Towards an Integrated Approach on Occupational Health to Tackle COVID19 Pandemic

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Abstract **Background**: Serological screening is crucial for the prevention of infection, ensuring the maintenance of the workers' health, thus promoting occupational health. It was reported that SARS-CoV-2 can survive in aerosols and on dry surfaces for several days to weeks. **Objectives**: We aimed to apply an integrated approach on Occupational Health to tackle COVID19 pandemic. **Materials and methods**: We performed a rapid immunoglobulin IgM-IgG immunoassay, ELISA and hematologic profile among workers (N = 740), in a Public Higher Education Institution from Portugal and an environmental assessment by two sampling methods (Air N = 49; Surfaces N = 101) and RT-PCR. **Results**: Regarding workers serologic surveillance, 1.89% of rapid test positivity was observed for SARS-CoV-2 IgM antibodies and a low prevalence of positivity for IgG (1.21%) in which only 33.3% were confirmed by ELISA. Hematologic surveillance data revealed the presence of 10.44% of abnormal hematological profiles, being anemia (3.78%) the most relevant. All the environmental samples analyzed were negative regarding SARS-CoV-2

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detection. **Discussion**: Low SARS-CoV-2 immunization and the negative environmental samples strongly indicate the effectiveness of the preventive measures. Nevertheless, COVID19 disease alters hematologic parameters. **Conclusion:** This study it was possible to implement an integrated approach on Occupational Health combining efforts with the Occupational Health Services.

Keywords Integrated approach · Occupational health · COVID19 pandemic · Seroprevalence · Environmental assessment

1 Introduction

A new Coronavirus (SARS-CoV-2) was reported at the end of 2019 and identified as the etiological agent of Coronavirus disease 2019 (COVID-2019) [1, 2]. The World Health Organization (WHO) has announced the COVID-19 pandemic on March 11, 2020 [3].

Although the positive impact of the vaccination in the pandemic, important research efforts are still ongoing, including investigations into the transmission routes of this virus. However, there are still numerous knowledge gaps concerning the understanding of what are the main drivers that foster the virus transmission, and what are the measures to control its dissemination in the population and workplaces [1, 2].

It is estimated that more than 50% of transmission of SARS-CoV-2 have originated from exposure to asymptomatic individuals [4]. These findings suggest that effective control of spread will require measures to reduce the risk of transmission on individuals that are not ill [4]. Carrying out serological screening tests is an important tool for the prevention of new cases of infection, ensuring the maintenance of the health of workers, thus promoting occupational health. Furthermore, during the evolution of a SARS-CoV-2 infection the hematopoietic system and hemostasis of individuals may suffer significant impact that can lead to several cardiovascular complications [5]. Although some studies showed that there was no significant alteration in red blood cell (RBC) and hemoglobin levels it is not yet fully known the impact of SARS-CoV-2 infection on these parameters [6]. Thus, monitoring of hematological parameters is essential to a better understanding of COVID-19 pathophysiology, to choose more appropriated treatment strategies and provide accessible methods for classifying and predicting the severity and disease outcomes of patients [7].

Hospital infections related to SARS-CoV-2 have been reported worldwide, and are probably linked to ineffective prevention and control measures [2, 8–10]. The drawbacks in having straightforward measures to avoid transmission in workplaces can be due to the fact that the transmission dynamics is multifactorial as proved by the previous observations of the relevant impact of contaminated air and surfaces in the transmission dynamics of diseases such as Severe Acute Respiratory Syndrome (SARS), Middle East Respiratory Syndrome (MERS), influenza, and others [2, 11, 12]. Additionally, it was reported that SARS-CoV-2 can survive in aerosols and on

dry surfaces for several days to weeks [13, 14] and several studies reported outbreaks associated with the air-conditioning systems [15].

Thus, all these virus features combined with the need to collect sufficient airborne viruses for detection by molecular techniques [16], can pose a real challenge for every industrial hygienist.

In the pursuit to obtain information a cross-sectional study design, applying an integrated approach on Occupational Health to tackle COVID19 pandemic, was performed aiming at estimating the point seroprevalence of SARS-CoV-2 antibodies using a rapid immunoglobulin IgM-IgG combined point-of-care lateral flow immunoassay and hematologic profile among workers from a Public Higher Education Institution from Portugal. The study also comprises environmental assessment of SARS-CoV-2 by Real Time PCR, achieved by two sampling methods, in the facilities of the same Academic Institution. This study was performed in a period prior to the introduction of SARS-CoV-2 vaccine in Portugal.

