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Original article

SARS-CoV-2 infection in meat and poultry workers after the "first wave" (Summer 2020): a cross-sectional study on knowledge, attitudes, practices (KAP) of Italian occupational physicians

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Abstract. *Background and aim:* This cross-sectional study assessed knowledge, attitudes and practices (KAP) of Italian Occupational Physicians (OPs) on Coronavirus disease 2019 (COVID-19) among meat/poultry processing plant workers (MPWs) (Summer season 2020). *Methods:* Data were collected through an online questionnaire including demographic characteristics, and items about COVID-19-related KAP in MPWs. A logistic regression was modelled in order to characterize explanatory variables of the outcome variable of having any professional experience as OP in meat/poultry processing industry. *Results:* A total of 424 OPs (mean age 49.0 ± 9.1years; 49.5% males) participated into the survey. Despite a generally good level of knowledge on SARS-CoV-2 pandemic, OPs having professional experience with MPWs failed to recognize any increased risk for COVID-19 (Odds Ratio [OR] 0.162; 95% Confidence intervals [95%CI] 0.039-0.670), and were less likely to recommend periodical tests via nasal swabs (OR 0.168, 95%CI 0.047-0.605). On the contrary, they identified socioeconomic status of MPWs as a risk factor (OR 5.686, 95%CI 1.413-22.881), recommending cleaning interventions on changing rooms and canteens (OR 16.090, 95%CI 1.099-259.244). *Conclusions*: In conclusion, we reported a diffuse underestimation of the risk for COVID-19, that was alarmingly higher among professionals who should be more familiar with the specific requirements of MPWs. Some significant knowledge gaps were also clearly identified, stressing the opportunity for tailored educative interventions. (www.actabiomedica.it)

Key words: SARS-CoV-2, COVID-19, poultry, meat-packing industry, health knowledge, attitudes, practice

Introduction

Meat and poultry processing plant workers (MPWs) are exposed to various microbial pathogens through different routes (e.g. *Escherichia coli*, *Campylobacter* species, *Leptospira* species, *Coxiella burnetii*, *Brucella* species, etc.) (1–8), and a series of field studies have reported on increased infection rates for respiratory viruses, including influenza virus (9–13). Even though the new emergent coronavirus, Severe Acute Respiratory Coronavirus 2 (SARS-CoV-2) and influenza viruses are quite distinctive pathogens, they

share several characteristics, particularly in terms of inter-human transmission and associated risk factors (14,15), including conditions that have been frequently reported in meat and poultry processing plants, i.e. crowded workplaces, low environmental temperatures with high relative humidity, inappropriate use of personal protective equipment (PPE) (10–13,16). Unsurprisingly, some field studies from meat and poultry industry have reported on occupational outbreaks characterized by a point prevalence of SARS-CoV-2 infection ranging from 21.4% to 43% (17–20), also because food supply chain workers have been categorized as "essential" workers, continuing their jobs on the frontline of the pandemic.

With a total of more than 250,000 confirmed cases, and a case fatality rate of 13.8% that largely exceeded world average (6.6%)(21,22), Italy has been severely hit by SARS-CoV-2 during the first months of the pandemic (23,24), representing an impacting challenge for occupational health (25). Even though the coronavirus pandemic has triggered a global jobs crisis, workers from the food supply chain have been requested to stay at work in order to avoid significant disruption in the supply of food (22,26). Therefore, National and Regional governments have issued specific rules and recommendations to ensure appropriate occupational health and safety, aiming to avoid SARS-CoV-2 workplace outbreaks, particularly when the initial lockdown measures were progressively relieved (27). However, during the summer season 2020, a series of alarming field reports, initially from USA and Germany (17–20), and then from Italy itself (28,29), urged several Italian Regional Health Authorities to recommend a reinforced surveillance plan dedicated to meat and poultry processing plants (17–20,30), that specifically involved the competent Occupational Physicians (OPs), the medical professionals responsible for health surveillance and promotion in workplaces (31–34). Alongside their usual requirements, OPs were urged to properly tune national recommendations to this specific occupational settings (including tailored preventive measures for high-risk workers), actively informing workers about occupational risk factors for COVID-19. Moreover, although the majority of Italian OP are in facts free practitioners (31,32,35), they were requested to contribute to the diagnosing, tracing and tracking activities of National/Regional Health Authorities (36). Despite their significant role during the ongoing crisis, OPs have been scarcely investigated about their knowledge (i.e., the awareness of official recommendations), attitudes (i.e., propensity towards a certain intervention), and practices (i.e., actual application of such intervention; collectively KAP) regarding SARS-CoV-2, and particularly in non-healthcare settings (37–42).

Our study, therefore, aimed to specifically assess KAP of Italian OPs involved in the managing of meat and poultry processing plants in order to identify their potential knowledge gaps, whose filling has the potential to significantly improve occupational health and safety of such high-risk workers.

Materials and methods

Study design

A cross-sectional questionnaire-based study designed according to the STROBE statement was performed between 01/07/2020 and 31/08/2020, and specifically targeted OPs participating in seven different private Facebook group pages and four closed forums focusing on occupational medicine, whose applications were officially limited to OPs. According to the built-in statistics of the parent social media, group pages had a total of 2,034 members, but no information could be obtained regarding cross-inscriptions, not even how many of these members were actively using Facebook.

To post the study invitation, the chief researcher contacted the administrators, and requested the preventive authorization to post the link to the questionnaire, that included short description of the aims of the survey. Users who clicked on the invitation texts were then provided with the full study information, an opportunity to give their informed consent (Authors' translation of the informed consent is available on request to the study Authors), and a web link to the survey (Google Forms; Google LLC; Menlo Park, California, CA, USA).

To be included in the sample, the participant was initially inquired whether he/she was living and

working in Italy as an OP. In case of two positive answers to these checkpoint items, the participants received the full questionnaire. Otherwise, the survey closed. The questionnaire was compiled anonymously, and no personal data, such as name, IP address, email address, or personal information unnecessary to the survey were requested, saved, or tracked. No monetary or other compensation was offered to the participants.

Questionnaire and availability of data and material

The questionnaire was formulated in Italian, and its test–retest reliability was preventively assessed through a survey on 15 occupational physicians completing the questionnaire at two different points in time. The testing questionnaires were ultimately excluded from the final analyses. All questions were self-reported, and not externally validated. An English translation of the questionnaire is available on request from the corresponding author. The final questionnaire included the following sections:

