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Editorial: Insights in occupational health and safety: 2021

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occupational health, occupational safety, prevention, worker, workplace

Editorial on the Research Topic
Insights in Occupational Health and Safety: 2021

Occupational Medicine has always been concerned with preventing health effects caused by working conditions, and with promoting and maintaining the highest level of physical, mental, and social wellbeing of workers in all occupations. This "*Insights in Occupational Health and Safety: 2021*" Research Topic, of 13 articles, reflects the geographic variety of occupational health and safety researchers with contributors from Asia, Europe, America, Africa, and Oceania. It includes forward looking contributions focused on new occupational risk factors, current challenges, recent advances and future perspectives in the field of Occupational Health and Safety. From this perspective, there has been an increasing effort in recent years to investigate the causes of occupational musculoskeletal disorders and to take action to prevent them. Regarding this issue Lourenço and Luís investigated how musculoskeletal disorders in welders may influence their quality of life, finding a higher incidence of symptoms in welders in comparison to non-welders. Furthermore, the presence of musculoskeletal disorders, particularly in the lumbar area, was related to an increased bodily pain and decreased health-related quality of life. Aleku et al. found that the frequency rate of low back pain was high amongst healthcare workers (HCWs). In this occupational category, this problem could be related to workloads due to the COVID-19 pandemic. A high workload, in fact, not only adversely affects safety, but also negatively affects job satisfaction and, as a result, contributes to high turnover and staff shortages. Li, Hu, Liu, et al. performed a physician comprehensive workload analysis among Chinese physicians. The assessment of workload proposed by the Authors could be a potential application for hospital managers to further determine and accurately identify physicians with high workload. Saleem et al. pointed out that it is appropriate to intervene on safety of some groups of workers such as those working in construction. Despite significant efforts over the past several decades, occupational safety is still, in fact, a highly relevant and serious issue worthy of academic attention (Liu L. et al.). On this basis, the challenge for occupational

medicine, in the near future, is to increase occupational safety and prioritize workplace health promotion and job satisfaction (Liu D. et al.). Only through this process it would be possible to face the new challenges related to health effects of gig-economy. The gig economy is a rising phenomenon globally, where gig workers present "alternative work arrangements" for pieces of jobs ("gigs") or more generally short-term contract, which are mainly agreed upon *via* digital platforms for different services, including food delivery or transportation. Focusing on the health effects among gig workers is of great public health relevance and epidemiological studies could better stimulate policies to design and implement preventive health measures (Freni-Sterrantino and Salerno).

Moreover, studies on interactions between environmental and genetic factors are assuming more and more urgency and importance. In this context the third follow-up of the study on occupational allergy risks cohort, in Germany, offers the opportunity to analyze the course of asthma and allergies and their associations to environmental, occupational, and psychosocial risk factors over more than 20 years from childhood to adulthood (Forster et al.). Fu et al. investigated acute respiratory distress syndrome caused by occupational exposure to waterproofing spray, while Hall et al. recommend ongoing research to understand links between military exposures and veteran health.

