgM, immunoglobulin M; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

(Table 2). Of the 38 symptomatic cases, 24 were IgG positive and 11 were IgM positive of whom 9 were also IgG positive (Table 2). Of the 17 asymptomatic subjects, one was only IgG positive and one was only IgM positive and none were double positive (Table 2).

The intensities of both the IgM and IgG reactivity in individual human sera ranged between weak, moderate, and strong as demonstrated in Figure 1 where the upper band (A) represents a positive control, the middle band (B) represents the IgG reactivity, and the lower band (C) represents the IgM reactivity.

We transformed the band intensities into numerical values so that the negative serum samples were taken as zero, whereas the samples of very weak reactivity, weak reactivity, moderate reactivity, strong reactivity were taken as 5, 10, 50, and 100, respectively. Noteworthily, the overall IgM prevalence was higher among humans of high socioeconomic standard compared with humans of low socioeconomic standard although the difference was not significant (Figure 2, left). However, the overall IgG prevalence was significantly ($p < .05$) higher among humans of low socioeconomic standards compared with those of high socioeconomic standards (Figure 2, right).

Interestingly, in both humans of low and high socioeconomic standards, the prevalence of either IgM or IgG was generally higher among females than males (Figure 3) although the differences were not significant in all cases.

Studying the potential implication of age in determining the rate of infection revealed a general inverse (negative) correlation between age and prevalence of both IgM and IgG in both genders from the two socioeconomic standards except for IgG in females and IgM in males both of low socioeconomic standard (Table 3).

4 | DISCUSSION

To the best of our knowledge, this is the first study from Egypt, Africa, and the Middle East trying to compare the levels of exposure of individual humans from different socioeconomic standards to, SARS-CoV-2, the novel coronavirus. Here, we relied on serum IgM and IgG as first-line indicators of human exposure to the virus and used the AMP SARS-CoV-2 IgG/IgM rapid test as readout.

In fact, the presence of immunoglobulins in human sera is very debatable in terms of their involvement in providing protection to exposed human subjects to viral infection and their capacity to neutralize the infectious virus.[11] Both the presence and duration of the existence of both IgM and IgG become more important[12–14] especially in light of the availability of several vaccines from human use to provide protection against novel corona infection. Whether the presence of IgM and IgG will interfere with the induced protective immunity by the generated vaccines and whether individuals positive for immunoglobulins should be vaccinated remain open questions.

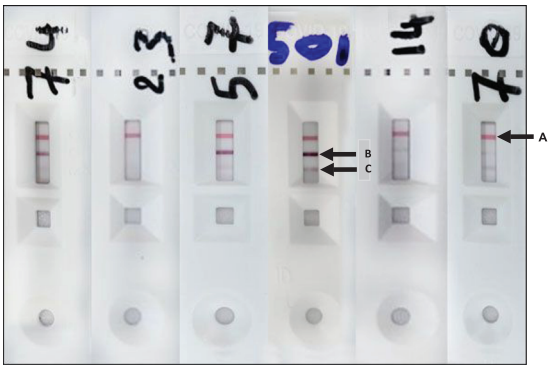

FIGURE 1 A representative figure showing the differential reactivity of both the anti-SARS-CoV-2 IgM and IgG in the studied human sera. The intensities of both the IgM and IgG reactivity in individual human sera ranged between weak, moderate, and strong where the upper band (A) represents a positive control, the middle band (B) represents the IgG reactivity, and the lower band (C) represents the IgM reactivity. IgG, immunoglobulin G; IgM, immunoglobulin M; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2