2 Materials and Methods

2.1 Workers Population Assessed

Among a total of 1050 workers, 740 volunteers were enrolled in the study (70% of the total expected). Workers of all units of the engaged Public Higher Education Institution from Portugal were invited to voluntarily participate in the surveillance project. The volunteers were scheduled for the screening testes during a 4-months period, from September to December 2020.

Before the enrolment in the screening tests, all volunteers filled a written informed consent and a questionnaire. This survey instrument consisted of a 37-item questionnaire assessing contact information, sociodemographic characteristics (age, sex, nationality, ethnicity, household size), habits and behaviours (diet, physical exercise and hours of sleep), health status (alcohol and smoking status, health conditions, continuous medication in prior 6 months, use of antibiotics or vitamins prior 3 months, status of the National Vaccine Program, namely the receipt of BCG, influenza or pneumococcal vaccine) and COVID-19 exposure characteristics (previous diagnostic, symptoms, and history of close contact with COVID-19 cases). The study was performed in a period before SARS-CoV-2 vaccine introduction in Europe.

The data obtained were subsequently entered into an anonymous questionnaire programmed in REDCap (Research Electronic Data Capture) to estimate the prevalence of individuals with SARS-CoV-2 antibodies and the hematologic alterations in the studied population.

This study complied with the Helsinki Declaration and Oviedo Convention and all data were stored and analyzed in accordance with the Portuguese General Data

Protection Regulation (GDPR) law nº 58/2019. The study protocol was approved by the ESTeSL-IPL ethics committee (CE-ESTeSL-Nº.45-2020).

2.2 Serologic Surveillance

For rapid serologic screening, capillary blood was collected through capillary puncture with a lancet in which a 20ul of blood was collected using a micropipette for the Immunochromatographic rapid test for the detection of IgM and IgG antibodies to SARS-CoV-2 virus in human whole blood, plasma or serum samples using VedaLab COVID-19-CHECK-1 kit (Ref.:200081-4-2-3L VEDALAB) with a calculated diagnostic sensitivity of 91.45% and specificity of 97%.

Serologic surveillance regarding IgG and IgM screening results were analyzed accordingly with the Kit manufacture guidelines. For positive IgM screening cases, nasopharynx swab was immediately performed for Real Time PCR diagnosis at CEDOC (NOVA Medical School). For positive IgG screening cases, venous blood was collected through venipuncture to a dry tube (serum) for IgG quantification by Enzyme-Linked Immunosorbent Assay (ELISA), specifically designed against the S1 domain of SARS-CoV-2 Spike protein. ELISA titers quantification was performed with the Anti-SARS-CoV-2 ELISA (IgG) EUROIMMUN kit (ref EI2606-9601 EUROIMMUN) in the equipment Optic Ivyman; System 2100C, with a calculated sensitivity of 94.4% after 10 days or more after symptom onset or positive direct detection and specificity of 99.6%. The default result units for this SARS-COV-2 IgG essay are the index calculated by the ratio of the sample optical density (OD) over the calibrator OD. According to the manufacturer's instructions, IgG results were deemed positive if the cut-off index (S/C) was $\geq$1.1, while negative results were defined by a cut-off of <0.8. Borderline values (index $\geq$0.8 to < 1.1) were considered inconclusive results.

2.3 Hematologic Surveillance

For hematologic screening, venous blood was collected through venipuncture to an EDTA tube (blood count) and the blood counts were processed in the Horiba 60 series automatic device and the hematological results analyzed. For each participant was determine complete blood count (RBC $\times$ 10^{12}/L, Hgb g/dL, Hct %, VGM fL, HGM pg, CHGM g/dL, RDW %, Leukocytes (total), Neutrophils, Eosinophils, Basophils, Lymphocytes, and Monocytes and platelets).

For hematologic surveillance, the collected blood was analyzed and complete blood count was performed. The hematological analyzed parameters indicated the presence of normal and abnormal hematological profiles. Among abnormal profiles we have assessed profiles with Anemia, including Microcytic and Hypochromic

Anemia and Normocytic and Normochromic Anemia, Erythropenia, Erythrocytosis, Leukocytosis, Thrombocytopenia, and Inverted differential leukocyte count.

2.4 Environmental Assessment

Regarding the environmental sampling campaign, all the ten Academic institution facilities (8 faculties, the Social services and Presidency building) were assessed and environmental samples (air and surfaces samples) were performed from workstations that had an increased risk due to occupation rates, to consider the community transmission risk [17, 18], activities performed that can potentiate the virus transmission [13–15] or based on workers serologic surveillance results.