1. Individual characteristics: age, seniority as OP, gender, whether they had: a) any professional experience as Occupational Physician in meat processing industry (yes vs. no); b) knowledge of COVID-19 cases among the workers of the assisted enterprises (yes vs. no); c) any personal interaction with COVID-19 (i.e. personal infection, infection in friends, relatives, etc.).
2. Knowledge test: participants received a 15-item questionnaire on SARS-CoV-2 and COVID-19 that was previously validated in a KAP study performed in the early stages of the pandemic (43,44). Briefly, the questionnaire included a total of 12 true/false items based on the understanding of COVID-19 at the time of the study (e.g. "SARS-CoV-2 is suspected to mainly spread through cough / droplets" - TRUE), and 3 multiple choice items based on the actual epidemiology of SARS-CoV-2 infection (e.g. "Lethality of COVID-19 in Italy is estimated to be .... 1 out of 10 symptomatic subjects (i.e. around 10%)" – TRUE). A General Knowledge Score (GKS) was calculated as the sum of correctly and incorrectly marked recommendations: when the participants answered correctly, +1 was added to a sum score, whereas a wrong indication or a missing/"don't know" answer added 0 to the sum score. GKS was dichotomized by median value in higher vs. lower knowledge status;
3. Risk perception: participants were initially asked to rate the perceived severity (C^{MPW}) and the perceived frequency (I^{MPW}) of SARS-CoV-2 infection in meat processing plant workers by means of a fully labeled 5-points Likert scale. Participants were then asked to similarly rate how they perceived the SARS-CoV-2 pandemic in Italy at the time of the survey in terms of severity (C^{ITA}) and frequency (I^{ITA}) (i.e. July 2020). The available options ranged from "not significant" (i.e., "of no significant concern in daily practice", score 1) to "very significant" (i.e., "of very high concern in daily practice", score 5). As perceived risk has been defined as a function of the perceived probability of an event and its expected consequences (34,45), a Risk Perception Score (RPS) was mathematically calculated as follows:

$$RPS = I \times C$$

Resulting RPS estimates (potential range: 1 to 25) for SARS-CoV-2 infection in MPWs (RPS^{MPWs}) and in Italian general population (RPS^{ITA}) were eventually reported as percent values.
4. Attitudes and Practices: we inquired participants about the perceived risk factors for SARS-CoV-2 infection among MPWs, and the potential interventions aimed to cope with the ongoing pandemic in meat processing plants. Both risk factors and potential preventive interventions were rated by participants by means of a fully labeled 5-point Likert scale, whose available options ranged from "totally disagree" (score = 1), to "totally agree" (score = 5). Reported answers were ultimately dichotomized in somewhat agree (i.e. 4 to 5, "agree" and "totally agree") vs. somewhat disagree (i.e. 1 to 3, "totally disagree", "disagree", "neutral").

The internal consistency or reliability of each of the sections of the questionnaire was assessed with the Cronbach alpha test, the results of which were interpreted in accordance with the literature.

Ethics approval

Before giving their consent to the survey, participants were briefed that principles and guidelines of the Helsinki Declaration would be followed across all steps of this study, and that all information would be gathered anonymously, handled confidentially and stored for a limited timeframe, in order to allow aggregate data analysis. Participation was voluntary, and the questionnaire was collected only from subjects who had expressed consent for study participation. As individuals cannot be identified based on the presented material, this study caused no plausible harm or stigma to participants. The study was deliberately designed by an anonymous, observational approach, and it did not include clinical data. Moreover, demographic was deliberately limited to very generic ones (i.e. age, seniority, and gender). According to the Italian law (Gazzetta Ufficiale no. 76, dated 31/3/2008), a preliminary evaluation by an Ethical Committee was therefore not required.

Data analysis

Continuous variables were initially tested for normal distribution with the D'Agostino and Pearson omnibus normality test. If normal distribution was rejected (D'Agostino and Pearson p value < 0.10), variables were compared using Mann–Whitney or Kruskal–Wallis tests for multiple independent samples, or by means of Spearman's correlation test where appropriate. Continuous variables passing the normality check (D'Agostino and Pearson p value ≥ 0.10) were compared by means of the Student's t test or ANOVA, and through calculation of the Pearson's correlation test, where appropriate.

Categorical variables were reported as per cent values, and their distribution in respect of the outcome variable of high-risk perception towards the risk of getting COVID-19 in meat and/or poultry processing workers was initially analyzed through chi-squared test.

All categorical variables that at univariate analysis were associated with the aforementioned status with a p value < 0.05 were included in a stepwise binary logistic regression analysis model in order to calculate adjusted odds ratios (aOR) and their respective 95% confidence intervals (95%CI). All statistical analyses were performed by means of IBM SPSS Statistics 27.0 for Macintosh (IBM Corp. Armonk, NY, USA).

Results

Descriptive analysis

As shown in Figure 1, a total of 424 OPs (20.8% of the potentially eligible population) participated to the inquiry.

As shown in Table 1, the mean age of the participants was 49.0 ± 9.1 years, with an average seniority as OPs of 15.8 ± 8.1 years. Of them, 49.5% were males, and 50.5% females. Overall, 27.6% of participants reported any professional experience as OP in the meat and poultry processing sector. Focusing on their previous interaction with SARS-CoV-2 infection, 59867 of them had knowledge of at least a case of COVID-19 among the workers of their own assisted enterprises, while 18.9% of all respondents reported some non-occupational interactions with COVID-19 (i.e. the participant was previously infected by SARS-CoV-2, or the disorder was reported among friends, relatives, etc.).

Assessment of knowledge about SARS-CoV-2/ COVID-19

After normalization, the mean GKS was generally high (84.0% ± 9.3; actual range 13.3%–100%; median 86.7%). Internal consistency coefficient of this set of 15 questions was good (Cronbach's alpha = 0.739) (Figure 2).

As shown in Table 2, while the general understanding of SARS-CoV-2 and COVID-19 was substantially appropriate, participants exhibited significant uncertainties regarding the epidemiology of COVID-19 in Italy at the time of the survey. For instance, 41.0% respondents properly reported that, since

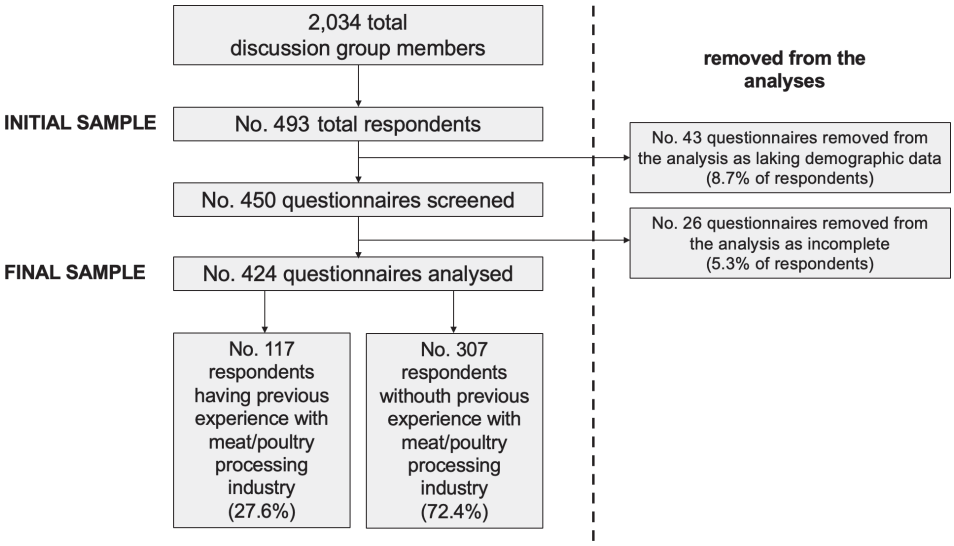

Figure 1. Flow chart of study participants.

Table 1. Characteristics of 424 Italian Occupational Physicians participating in the survey (July 2020). Likert scale for perceived severity and perceived frequency of COVID-19 were dichotomized as "higher" and "much higher" vs. all other values.