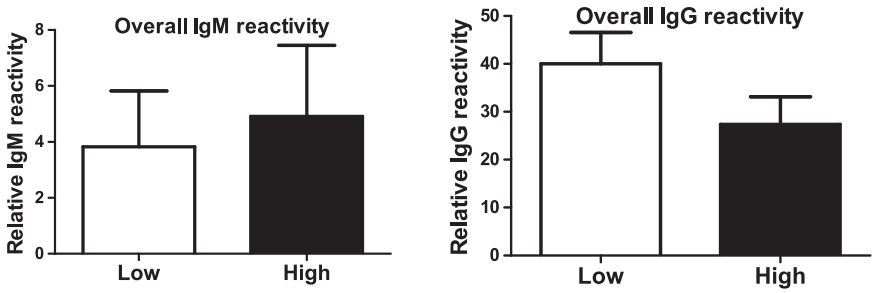

FIGURE 2 The overall anti-SARS-CoV-2 IgM (left) and IgG (right) prevalence in human subjects of low and high socioeconomic standards. The numbers of the studied human subjects of low and high socioeconomic levels were 51 and 55, respectively. Band intensities of both immunoglobulin classes were transformed into numerical values so that the negative serum samples were taken as zero, whereas the samples of very weak reactivity, weak reactivity, moderate reactivity, and strong reactivity were taken as 5, 10, 50, and 100, respectively. The overall IgM prevalence was higher among humans of high socioeconomic standard compared with humans of low socioeconomic standard although the difference was not significant (left). However, the overall IgG prevalence was significantly ($p < .05$) higher among humans of low socioeconomic standards as compared with those of high socioeconomic standards (right). IgG, immunoglobulin G; IgM, immunoglobulin M; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2

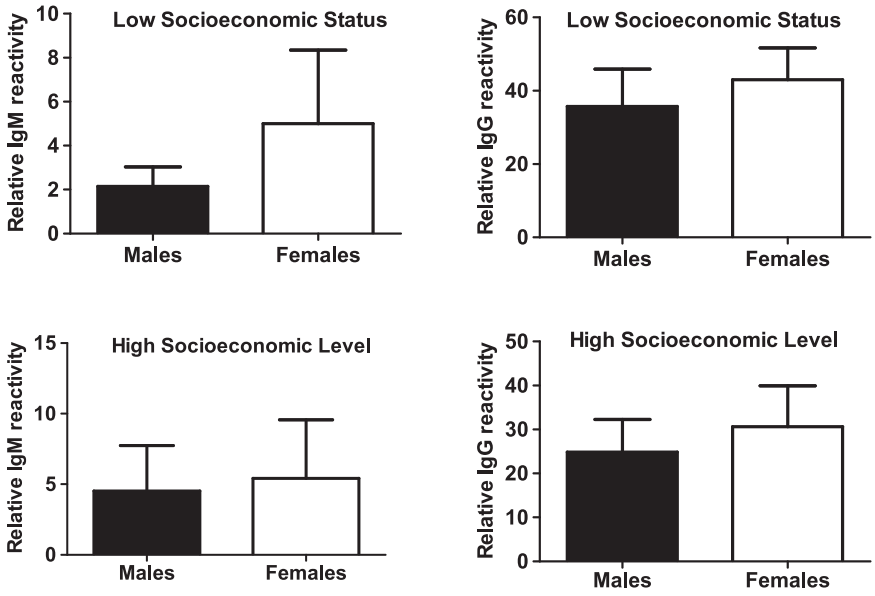

FIGURE 3 Gender-specific prevalence of anti-SARS-CoV-2 IgM and IgG in the studied human subjects of low and high socioeconomic standards. The 51 humans of low socioeconomic standard were 30 females and 21 males, whereas the 55 of high socioeconomic standard were 24 females and 31 males. Results showed that regardless of the socioeconomic standard the prevalence of either IgM or IgG was generally higher among females than males although the differences were not significant in all cases. IgG, immunoglobulin G; IgM, immunoglobulin M; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2

TABLE 3 Correlation between anti-SARS-CoV-2 antibodies levels and age within the two genders from various socioeconomic standards

Socioeconomic level	Low				High			
Gender	Females		Males		Females		Males	
Correlated parameters	IgM/Age	IgG/Age	IgM/Age	IgG/Age	IgM/Age	IgG/Age	IgM/Age	IgG/Age
Correlation coefficient (r^2)	−.051	.264	.236	−.070	−.078	−.245	−.194	−.186
p-value	.790	.159	.304	.764	.719	.250	.296	.317
	NS	NS	NS	NS	NS	NS	NS	NS

Abbreviations: IgG, immunoglobulin G; IgM, immunoglobulin M; NS, not significant; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

The symptomatic human subjects who were negative for both SARS-CoV-2 IgM and IgG may have been infected by any of the viruses which might cause flu-like symptoms that can be sometimes confused with those caused by the novel coronavirus.[15,16] On the other hand, they might be infected with SARS-CoV-2 but were not recognized by the rapid IgM/IgG detection system used in the study due to limited sensitivity.[17,18] On the other hand, the asymptomatic human subjects who were IgM and/or IgG positive may refer to the capacity of some of the immune responses in some individuals to clear the infection without developing symptoms, which supports the concept of using convalescent plasma from recovered individuals to passively protect against, or treat, SARS-CoV-2-infected patients.[19,20] In agreement with the recorded asymptomatic antibody-positive individuals in the present work, a study in Iran demonstrated that seroprevalence is likely to be much higher than the reported prevalence of COVID-19 based on confirmed cases.[21]

In addition, the presence of both symptomatic antibody-positive individuals and asymptomatic antibody-positive individuals confirms the heterogeneity of the individualized (personalized) human responses to the SARS-CoV-2 infection.