2.4.1 Sampling Collection

The facilities assessed were the ones presenting 50–80% of the workers present in their workplaces. Two sampling methods were applied combining active and passive methods. Regarding air samples (N = 49) 600 L were collected per sample into a conical vial containing 5 mL Buffer NVL (NZY Viral RNA Isolation kit (MB40701) component) by Coriolis μ air sampler (Bertin Technologies, Montignyle-Bretonneux, France) [19]. The air inlet of the device was disinfected between samples with a 70% alcohol solution). Surface samples (N = 101) were collected by swabbing the areas of each local using flocked swabs moistened in sterilized water into a 15 mL falcon containing 1.5 mL Buffer NVL (NZY Viral RNA Isolation kit (MB40701) component). In some specific surfaces were performed composite samples (swabbing different surfaces with the same swab) since the type of use, surfaces material and cleaning procedures were common (Table 1). All collected samples were maintained refrigerated (0–4 °C) in sterilized bags during transportation and prior to analysis.

The sampling campaign was performed in workplaces defined as having higher risk of exposure by the Occupational Health Services. The other criteria applied, and since we were assessing one week after the workers serologic surveillance, was having workers in the workplaces with positive result for IgM+ or IgG+ (see Fig. 1).

2.4.2 RNA Extraction and Environmental SARS-CoV-2 Detection

RNA was extracted from the isolated sample (5 mL in air samples and 1.5 ml in surface samples) with the NZY Viral RNA Isolation kit, from Nzytech, according to manufacturer's instructions. One step-RT qPCR was performed using NZYSpeedy One-step RT-qPCR probe Master Mix with primers and probes published by CDC (available on https://www.cdc.gov/coronavirus/2019-ncov/lab/rt-pcr-panel-primer-probes.html), which detect two viral gene regions (N1 and N2) (Table 2). qPCR was performed on BioRad CFX Connect PCR machine. In each analysis a positive (a

Table 1 Faculties and areas assessed and number of environmental samples collected

Facilities	Assessed areas	Air sampling (600L)	Surfaces swabs
Presidency building (PB)	– Communication Office (Doorknob + Ventilation grids) – Drivers Reception (Counter) – Entrance (Coffee machine) – Lunchroom (Microwave + Coffee machine + Refrigerator + Ventilation grids) – Human Resources (Coffee machines + Access card + Staplers and stamps + Ventilation grids) – Financial Resources (Staplers and stamps + Ventilation grids in operation) – Human and Financial Resources (Windows + Doorknobs) – Reception (Printer + Table) – Shopping Department (1st floor) (Windows + Keys and card + − Ventilation grids in operation) – Male Bathroom (1st floor) (Doorknobs + Faucets) – Female Bathroom (1st floor) (Doorknobs + Faucets) – Printer (1st floor) – Academics, Quality and Planning Department (Mobile air conditioning equipment)	0	25
Social Services (SS)	– Lunchroom (Microwave + Refrigerator + Door) – Waiting Room / Classroom (Coffee Machine + Table) – Reception (Counter + Door + Water Machine) – Bathroom (Doors + Faucets) – Service Room (Table + Acrylic Protection) – Accounting (Printer + Doors)	6	10

(continued)

Table 1 (continued)

Facilities	Assessed areas	Air sampling (600L)	Surfaces swabs
Faculty 1	– Logistics (Door + Window) – Accounting / Provisioning (Printer + Door + Stapler) – Academic Services (Printer (SA) + Printer (corridor)) – Reception (Door + Handrail + Balcony) – Bar (Chairs + Door) – Library (Printer + Computer) – Lunchroom (1st floor) (Fridge + microwave) – Lunchroom (2nd floor) (Fridge + microwave) – Printer (1st floor) – Bathroom (1st floor) (Doorknobs + Door + Flush toilet) – Office (1.16) (Mouse + Keyboard + Light switch + Door + Doorknob) – Printer (2nd floor) – Bathroom (2nd floor) (Doorknobs + Door + Flush toilet)	8	8
Faculty 2	– Financial Services (Printers + Stapler) – Teachers Room 1 (Printers + Computers) – Teachers Room 2 (Printer + Computers + TV control) – Cafeteria / Bar (Counter + Tables) – Auditorium (Handrail + Light switch + Door) – Social Room (Door + Fridge + Microwave + Faucet + Coffee Machine) – Library (Printer + Computers) – Human Resources (Printer + Door + Acrylics + Counter + Light switch)	8	8

(continued)