Variable	No./424, %	Average ± SD
Gender		
Males	210, 49.5%	
Females	214, 50.5%	
Age (years)		49.0 ± 9.1
Seniority (years)		15.8 ± 8.1
Knowledge Score (%)		84.0 ± 9.3
Knowledge Score > median (86.7%)	81, 19.1%	
Any professional experience as Occupational Physician in meat processing industry	117, 27.6%	
Knowledge of COVID-19 cases among the workers of the assisted enterprises	253, 59.7%	
Any interaction with COVID-19 (i.e. personal infection, infection in friends, relatives…)	80, 18.9%	
Perceptions about SARS-CoV-2 pandemic		
SARS-CoV-2 infection rates in meat and poultry processing workers acknowledged as higher / much higher than in general population.	268, 63.2%	
COVID-19 severity in meat and poultry processing workers acknowledged as higher / much higher than in general population.	101, 23.8%	
Current (i.e. July 2020) SARS-CoV-2 infection rates in Italian general population acknowledged as higher / much higher than in early stages of pandemic (i.e. March-April 2020)	66, 15.6%	
Current (i.e. July 2020) COVID-19 severity in Italian general population acknowledged as higher / much higher than in early stages of pandemic (i.e. March-April 2020).	30, 7.1%	
Risk Perception Score for COVID-19 in Meat Processing Workers (%)		48.9 ± 18.5
Risk Perception Score for COVID-19 in Meta Processing Workers > median (48.0%)	120, 28.3%	
Risk Perception Score for COVID-19 in Italy (Summer 2020) (%)		27.3 ± 18.5
Risk Perception Score for COVID-19 in Italy (Summer 2020) > median (24.0%)	148, 34.9%	

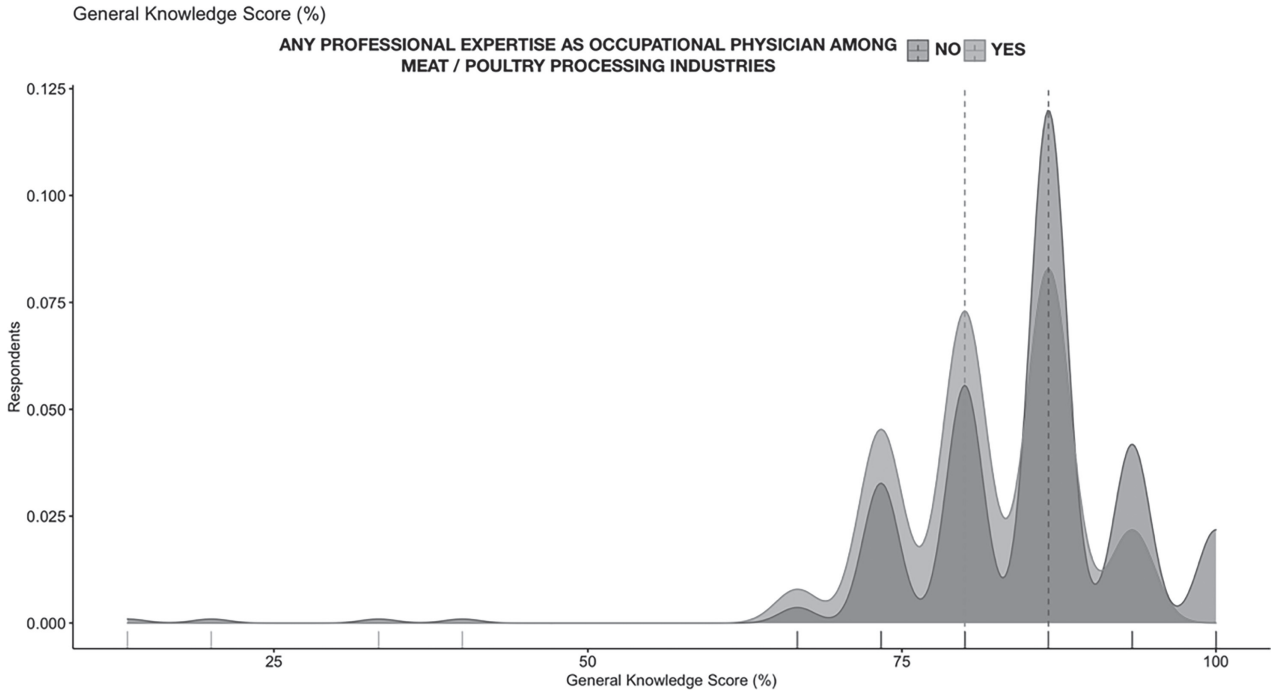

Figure 2. General Knowledge Score (GKS) among 424 Occupational Physicians (OP) participating into the survey (Italy, Summer 2020; average: 84.0% ± 9.3 standard deviation), broken down by having (81.9% ± 6.7) or having not any professional expertise as OP in meat and/or poultry processing industries (84.8% ± 10.0; Mann-Whitney U test $p < 0.001$). Data were substantially skewed both at visual inspection and according D'Agostino-Pearson test (skew = -2.349; z = -12.567; p = 0.001).

the beginning of the pandemic, 100,000 to 500,000 cases have occurred in Italy (more precisely 248,000 by 02/08/2020). Moreover, participants largely underestimated the case fatality ratio per COVID-19, as 42.7% of them reported a case fatality ratio equals to 1%, and 17.9% suggested an even lower rate of 0.1%. Official Italian figures of the "first wave" (by August 2nd, 2020) in fact accounted a total of 35,154 confirmed deaths, with a case fatality ratio of 14.2% that was properly identified by only 13.2% of participants.

Assessment of the risk perception

Overall, 63.2% of respondents acknowledged SARS-CoV-2 infection rates among MPWs as higher or even much higher than those reported among the general population, while only 23.8% reported a severity higher or much higher than in general population. A correspondent RPS^{MPWs} equals to 48.9% ± 18.5 was therefore calculated (Figure 3).

Focusing on the SARS-CoV-2 pandemic in the Italian general population at the time of the survey (i.e. July 2000), only 15.6% of respondents acknowledged infection rates higher than during the months of March and April 2020, whereas 7.1% identified a potential severity higher or much higher than in early stages of the pandemic, with an even lower RPS^{ITA} of 27.3% ± 18.5, that indicated a diffuse underestimation for COVID-19 not only on the workplaces (Figure 4).

Assessment of perceived risk factors and perceived efficacy of preventive interventions

Perceived risk factors and perceived efficacy of preventive interventions are extensively reported in Table 3 and Table S1. Briefly, after dichotomization,

Table 2. Knowledge test: response distribution of presented items proposed to the 424 Occupational Physicians participating in the survey and contributing to the assessment of General Knowledge Score (GKS) (Cronbach's Alpha = 0.739).