The significant overall IgG reactivity among the studied human subjects of low socioeconomic standards compared with those of high socioeconomic standards indicates the increased probability of multiple exposures to reinfection with, or propagation of, SARS-CoV-2 in individuals of low socioeconomic standards leading to the production of more IgG which represents a secondary immune response. This might be due to the less careful attitude of humans of low socioeconomic standard in terms of irregular use of disinfectants, improper use of disposable face masks, or using multiple crowded public transportation from home to work and the other way around. This agrees with several studies conducted in the United States that pin-point socioeconomic factors as determinants in SARS-CoV-2 transmission/control.[22–24] In concordance, a recent study in Brazil demonstrate that antibody prevalence is strongly associated with Indigenous ancestry and low socioeconomic status.[25]

The general higher both IgM and IgG reactivities among females of both low and high socioeconomic standards compared with males can be attributed to their heavier familial responsibilities than males in Egypt (a developing country). These can be summarized as bringing children to and from schools and buying home needs from markets, which makes them subject to more human-to-human contact. In addition, they also work, which makes them equally exposed to infection as males. Moreover, it has been reported that the virus is excreted in the feces of infected human subjects.[26] As women both at home and work are more involved in cleaning toilets, this might make them subject to more exposure to the excreted virus in the feces compared with men. Although in a completely different etiological situation, this agrees with the reported occupational hazards for Hispanic female domestic cleaners in the United States that lead to increased irritation of both eyes and noses, asthma, bronchial hyper-responsiveness along with other respiratory symptoms due to excessive use of cleaning liquids and detergents while performing their cleaning tasks.[27]

Of great interest, one of the studied human subjects of the low socioeconomic standard was strongly positive for IgG, while his wife who is also a cleaner at the National Research Center and joins him every day from home to work and vice versa was negative for both IgM and IgG. By interviewing both of them, we found that they are almost equally exposed to the same risk factors of receiving infection and have been together all the time. This reflects an individualized element of exposure/reaction to SARS-CoV-2 infection, which needs extensive study.

The general inverse (negative) correlation between IgM/IgG in the majority of studied human groups with age might be attributed to, (1) the older the age, the less the mobility of people (lazier) and as a result the less they get exposed to infection and (2) the older the people, the poorer the capacity of their immune system to react to SARS-CoV-2 infection which makes older people a high-risk group to get infected. Accordingly, aged individuals who are known to have impaired immunity are highly encouraged to perform sport daily to support their immune system to function properly. [28]

In conclusion, our results clearly demonstrate (1) the impact of the socioeconomic standard, gender, and age on both primary and secondary immune responses to SARS-CoV-2 infection and (2) heterogeneity in individualized human responses to the SARS-CoV-2 infection, which sometimes is asymptomatic and at other times is associated with a broad range of symptoms.

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CONFLICT OF INTERESTS

The authors declare that there are no conflict of interests.

AUTHOR CONTRIBUTIONS

Mahmoud Mohamed Bahgat proposed the study, provided the necessary funds to carry out the work from awarded grant to him by the NRC, submitted the application for the approval of the NRC Medical Ethics Committee, analyzed the results, and wrote the manuscript. Dina Nadeem Abd-Elshafy, Mona Abd-Elkader Awad, and Solaf Kamel helped in designing the questionnaire. Rola Nadeem and Mohamed Hassan Nasraa did the majority of the interviews with the studied human subjects, the filling of the questionnaires, and the preparation of the primary data sheets. Dina Nadeem Abd-Elshafy has done all the sample preparations, sera separation, and aliquoting. Together with Solaf Kamel, all authors contributed to performing the rapid anti-SARS-CoV-2 IgM and IgG detection assay, monitoring reaction development, and recording results. All coauthors have read and approved the manuscript submission.

PEER REVIEW

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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