Table 1 (continued)

Facilities	Assessed areas	Air sampling (600L)	Surfaces swabs
Faculty 3	– Library (Computer + Printer + Doorknob) – Lunchroom 1 (Faucet + Doorknob + Chair + Table + Microwave + Coffee machine + Faucet) – Lunchroom 2 (Microwave + Toaster + Kettle + Doorknob + Door + Table + Chair) – Bar 1 (Microwave + Refrigerator + Handles + Cash register + ATM) – Workshop (Machine + Doorknob + Door) – Bar 2 (Cash register + Control + Fridge + Microwave) – Organic Chemistry Lab (Scale + Faucets) – Organic Chemistry Lab – research (Equipment + Door + Doorknob) – Inorganic Chemistry Lab (Computer + Doorknobs + Equipment + Micropipettes + Refrigerator) – Canteen (Faucets + Counter + Acrylic + Cash Register) – Auditorium (Doorknobs + Door + Table + Chair + Eraser)	11	11
Faculty 4	– Library (PC + Windows + Tables) – Canteen (Chairs + Table + PC + Doorknob) – Bar (Counter + Napkin Holder + PC + Coffee Machine + Table) – Grand Auditorium (Doorknob + PC + Chairs) – Small Auditorium – Scenic Interpretation Studio (Door + Table + Doorknob + Chairs) – Computer Room (Switch + Mouse + PC + Keyboard + Door + Doorknob) – Workshop (Doorknob + Tables + Lockers + Equipment)	7	7
Faculty 5	– Bar/Cafeteria (Cash Register + Counters) – Science Laboratory (FQ) (Chairs + Scales + Faucets + Handle) – Social Room (Microwave + Faucet + Windows + Chairs) – Theatre and Choir Room (Switches + Windows + Chairs + Tables) – Changing room / dressing room (Doors + Doorknobs + Faucets) – Gym (Doors + Doorknobs + Table + Chair + Equipment) – Ceramic Workshop (Tables + Chairs + Faucets + Eraser + Doorknob + Door) – Dance Room (Doorknobs + Doors + Eraser) – Music Room (Switch + Handle + Window + Chairs + Piano)	9	9

(continued)

Table 1 (continued)

Facilities	Assessed areas	Air sampling (600L)	Surfaces swabs
Faculty 6	– Grand Auditorium (Chairs + Tables + Piano + Tripods) – Small Auditorium (Switch + Window + Doorknob + Chairs) – Library (Computers + Tables) – Academic Services (Printer + Doorknob + Cabinets) – Printer (corridor) – Academic Services – Customer Service (Acrylic + Pens + Coffee Machine + Tables) – Lunchroom (Microwave + Tables + Chairs + Refrigerator + Doorknobs + Switch) – Choir Room (Chairs + Tables + Piano + Eraser + Switch + Door + Doorknobs) – Music Room (Doorknobs + Switch)	0	9
Faculty 7	– Bar (Chairs + Tables + Cash Register + Acrylic + Counter + Calculator) – Study room (Food and coffee machines + Chairs + Tables) – Printer (corridor) – "Home Food" Space (Microwave + Water machine + Tables + Chairs) – Auditorium (Door + Doorknob + Chairs) – Academic Services (Tables + Switch + Chairs + Acrylic + Printer + Stapler + Hole Puncher + Door + Doorknob) – Library (Tables + Chairs + Acrylic) – Multimedia Warehouse (Printer + Computers + Keyboards + Mouse + Barcode reader + Microwave + TV + Chairs)	0	8
Faculty 8	– Academic Services (Printer + Doorknob + Acrylic + Table) – Dance Reception (Doorknob + Computer + Telephone + Keys) – Teachers room (Doorknob + Printer + Switch + Flush toilet + Table + Chairs) – Atrium Studio C –1 (Bar + Sound System) – Studio D1 (Bar + Sound System) – Studio A1 (Bar + Sound system)	0	6

SARS-CoV-2 positive sample) and a negative (water) sample was included. Moreover, in order to detect possible PCR inhibitors an internal control was added to each PCR (TATAA Universal RNA Spike I). Whenever a sample showed dubious results, including, for example, lack of amplification of both viral gene regions, they were considered inconclusive and the assay was repeated. All the results were analysed by two independent researchers.