Knowledge Test	CORRECT ANSWER	No./424, %
Q01. Severe cases of COVID-19 are more frequently reported in elderly and/or frail subjects	TRUE	409, 96.5%
Q02. Main complication of COVID-19 is represented by respiratory failure	TRUE	397, 93.6%
Q03. By July 10th, 2020, the number of official diagnoses of COVID-19 in Italy accounted to …		
< 1,000 cases	FALSE	71, 16.7%
1,000 to 10,000 cases	FALSE	37, 8.7%
10,000 to 50,000 cases	FALSE	57, 13.4%
50,000 to 100,000 cases	FALSE	39, 9.2%
100,000 to 500,000 cases	TRUE	174, 41.0%
≥ 500,000 cases	FALSE	19, 4.5%
Don't known	-	27, 6.4%
Q04. Lethality of COVID-19 in Italy is estimated to be* ...		
More than 1 out of 10 symptomatic subjects (i.e. > 10%)	FALSE	29, 6.8%
1 out of 10 symptomatic subjects (i.e. around 10%)	TRUE	56, 13.2%
1 out of 100 symptomatic subjects (i.e. around 1%)	FALSE	181, 42.7%
1 out of 1,000 symptomatic subjects (i.e. around 0.1%)	FALSE	76, 17.9%
It is still unknown	FALSE	50, 11.8%
Don't known	-	16, 3.8%
Q05. All infected people become sick	FALSE	416, 98.1%
Q06. Etiologic agent of COVID-19 is a virus somewhat similar to …		
SARS virus	TRUE	407, 96.0%
Influenza-virus	FALSE	15, 3.5%
Measles virus	FALSE	0, -
Hepatitis C Virus	FALSE	0, -
Human Immunodeficiency Virus	FALSE	0, -
Don't known	-	2, 0.5%
Q07. Etiologic agent of COVID-19 is suspected to spread through contaminated running water	FALSE	352, 83.0%
Q08. Etiologic agent of COVID-19 is suspected to spread through cough / droplets	TRUE	420, 99.1%
Q09. Etiologic agent of COVID-19 is suspected to mainly spread through contaminated blood	FALSE	366, 86.3%
Q10. A vaccine against COVID-19 is available and effective	FALSE	420, 99.1%
Q11. All people infected by etiologic agent of COVID-19 exhibit some symptoms	FALSE	420, 99.1%
Q12. A specific pharmacological treatment for COVID-19 is available and effective	FALSE	339, 80.0%
Q13. Latency of COVID-19 may reach 14 days.	TRUE	338, 79.7%
Q14. Diagnostic gold standard for COVID-19 is a Real-Time Polymerase Chain Reaction test on specimens collected through nasal swabs	TRUE	408, 96.2%
Q15. Frequent hand-washing or disinfection with alcohol-based hand sanitizer effectively reduces the risk of COVID-19	TRUE	416, 98.1%

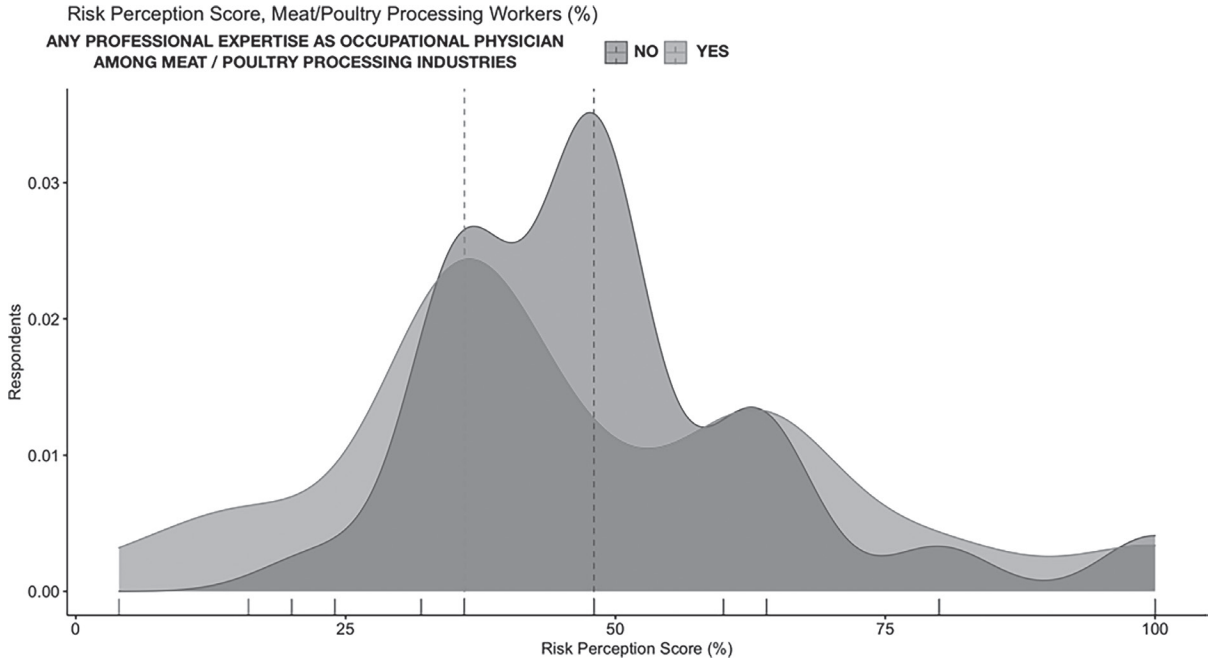

Figure 3. Risk Perception Score (RPS) calculated among the 424 occupational physicians participating into the present survey (Italy, late summer 2020), on the risk to get COVID-19 among meat and poultry workers. The estimates were quite skewed, both at visual inspection and by D'Agostino-Pearson test (skew = 0.918, z = 6.785, p < 0.001). Participants without specific expertise on management of meat/poultry processing industries exhibited not significantly higher RPS for getting COVID-19 among these workers (49.7% ± 16.6 vs. 46.9% ± 22.5, p = 0.223).

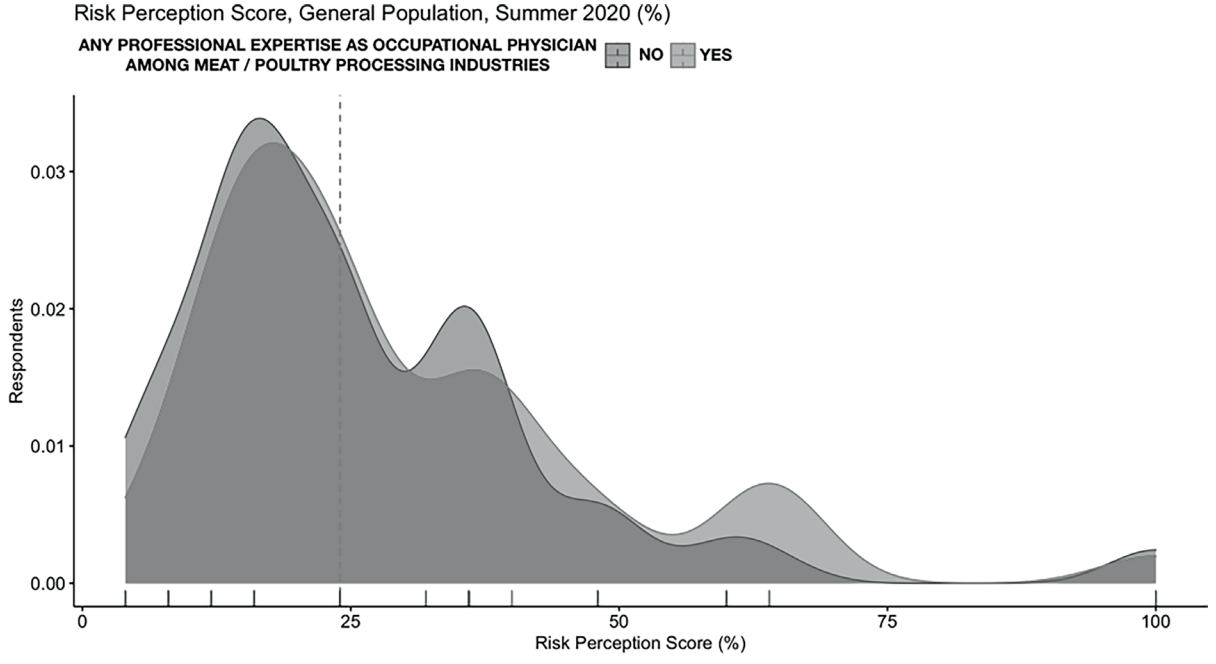

Figure 4. Risk Perception Score (RPS) calculated among the 424 occupational physicians participating into the present survey (Italy, late summer 2020), on the risk to get COVID-19 in the Italian general population as for summer 2020 compared to early months of the pandemic. The estimates were quite skewed, both at visual inspection and by D'Agostino-Pearson test (skew = 1.811, z = 10.844, p < 0.001 for RPS on the general population). Participants reporting specific expertise on management of meat/poultry processing industries scored a not significantly higher RPS than those having not (29.9% ± 19.4 vs. 26.4% ± 18.1; p = 0.088).