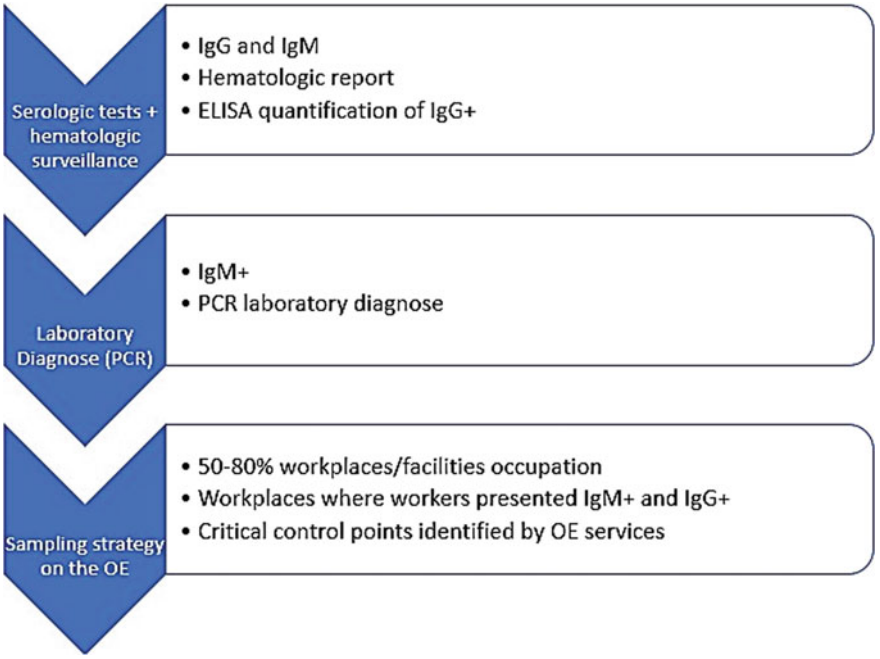

Fig. 1 Flowchart applied regarding the integrated approach on Occupational Health

Table 2 Novel coronavirus (2019-nCoV) real-time RT-PCR panel primers and probes

Name	Description	Oligonucleotide Sequence (5′ > 3′)	Label
2019-nCoV_N1-F	2019-nCoV_N1 Forward Primer	5′-GAC CCC AAA ATC AGC GAA AT-3′	–
2019-nCoV_N1-R	2019-nCoV_N1 Reverse Primer	5′-TCT GGT TAC TGC CAG TTG AAT CTG-3′	–
2019-nCoV_N1-P	2019-nCoV_N1 Probe	5′-FAM-ACC CCG CAT TAC GTT TGG TGG ACC-BHQ1-3′	FAM, BHQ-1
2019-nCoV_N2-F	2019-nCoV_N2 Forward Primer	5′-TTA CAA ACA TTG GCC GCA AA-3′	–
2019-nCoV_N2-R	2019-nCoV_N2 Reverse Primer	5′-GCG CGA CAT TCC GAA GAA-3′	–
2019-nCoV_N2-P	2019-nCoV_N2 Probe	5′-FAM-ACA ATT TGC CCC CAG CGC TTC AG-BHQ1-3′	FAM, BHQ-1
Spike In		TATAA Universal RNA Spike I	FAM

The SARS-CoV-2 viability was not assessed to ensure safety levels for the professionals engaged in the field and lab work.

3 Results

3.1 Serologic Surveillance

Regarding workers serologic surveillance, data demonstrated a 1.89% of rapid test positivity for SARS-CoV-2 IgM antibodies. For these volunteers, in particular, in order to outlaw a potential active SARS-CoV-2 infection with IgM antibodies immunologic response, nasopharynx and oropharynx swabs were collected and stented for molecular biology diagnose trough PCR (Table 3 and Fig. 2). All samples were negative for SARS-CoV-2 RT-PCR identification, which may indicate either a false positive due to cross reactions or due to a previous SARS-CoV-2 infection with associated IgM positive response but for which the virus is no longer detectable. On the other hand, was reported a low prevalence of rapid test positivity for SARS-CoV-2 IgG antibodies (1.21%) in which only 33.3% were confirmed by ELISA technique (Table 3). These results indicate the presence of false positive test probably due to cross reactions.

Data also demonstrated that Faculty 1 and Faculty 7 reported the higher IgM/IgG positive screening while Faculty 6 and Faculty 8 had no identified cases. Moreover, ELISA confirmed IgG antibodies were detected in workers from Presidency building, Faculty 1 and Faculty 7.

3.2 Hematologic Surveillance

Hematologic surveillance data revealed the presence of 10.44% of abnormal hematological profiles among the tested Higher Education Institution community (Table 4). The most prominent and concerning hematological alteration is anemia (3.78%) which was classified in Microcytic and Hypochromic anemia (2.35%) and Normocytic and Normochromic Anemia (2.35%). Relevant levels of Erythropenia (2.48%) and Thrombocytopenia (2.09%) were also reported as well as other alterations such

Table 3 Serologic screening prevalence of SARS-CoV-2 IgM, RT-PCR for IgM positive confirmation, and IgG and ELISA IgG confirmation

Parameter	IgM (RDT) N = 740	RT PCR N = 14	IgG (RDT) N = 740	ELISA (IgG) N = 9
Positive prevalence	1.89% N = 14	0.00%	1.21% N = 9	33.3% n = 3

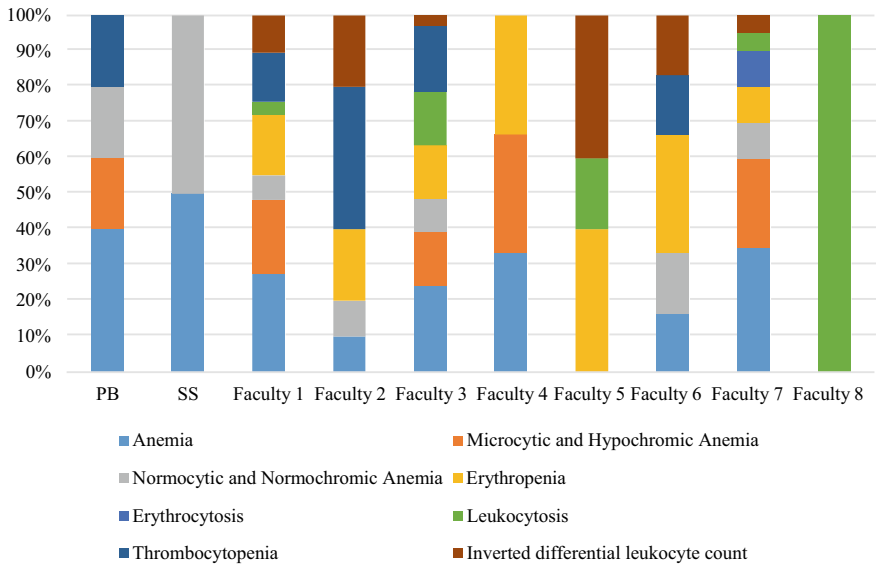

Fig. 2 Hematologic screening data regarding abnormal hematological profiles prevalence and hematological anomalies identification *per* facilities

as increased red blood cells and white blood cells numbers (Erythrocytosis 0.26% and Leukocytosis 1.17%, respectively) (Table 3). Moreover, inverted differential leukocyte count (1.31%) (Table 4) was also reported, revealing that lymphocyte values were higher than neutrophils.

Furthermore, for hematologic surveillance data analysis, potential divergences were also considered in all the facilities. Abnormal hematological profiles were reported in all the assessed facilities with divergent results between them. However, Faculty 7 data demonstrated the higher hematological abnormal profiles, followed

Table 4 Hematologic screening data regarding abnormal hematological profiles prevalence and hematological anomalies identification

Abnormal hematological profile	Prevalence (%) N = 80
Abnormal blood count	10.44
Anemia	3.78
Microcytic and Hypochromic anemia	2.35
Normocytic and Normochromic Anemia	1.44
Erythropenia	2.48
Erythrocytosis	0.26
Leukocytosis	1.17
Thrombocytopenia	2.09
Inverted differential leukocyte count	1.31

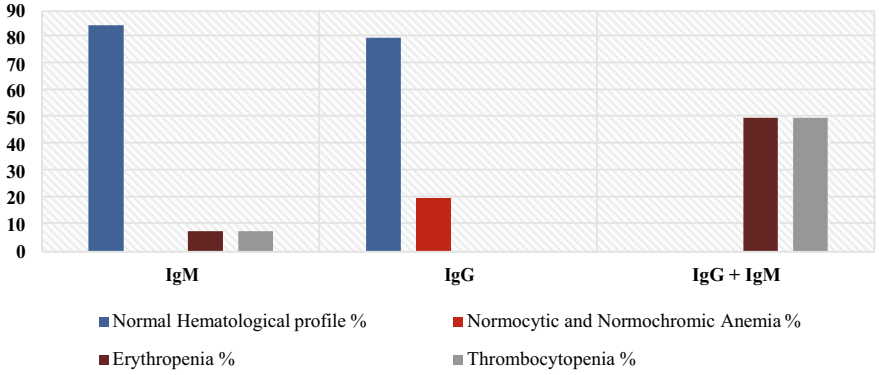

Fig. 3 Graphic representation of serologic and hematological anomalies correlation

by Faculty 1 and Faculty 3 (Fig. 2). Relevantly, these results were not correlated with higher numbers of volunteers since Faculty 7 had n = 67 and Faculty 1 n = 141 and Faculty 3 n = 213.