Table 3. Perceived risk factors for SARS-CoV-2 infections among meat processing workers, and perceived efficacy of preventive interventions against SARS-CoV-2 infection. The 5-point Likert scales ("*totally disagree*" to "*totally agree*") were dichotomized as "*agree*" and "*totally agree*" vs. all other values.

Perceived Risk Factors	**No.,/424 %**
FR01. Low environmental temperatures (< 17°C)	196, 46.2%
FR02. Inappropriate use of PPE - gloves	158, 37.3%
FR03. Inappropriate use of PPE - masks	237, 55.9%
FR04. Inappropriate personal hygiene (mainly, hand washing)	233, 55.0%
FR05. Inappropriate risk perception	336, 79.2%
FR06. Inappropriate health literacy	291, 68.6%
FR07. Lack of physical distancing	350, 82.5%
FR08. Lack of preventive measures specifically designed and applied by competent employers	200, 47.2%
FR09. Lack of support by Local Health Authorities	197, 46.5%
FR10. Environmental factors other than temperature (humidity, presence of air conditioners, etc.)	252, 59.4%
FR11. Possible contamination of meat processing workers by slaughtered animal bodies	77, 18.2%
FR12. Low socioeconomic status of meat processing workers	190, 44.8%
FR13. High share of workers with a migration background	212, 50.0%
Perceived Efficacy of preventive interventions	
01. Point-of-Care tests on the Workplaces	140, 33.3%
02. Serological tests (periodical)	222, 52.4%
03. Serological tests (during annual medical surveillance)	148, 34.9%
04. Molecular tests via Nasal Swabs (periodical)	276, 65.1%
05. Temperature measurement check-point	239, 56.4%
06. Surgical masks (mandatory use)	370, 87.3%
07. Respiratory masks (e.g. FFP2/3, N95/ N100; mandatory use)	342, 80.7%
08. Increased physical distancing	373, 88.0%
09. Regular (e.g. daily) cleaning and disinfection, workplaces	374, 88.2%
10. Regular (e.g. daily) cleaning and disinfection, changing rooms and canteens	378, 89.2%
11. Interventions on health education, workplaces	397, 93.6%

Abbreviations: PPE: personal protective equipment.

the large majority of respondents agreed on identifying among the main risk factors for the spreading of SARS-CoV-2 infection the lack of physical distancing (82.5%), the inappropriate risk perception of workers (79.2%), and their inappropriate health literacy (68.6%). Environmental factors were reported by a large majority of participants (59.4%), while temperature was claimed as a risk factor by 46.2% of respondents. Focusing on PPE, the inappropriate use of face masks was identified by more than half of participants (55.9%), whereas only 37.3% of respondents complained about the use of gloves by MPWs. Interestingly, less than a fifth of respondents suggested that SARS-CoV-2 may be carried by slaughtered animal bodies (18.2%).

When dealing with the perceived efficacy of interventions, the majority of respondents agreed that improving health education of workers (93.6%) may be effective in avoiding workplace infections. A large share of respondents then agreed on interventions promoting the mandatory use of PPE, either surgical masks (87.3%) and/or respiratory masks (80.7%), but also on increasing physical distancing (88.0%), and hygienic measures (i.e. cleaning and disinfection of changing rooms and canteens, 89.2%; regular hygiene of workplaces, 88.2%). Eventually, screening procedures such as the implementation of temperature checkpoints (56.4%), periodical molecular test via nasal swabs (65.1%), serological tests, either periodical (52.4%) or during annual medical surveillance (34.9%), and the use of point-of-care tests (33.3%), reported a mixed approval.

Univariate analysis

In univariate analysis, both RPS^{MPWs} and nor RPS^{ITA} were negatively correlated with GKS (rho = -0.148, p = 0.002; and rho = -0.167, p = 0.001, respectively). In other words, a better knowledge status (i.e., fewer misconceptions and/or less personal attitudes guiding the approach to the management of SARS-CoV-2 in the workplaces) was associated with a lower risk perception for COVID-19 in MPWs or during the Summer Season 2020 in Italian general population. Interestingly enough, both RPS were not correlated with the estimates for Relative Searches Volumes from Google Trends, a quantification of

the users' web interest in a certain keyword, on COVID-19 during the timeframe of the study (rho = -0.034, p = 0.479 for RPS^{MPWs}, and rho = 0.091, p = 0.060 for RPS^{ITA}).

As shown in Table 4, OP reporting higher risk perception on MPWs was negatively associated with being more than 50-year-old at the time of the survey (31.7% vs. 43.1%, p = 0.030), reporting more than 10 years of seniority (68.3% vs. 81.9%, p = 0.002), but also with better GKS (68.3% vs. 81.9%, p < 0.001). On the contrary, higher RPS^{ITA} (55.8% vs. 26.6%) was positively associated with higher risk perception on MPWs (p < 0.001).

When focusing on alleged risk factors, OPs scoring a higher RPS^{MPW} were more likely to recall the inappropriate use of gloves (51.7% vs. 31.6%, p < 0.001), inappropriate risk perception (93.3% vs. 73.7%, p < 0.001) and health literacy (90.0% vs. 60.2%, p < 0.001), but also the lack of workplace interventions, both in general (59.2% vs. 42.4%, p = 0.002) and more specifically the physical distancing (96.7% vs. 77.0%, p < 0.001), as well as the lack of support from the local health authorities (58.3% vs. 41.8%, p = 0.002). Also sociodemographic characteristics of MPWs, i.e. the low socioeconomic status of a large share of MPWs (53.3% vs. 41.4%, p = 0.027), and the high share of migrant workers (66.7% vs. 43.4%, p < 0.001), were positively associated with higher risk perception. Nevertheless, also acknowledging the possible contamination by SARS-CoV-2 of slaughtered bodies was positively associated with higher risk perception (66.7% vs. 43.4%, p < 0.001).

Eventually, focusing on perceived efficacy of preventive interventions, only measuring of body temperature at check-points was positively associated with higher risk perception (74.2% vs. 49.3%, p < 0.001).

Multivariate analysis

Regression analysis (Table 4) was modelled including the following explanatory variables: being older than 50-year-old; reporting more than 10 years of seniority as OP; a GKS higher than median value (86.7%); a RPS^{ITA} higher than median value (24.0%); acknowledging the temperature measurement as an effective preventive action; acknowledging as significant ones the following risk factors: inappropriate use of gloves; inappropriate risk perception; inappropriate health literacy; lack of preventive measures among parent enterprises; lack of physical distancing; lack of support from local health authorities; claims for potential SARS-CoV-2 contamination by slaughtered animals; low socioeconomic status of MPWs; migration background of MPWs.

In fact, reporting a higher RPS for MPWs was negatively associated with a better knowledge status (aOR 0.205, 95%CI 0.087 to 0.486), while it was positively associated with a higher RPS for getting COVID-19 among Italian general population (aOR 2.182, 95%CI 1.241 to 3.836), and with perceiving body temperature measurement as an effective intervention (aOR 2.390, 95%CI 1.304 to 4.379). Among complained risk factors, a substantial association was found with inappropriate health literacy of MPWs (aOR 4.087, 95%CI 1.690 to 9.883), the lack of physical distancing (aOR 3.776, 95%CI 1.203 to 11.845), and the high share of workers with a migration background (aOR 1.969, 95%CI 1.030 to 3.764).

Discussion

Our survey had mixed and somewhat surprisingly conflicting results. On the one hand, Italian OPs exhibited a quite satisfying general understanding of the SARS-CoV-2 pandemic, and this was somehow unexpected considering their far from in-depth training in the epidemiological field of infectious diseases. However, while previous studies from other European Countries reported high level of knowledge of health professionals about SARS-CoV-2 (46), an early web-based survey from Italy has identified significant knowledge gaps on SARS-CoV-2 issues (44).

On the other hand, participating OPs exhibited some knowledge gaps regarding the actual features of COVID-19 in MPWs, whose eventual risk was largely underestimated. Collectively, our data stress therefore the need to improve their understanding of biological risk issues and COVID-19 preventive measures in the meat and poultry industry through specifically tailored formative interventions. In other words, interventions based on health education of workers, employers and

Table 4. Factors associated with higher risk perception for COVID-19 among meat and/or poultry processing workers (MPWs) in 424 Italian Occupational Physicians (July 2020). Note: aOR = adjusted Odds Ratio (i.e., Odds Ratio calculated through binary logistic regression); 95%CI = 95% confidence interval.

	Risk Perception on MPWs			
Variable	**High (No./120, %)**	**Low (No./304, %)**	***p* value**	**aOR (95%CI)**
Male Gender	62, 51.7%	148, 48.7%	0.580	-
Age > 50 years	38, 31.7%	131, 43.1%	0.030	0.613 (0.310; 1.214)
Seniority > 10 years	82, 68.3%	249, 81.9%	0.002	0.652 (0.344; 1.234)
Knowledge Score > median (86.7%)	8, 6.7%	73, 24.0%	< 0.001	0.205 (0.087; 0.486)
Any professional expertise on Meat and/or Poultry processing industry	41, 34.2%	76, 25.0%	0.057	-
Knowledge of COVID-19 cases among the workers of the assisted enterprises	65, 54.2%	188, 61.8%	0.147	-
Any interaction with COVID-19 (i.e. personal infection, infection in friends, relatives…)	22, 18.3%	58, 19.1%	0.860	-
RPS^{ITA} > median (24.0%)	67, 55.8%	81, 26.6%	< 0.001	2.182 (1.241; 3.836)
Perceived Risk Factors for SARS-CoV-2 infections among meat processing workers (Important / Very Important)				
FR01. Low environmental temperatures (< 17°C)	64, 53.3%	132, 43.4%	0.065	-
FR02. Inappropriate use of PPE - gloves	62, 51.7%	96, 31.6%	< 0.001	1.168 (0.653; 2.091)
FR03. Inappropriate use of PPE - masks	74, 61.7%	163, 53.6%	0.133	-
FR04. Inappropriate personal hygiene (mainly, hand washing)	66, 55.0%	167, 54.9%	0.990	-
FR05. Inappropriate risk perception	112, 93.3%	224, 73.7%	< 0.001	1.198 (0.402; 3.574)
FR06. Inappropriate health literacy	108, 90.0%	183, 60.2%	< 0.001	4.087 (1.690; 9.883)
FR07. Lack of physical distancing	116, 96.7%	234, 77.0%	< 0.001	3.776 (1.203; 11.845)
FR08. Lack of preventive measures specifically designed and applied by competent employers	71, 59.2%	129, 42.4%	0.002	0.581 (0.319; 1.058)
FR09. Lack of support by Local Health Authorities	70, 58.3%	127, 41.8%	0.002	1.286 (0.718; 2.302)
FR10. Environmental factors other than temperature (humidity, presence of air conditioners, etc.)	79, 65.8%	173, 56.9%	0.092	-
FR11. Possible contamination of meat processing workers by slaughtered animal bodies	37, 30.8%	40, 13.2%	< 0.001	1.769 (0.928; 3.371)
FR12. Low socioeconomic status of meat processing workers	64, 53.3%	126, 41.4%	0.027	0.722 (0.375; 1.389)
FR13. High share of workers with a migration background	80, 66.7%	132, 43.4%	< 0.001	1.969 (1.030; 3.764)
Perceived Efficacy of preventive interventions against SARS-CoV-2 infection among meat processing workers (Important / Very Important)				-
01. Point-of-Care tests on the Workplaces	48, 40.0%	98, 30.3%	0.055	-
02. Serological tests (periodical)	54, 45.0%	168, 55.3%	0.057	-
03. Serological tests (during annual medical surveillance)	40, 33.3%	108, 35.5%	0.670	-
04. Molecular tests via Nasal Swabs (periodical)	78, 65.0%	198, 65.1%	0.980	-
05. Temperature measurement check-point	89, 74.2%	150, 49.3%	< 0.001	2.390 (1.304; 4.379)
06. Face masks (mandatory use)	108, 90.0%	262, 86.2%	0.288	-
07. Respiratory masks (e.g. FFP2/3, N95/N100; mandatory use)	98, 81.7%	244, 80.3%	0.742	-
08. Increased physical distancing	108, 90.0%	265, 87.2%	0.420	
09. Regular (e.g. daily) cleaning and disinfection, workplaces	108, 90.0%	266, 87.5%	0.472	
10. Regular (e.g. daily) cleaning and disinfection, changing rooms and canteens	112, 93.3%	266, 87.5%	0.082	-
11. Interventions on health education, workplaces	116, 96.7%	293, 96.4%	0.886	

supervisors are one of the basic principles of occupational health (19,20), being nowadays extensively recommended as effective in specifically countering the risk for SARS-CoV-2 among MPWs (47), and should also involve OPs.

Our results suggest that even OPs with professional experience in meat and poultry processing industry are not exempt from unsatisfactory knowledge of important aspects of COVID-19 and SARS-CoV-2 infection in this high-risk occupational setting. For example, although human SARS-CoV-2 infections through slaughtered animal bodies have not been substantially proven (48), around a fifth of participants advocated this potential occupational exposure as a significant risk factor, suggesting a "common sense" answer rather than an evidence-based one. This lack of knowledge is not radically new when dealing with healthcare professionals, and specifically OPs (33,46). OPs are often requested to offer advice and support on topics they are not familiar with, such as the biological risk, and while their intervention could radially improve health and safety of surveilled workers (46), knowledge gaps and inappropriate risk perception can, in turn, jeopardize the successful of every preventive measure (34).