3.3 Serologic and Hematologic Surveillance Correlation

The performed correlation between serologic results with ELISA confirmation regarding IgG positivity and data from the applied questioners regarding individuals with previous diagnosed *SARS-CoV-2* infections and hematologic surveillance results clearly suggests that SARS-CoV-2 infection has the ability to affect hematological profile, as all individuals with SARS-CoV-2 IgG and IgM positive antibodies, which is indicative of recent infection, presented abnormal hematological profiles with decreased red blood cells (Erythropenia) and platelets (Thrombocytopenia) (Fig. 3).

3.4 Correlation Analyses Between Serologic and Hematologic Surveillance and Questionnaires Data

Table 5 shows the population characterization by age groups and prevalence (%) data of *SARS-CoV-2* IgM and IgG by gender. From the 14 and 9 positive samples of IgM and IgG, respectively, 2 of them were simultaneously positive (one male and one female). The highest prevalence of the studied population was between 40 and 60 years old, 72.4% and 69.6% female and male, respectively. From the total female (n = 428) in study only 8 and 5 was positive for IgM and IgG, respectively. The

Table 5 Population characterization by age groups and prevalence (%) data of *SARS-CoV-2* IgM and IgG by gender

Age group	Female	Male		
	n = 428	%	n = 312	100
18–40	73	17.1	47	15.1
40–60	310	72.4	217	69.6
>60	45	10.5	48	15.4
IgM+	8	1.87	6	1.92
IgG+	5	1.17	4	1.28
Positive COVID-19	3	0.70	1	0.30

prevalence for male was very similar, with around 1.92% and 1.28 for IgM and IgG, respectively. For both genders the prevalence of COVID-19 was lower than 1.0.

The prevalence data from questionnaires sorted by gender. Considering the total assessed population (female n = 428 and male n = 312) more that 90% for both genders have a Mediterranean diet. Prevalence lower than 5%, for both genders, was associated with other diet options (vegetarian, macrobiotic and Fast-Food). Similar results were found for the relation between female and male and follow assessed items: physical activity (ratio male/female = 1.21); diseases (ratio male/female = 0.97); medications ingested in the last 6 months (ratio male/female = 0.67); antibiotics ingested in the last 6 months (ratio male/female = 0.73); vitamins ingested in the last 6 months (ratio male/female = 0.74).

Regarding the vaccines the obtained answers were quite different: 72.4% and 64.1% of females and males, respectively, took BCG vaccine; 9.3% and 15.4% of females and males, respectively, took influenza vaccine; and only 4.2% and 4.5% of females and males, respectively, took pneumococci vaccine.

3.5 Environmental Assessment from SARS-CoV-2

In all the environmental samples analyzed, comprising air and swabs samples, the results were negative regarding SARS-CoV-2 detection. In all PCR experiments positive control amplified and internal control also amplified and at the same CT value for all the samples and controls, indicating no PCR inhibition in the collected samples.

4 Discussion

To our knowledge this was the first study performed in academic environment and comprising serologic and hematologic surveillance coupled with environmental assessment.

This study allowed us to infer that the prevalence of SARS-CoV-2 immunity is very low within workers (about 1%). These results indicate, in the one hand, extremely low immunization levels of the analyzed workers, which suggest a low contact with SARS-CoV-2 virus, and, in the other hand, the effectiveness of the preventive measures endured by the individuals including to keep a safe distance from others, particularly in closed spaces, windows open indoor when possible, wear a mask, keep hands clean at all times, cover coughs and sneezes and not leave home when feeling unwell. Probably this is related with the fact that this specific population is more aware of the dangerous pandemic setting and has strictly followed the National Health Service recommendations thus contributing to a lower incidence of infections. On the other hand, it is relevant to consider the possibility of early infected individuals that tested negative with IgM (i.e. false negative cases due to low sensitivity) as one of the limitations of the serologic screening.

In contrast to amplification approaches, immunoassay methods such as lateral flow immunoassay (LFIA) and microplate enzyme-linked immunosorbent assay (ELISA) offer more straightforward testing and both techniques have been proven to be successful for rapid mass COVID-19 screening in routine clinical settings [20, 21]. However, the sensitivity and reliability of this method are limited by the visual colorimetric detection principle that underlies the evaluation of LFIA testing results. The primary disadvantage of ELISA, in contrast, is extended (several hour) testing.