Food production and processing is one of the vital sectors of society and must be particularly safeguarded during the ongoing pandemic. In facts, while the meat and poultry sector has been scarcely affected by job crisis, it experienced the greatest increase in absenteeism during the pandemic, as happened for other essential workers, whose absence rate approached 30% during the first pandemic surge, somehow in line a 2011 research that indicates that absenteeism rates are anticipated to be as high as 40% during a pandemic (49). The causes remain rather unclear, although the evidence collected on the sidelines of almost two years of the pandemic allows us to consider some possible factors underlying this phenomenon: first, the imposition of restriction and default measures in the event of the appearance of the slightest flu-like symptoms, especially the first pandemic wave; secondly, the lack of ability to contain the spread of the virus in the early phases inevitably led to an increase in cases of absence due to illness. The perception of risk, and the fear of being able to convey the virus to third parties (family members, fragile), may have played as a third key factor (50,51). Despite some reports on occupational outbreaks (17–20,47,52,53), at the end of the first year of the pandemic, official figures did struggle to confirm a significantly increased risk for SARS-CoV-2 infections among MPWs. For instance, the official report from the Italian National Institute for Insurance against Accidents at Work (INAIL) did not include the specific infection rates for MPWs, as this economic sector is classified alongside other work activities from manufacturing and agriculture, forestry, fishing (27,54), that collectively accounted to 2.9% of all work-related SARS-CoV-2 infection cases. However, as most of those economic sectors benefited from lockdown measures during the early stages of the pandemic, weighting the effecting relevance of meat and poultry processing industry still remains quite difficult. Interestingly, early figures from the SARS-CoV-2 surveillance campaign in the Emilia Romagna Region (Emilia Romagna Regional Government 2020), reported infection rates not exceeding 1% of all sampled MPWs (around 5000 subjects; M Broccoli, Regional Health Authority from Emilia Romagna Region, personal communication), but again such figures require some commentaries. More precisely, as the aforementioned surveillance campaign was performed during the summer season 2020, i.e. during a sustained respite that anticipated the "second wave", an infection rate equals to 1% nearly doubled the notification rates from the Emilia Romagna Region during the first decade of August 2020 (28).

Such mixed evidences may explain why OPs having professional experience in the meat and poultry industry were less likely to report SARS-CoV-2 cases among the workers of the assisted enterprises, and acknowledged a rather reduced risk for COVID-19 among MPWs. In other words, being the incident cases relatively few during the Summer Season 2020 (total daily rates in Emilia Romagna Region, for example, not exceeded 1.5 cases per 100,000 during the first decade of August 2020), and mostly clustered in some industrial plants (28,55,56), as in previous international reports (17–20), it is reasonable that OPs unwillingly underscored the relevance of the pandemic in this economic sector.

This is particularly frustrating, as these workers have less chances to avoid exposure to SARS-CoV-2, and their occupational safety would require the instatement of appropriate preventive measures, and active collaboration of the competent OPs. Moreover, some preventive interventions may be difficult to implement because of specific features of these working environments, as previously pointed out by studies on Avian Influenza outbreaks among MPWs (9–13), and more precisely: close proximity of crowded workstations with prolonged contact among employees (20); low temperatures, very high or very low relative humidity; extensive metallic surfaces that are able to retain viable viruses; extensive production of aerosols that include materials able to host viral particles (17–20,49); air conditioning systems often enhancing the diffusion of aerosols containing viral particles (57).

In such environments, microbiological properties of SARS-CoV-2 allow a rapid spread among susceptible workers, and appropriate mitigation programs would require engineering and administrative interventions that are often out of reach for the companies.

Despite the potential significance in the ongoing pandemic, our study suggests that without professional experience on MPWs may have underestimated the role played by specific characteristics of this workforce, often relying on migrant workers (17,47,53,58–60). Even though there is considerable evidence that migrant workers are at a disproportionately higher risk to develop SARS-CoV-2 infection (61–63), their actual risk has been often overlooked. This underestimation probably comes from both social neglect and a sort of social desirability bias (59,60): since combining migrant workers with a higher risk of infectious disease is often regarded as a populistic, right radical (or even openly "negative") attitude, some professionals may unconsciously deny the actual risk of such social groups (64,65).

Second, workers of low socioeconomic status (SES), and particularly migrant workers from ethnic minorities are usually characterized by high socializing outside work (59,60). As a consequence, contacts between employees do not occur only in shared areas (e.g. cafeterias, locker rooms, equipment-dispensing locations), but also outside the facilities (19,20), enhancing the spread of SARS-CoV-2 infection from and within this community (20). Not coincidentally, in a recent field study on 241 meat processing workers with a previous diagnosis of COVID-19, close contact with a visibly ill person was reported by 29% of participants, in particular in production areas (74%), and cafeteria/breaks areas (51%) (19). These data are aligned with our study, since professionals with actual experience of meat and poultry processing plant were more eager to recommend regular cleaning and disinfection of changing rooms and canteens.

During the early phases of the pandemic, and with increased emphasis when the lockdown measures were progressively relieved, Italian National and Regional Health Authorities stressed the importance of implementing a series of preventive measures that were specifically inquired in our survey, and again our results are quite conflicting (17–20,30). For example, temperature checkpoints and screening based on symptoms associated with COVID-19 have been extensively promoted across workplaces: implementing a worker temperature or symptom screening is among the most common prevention interventions established in US meat and poultry facilities (47). However, evidence suggests that such measures may be of limited preventive significance, particularly among MPWs (17,19,47). In available studies, the share of MPWs infected by SARS-CoV-2 but substantially asymptomatic was up to one third of all participants (19). Despite ongoing controversies, it is reasonable that asymptomatic subjects still contribute to the virus transmission: not coincidentally, the share of participating OPs that recommended such preventive measures was relatively low (51.5%), with no differences among professionals usually operating in meat processing industry or not. Also, periodical point-of-care tests of workers are of limited usefulness in daily practice because of a mixture of technical shortcomings (66), and characteristics of the immune response to SARS-CoV-2, extremely variable in time and across individuals (67). Again, study participants shared significant doubts about such procedures, which were advocated as useful in daily practice for MPWs by less than a third of all surveyed OPs, consistently with a previous report (38). On the contrary, mandatory usage of facial masks by employees, and periodical oropharyngeal swab tests at workplace supervised by OPs

during the health surveillance programs, as well as the observance of hygiene rules at workplace are essential for an effective occupational health response to SARS-CoV-2 (19,20,47,68,69). It is particularly important to stress that, in meat and poultry industry, maintaining social distancing is difficult or even impossible: not coincidentally, highest attack rates in available reports were identified among workers involved in tasks that require close contact (well less than 2 meters of distancing) during the procedures, such as cut, conversion and harvest (20). In such settings, only the strict use of hygienic countermeasures, including the appropriate use of PPE, may guarantee some protection against the shedding of viral particles from infected workers. The extensive referral of such measures among study participants and the lack of significant differences between OPs with and without professional experience in meat and poultry industry may be explained through the current diffuse awareness of the value of such interventions across workplaces (70).

Our study has some limitations. Firstly, the cross-sectional design of the study prevents us from drawing any causal inferences based on our findings. Second, it shares the implicit limits of Internet-based surveys (71,72). Even though such studies are substantially reliable and cost-effective, they are substantially based on volunteer participants and, therefore, can introduce selection bias. In other words, the final sample may potentially over-represent some sub-groups (e.g., subjects from younger age groups, with a greater literacy, and more accustomed to the internet access), eventually failing to represent the original population. Therefore, a significant selection bias cannot be ruled out. Again, as in conventional paper-based surveys, participating voluntarily could be due to a proactive attitude or greater knowledge about the survey theme. In the same way, the fact of not participating could be understood as a negative attitude or a lack of knowledge about the main study theme. Moreover, we cannot rule out that some of the items assessed through the knowledge test may be affected by a significant social desirability bias, with participants reporting the "socially appropriated" rather than their authentic behaviors, so that our results could have ultimately overstated the share of occupational physicians having an effective understanding of COVID-19 in MPWs. Again, this habit is a tantalizing explanation for the lack of correlation between knowledge score and risk perception.

Another potential shortcoming of our sample was its limited size, as it included only 424 professionals among the over 7,000 occupational physicians from the national list (33). In this regard, even though social media managers of specific discussion groups usually perform a certain selection of potential members (e.g., by registering only subjects who receive a specific invitation by the manager; answering to specific "selection" questions; etc.), we cannot rule out that some of the respondents were not actively working as OPs, limitedly or even not fulfilling our initial selection criteria. In this regard, it should be stressed that collected data were not externally validated, lacking an estimate of high-risk workers actually followed by sampled occupational physicians. More specifically, we are neither able to ascertain how often sampled professionals actually interact with MPWs, nor which share of their practice they actually represent. As a consequence, we were unable to estimate the effective extent of the social desirability bias, particularly when dealing with recommended countermeasures.

It should be stressed that we deliberately avoided to collect data on the Region of residence and/or main working activity of participating OPs in order to guaranteeing the privacy of respondents. As Italy is quite heterogeneous in terms of health literacy, our results should be cautiously interpreted as representative of the national level (31,73,74). Moreover, also Italian agroindustry is quite regionalized, and the broader term of meat and poultry industry in reality encompasses a larger set of processed foods, with strikingly heterogenous working conditions (75).

Finally, information about COVID-19 is continuously expanding and changing, thus the survey questions about COVID-19 knowledge shall be revised for future studies (76).

Conclusions

Our study, suggests a relatively good understanding of SARS-CoV-2 pandemic among sampled OPs, but also a diffuse and alarming underestimation of the risks associated with meat and poultry processing

industry, particularly among OPs who actively assist MPWs. Collectively, these results lead us to believe that prevention programs can be useful in improve occupational health and safety of MPWs. However, such programs cannot be truly effective, if not accompanied by significant efforts to improve the understanding of the actual epidemiology of SARS-CoV-2 pandemic in the workplaces, specifically tailored on the characteristics of the vulnerable workforce represented by individual of low socioeconomic status, such as migrant and refugee workers, extensively employed in meat and poultry processing industry. Last but not least, we strongly underline the importance and the need to prepare training courses that contemplate a structured framework of skills of the occupational physician, and of the other figures involved - first and foremost the employer, as recalled by national and supranational bodies , so as not to have to rely, in case of emergencies, on suggestive skills more akin to dowsing than on a rigorous process of managing workers' health and safety.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki; ethical review and approval were waived for this study, due to the anonymous, observational design and the lack of clinical data about patients. The study, therefore, did not configure itself as a clinical trial, and a preliminary evaluation by an Ethical Committee was not required, according to the Italian law (Gazzetta Ufficiale no. 76, dated 31 March 2008).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

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Appendix – Supplementary files

Table S1. Factors associated with higher risk perception for SARS-CoV-2 infection and COVID-19 severity among meat processing workers in 424 Italian Occupational Physicians (July 2020). Abbreviations: aOR: adjusted Odds Ratio (i.e., Odds Ratio calculated through binary logistic regression); 95%CI = 95% confidence interval. Subanalysis on OP with expertise on meat and poultry processing industry.

	Risk Perception on MPPW			
Variable	**High (No./41, %)**	**Low (No./76, %)**	**P value**	
Male Gender	30, 73.2%	35, 46.1%	0.009	
Age > 50 years	22, 53.7%	34, 44.7%	0.467	
Seniority > 10 years	30, 73.2%	64, 84.2%	0.234	
Knowledge Score > median (80.0%)	11, 26.8%	42, 55.3%	0.006	
Knowledge of COVID-19 cases among the workers of the assisted enterprises	8, 19.5%	23, 30.3%	0.209	
Any interaction with COVID-19 (i.e. personal infection, infection in friends, relatives…)	8, 19.5%	30, 39.5%	0.046	
RPS^{ITA} > median (24.0%)	29, 70.7%	15, 19.7%	< 0.001	
Perceived Risk Factors for SARS-CoV-2 infections among meat processing workers (Important / Very Important)				
FR01. Low environmental temperatures (< 17°C)	26, 63.4%	38, 50.0%	0.232	
FR02. Inappropriate use of PPE - gloves	25, 61.0%	26, 34.2%	0.010	
FR03. Inappropriate use of PPE - masks	29, 70.7%	41, 53.9%	0.117	
FR04. Inappropriate personal hygiene (mainly, hand washing)	25, 61.0%	41, 53.9%	0.592	
FR05. Inappropriate risk perception	33, 80.5%	56, 73.7%	0.551	
FR06. Inappropriate health literacy	37, 90.2%	49, 64.5%	0.005	
FR07. Lack of physical distancing	37, 90.2%	65, 85.5%	0.661	
FR08. Lack of preventive measures specifically designed and applied by competent employers	29, 70.7%	27, 35.5%	0.001	
FR09. Lack of support by Local Health Authorities	25, 61.0%	34, 44.7%	0.138	
FR10. Environmental factors other than temperature (humidity, presence of air conditioners, etc.)	29, 70.7%	42, 55.3%	0.151	
FR11. Possible contamination of meat processing workers by slaughtered animal bodies	3, 7.3%	4, 5.3%	0.969	
FR12. Low socioeconomic status of meat processing workers	22, 53.7%	52, 68.4%	0.114	
FR13. High share of workers with a migration background	30, 73.2%	38, 50.0%	0.026	
Perceived Efficacy of preventive interventions against SARS-CoV-2 infection among meat processing workers (Important / Very Important)				
01. Point-of-Care tests on the Workplaces	29, 70.7%	22, 28.9%	< 0.001	
02. Serological tests (periodical)	21, 51.2%	41, 53.9%	0.930	
03. Serological tests (during annual medical surveillance)	25, 61.0%	26, 34.2%	0.010	
04. Molecular tests via Nasal Swabs (periodical)	19, 46.3%	45, 59.2%	0.254	
05. Temperature measurement check-point	33, 80.5%	30, 39.5%	< 0.001	
06. Face masks (mandatory use)	37, 90.2%	61, 80.3%	0.163	
07. Respiratory masks (e.g. FFP2/3, N95/N100; mandatory use)	26, 63.4%	57, 75.0%	0.270	-
08. Increased physical distancing	33, 80.5%	68, 89.5%	0.286	
09. Regular (e.g. daily) cleaning and disinfection, workplaces	33, 80.5%	72, 94.7%	0.035	
10. Regular (e.g. daily) cleaning and disinfection, changing rooms and canteens	37, 90.2%	76, 100%	0.025	-
11. Interventions on health education, workplaces	41, 100%	76, 100%	-	