SARS-CoV-2 infection also affects the hematopoietic system and thus, hemostasis may suffer significant impact leading to several cardiovascular complications [5]. Although previous data has suggested no clear correlation regarding RBC and hemoglobin alterations with SARS-CoV-2 infection, in fact, the true impact in these parameters is not yet fully understood [22]. It is well known that other virus such as influenza can agglutinate erythrocytes [23] and cause hematologic alterations such as higher RDW levels and lower RBC, hemoglobin and hematocrit levels [24]. Moreover, an association between elevated RDW levels and mortality has in fact been reported [25] and frequently identified the thrombocytopenia as an important alteration on SARS-CoV-2 infections [7]. Although some studies showed that there was no significant alteration in RBC and hemoglobin levels it is not yet fully known the impact of SARS-CoV-2 infection on these parameters [22]. Regarding the hematologic study performed, two important concerns were raised. First, it is evident that COVID19 disease alters the hematologic parameters (we have a very small sample for positives that should be confirmed). Second the prevalence of abnormal hematological profiles is high, raising public health concerns that should be evaluated and followed in the future. Furthermore, regarding the reported data of inverted differential leukocyte count, this variation may occur naturally in many people; however,

it is advisable to understand if this variation is physiological, or if there is any factor that may condition this inversion, thus we have recommended blood count repetition in a reference laboratory.

Correlation analyses between serologic and hematologic surveillance and questionnaires data demonstrated no relation between IgM and IgG positivity as well as hematological alterations and genders. Additionally, the large majority of the analyzed individuals have a Mediterranean diet and booth genders had similar indications regarding physical activity, diseases, medications, antibiotics and vitamins ingested in the last 6 months and vaccination.

Moreover, environmental samples collected from faculties' facilities were all negative for *SARS-CoV-2*, as shown by the molecular detection by RT-qPCR, demonstrating once again that the cleaning activities seem to be in accordance with the Portuguese Health Directorate recommendations. Among industrial hygienist's community discussion has being raised and still ongoing about the sampling and analyses methods for SARS-CoV-2 exposure assessment. This is mainly due the fact that studies regarding virus exposure assessment have been very restricted in numbers, due to the reported difficulties in collecting and analysing airborne viruses. Amongst the active sampling methods, several sampling equipment's can be applied in the assessment virus, being the most commonly used the impingers such as the one applied in this study [16, 19, 22, 26–33]. Besides air sampling, also passive methods, such as surface swabs were applied, and their use has been widely employed [6, 19, 22, 34–37]. Indeed, surface swabs have been frequently used in health care facilities [38] or in other indoor environments [39], coupled with air sampling, to assess bioburden exposure (comprising fungi and bacteria). The air sampling volume and airflow rate followed the procedures from a study performed in a health care facility with positive detection [19]. However, a more recent technical suggestion was the use of an airflow rate of 200 L/min and the minimal of 1 m^3 of air during each sample collection when using Coriolis μ (impinger method device) for SARS-CoV-2 assessment [40]. Indeed, the lower sampling volume can be a limitation to our study. Nevertheless, all the surface swabs were also negative corroborating the efficacy of the implemented preventive measures.

Impinger methods using liquid medium can ensure the viral integrity and viability [41]. However, in our study the liquid used promoted the inactivation of the SARS-CoV-2 due to safety reasons consider both in the field work and in be lab work. This can be also to be proposed since most of the industrial hygiene laboratories don´t have the needed safety conditions to deal with a pandemic virus, such as SARS-CoV-2. Furthermore, safety measures to be recommended should be implemented when positive detection is achieved, regardless of the viability status of the virus.

Concerning assays used to detect SARS-CoV-2, the high sensitivity of the RT-qPCR method, widely used to accurately detect the virus load in nasal swab samples, would enable detection of viral particles in case they were present. The fact that none of the samples were positive strongly indicates that the cleaning procedures have been effective.

5 Conclusions

Overall, this study corroborated the efficacy of the preventive measures implemented in the assessed academic environment, since low contact with SARS-CoV-2 virus was verified among workers and environmental samples collected from faculties' facilities were all negative. It was possible to implement an integrated approach on Occupational Health combining efforts from the Occupational Health Services, by informing the workplaces with higher risk, and the results of the serological surveillance to prioritize the workplaces to be assessed.

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