Finally, the coronavirus disease 2019 (COVID-19) pandemic has also changed the public opinion on the need for safe practices in the workplace and has focused the attention of governments and institutions worldwide on the fundamental role that the occupational safety and health services play. In particular healthcare workers (HCWs) are a group at high risk of infection in general and specifically of SARS-CoV-2 infection (Keleb et al.), even with psychological harm (Li, Hu, Chen et al.). Since the start of the pandemic several studies have been carried out on prevalence of COVID-19, and on related risk factors in this group of workers. An Italian multicenter study, conducted during the first months of the pandemic, revealed that the prevalence of infection in HCWs varied across centers, with results collected in centers ranging from 3.0 to 22.0%, and was strongly correlated with that of the respective geographic areas. The lack of difference in risk between HCWs who worked in designated COVID-19 departments and those who worked in other departments was reassuring as it indicates that working in high-risk environment did not entail a higher risk of infection, probably because of increased awareness and proper use of PPEs by the employees (1). Monitoring HCWs, both symptomatic and asymptomatic, through screening programs is crucial to rapidly identify and isolate infected subjects and, consequently, to avoid hospital infection outbreaks and to allow healthcare workers to return to work promptly (2). Moreover, alongside screening programs, the implementation of preventive measures and protocols in hospital settings has been shown to be highly effective in reducing the number of cases (3–7). In order to prevent transmission of the virus and protect their parents or children from the pandemic, some HCW have temporarily quarantined themselves from their family. Consistent person-to-person transmission of this novel coronavirus in family settings has been documented (8). Mostly during the first months of the pandemic the quarantine hotels provided the much-needed private space to rest or self-isolate, making life a little less stressful for those battling COVID-19 (Teng et al.) (9). As the COVID-19 pandemic continues, the need to understand and respond to long COVID is increasingly pressing. The term "long COVID" is commonly used to describe signs and symptoms that continue or develop after acute COVID-19. Symptoms such as persistent fatigue, breathlessness, brain fog, and depression could debilitate many millions of people globally. Working on predictive risk factors, such as overweight and obesity, will be a key factor in reducing the incidence of long COVID (10).

In conclusion, this Research Topic broadly encompasses a variety of occupational health-related issues that impact not only workers worldwide, but also and the communities in which they live, highlighting the progress made in the past decade as well as existing and future challenges still needing to be addressed.

Author contributions

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Corporate Social Responsibility in Public Health During the COVID-19 Pandemic: Quarantine Hotel in China

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INTRODUCTION

The outbreak of a novel coronavirus pneumonia, known as COVID-19, started in Wuhan, China, and spread rapidly and widely around the globe. The COVID-19 pandemic has had a major impact on the well-being of people and countries around the world, with major implications for public health, society, safety and the economy (1, 2). As a result, hotels, viewed as a declining industry, have suffered a staggering drop in average occupancy rates (3). The hospitality industry is "*already facing collapse*" and is "*fighting for survival*," as a result of the pandemic.

As positive cases of COVID-19 escalate, hospitals face problems with overcrowding and insufficient isolation space (4). In addition, scholars propose that those patients suspected to have COVID-19 and patients with COVID-19 experiencing only mild symptoms should prevent interaction with other household members by isolating themselves in a hotel (5). The hotel, coordinated by a tertiary referral hospital and attended the preventive medicine regulations, not only as a public health resource for the containment of COVID-19 but also as more than a place for quarantining in Madrid (6). Further, there is increasing worry from frontline healthcare workers (HCW) about contracting the virus and contaminating loved ones (7). To prevent the transmission of the virus and protect parents and/or children from the epidemic, HCW and suspected COVID-19 patients, need temporary quarantine from their families. A quarantine hotel is a possible solution to address this demand for temporary quarantine accommodation. Prior literatures also discussed about the role of quarantine hotels associated with the use of preventive protocols in hospitals to reduce the occurrence of hospital outbreaks. The authors reveal the hospitals and hotels have common characteristics, such as individual rooms and toilets, which made the quarantine hotels not only a viable solution for the containment of COVID-19, but for the caring of patients and HCWs (6, 8). Quarantine hotels are a community-based public health intervention designed to mitigate the spread of COVID-19 within the community.

With the COVID-19 virus sweeping the world and disrupting lives, livelihoods, and communities, and putting enormous strain on public health as a whole, "corporate social responsibility" must now play its part. Stakeholder theory has also been actively applied in the theory and practice of "corporate social responsibility" (9). "Corporate social responsibility" refers to "*the responsibility of enterprises for their impacts on society*" (10). Today, "corporate social responsibility" is the new tool for hoteliers when they encounter an irresistible force. Especially for the time of necessitating an urgent search of the external factors. Thus, focusing on "corporate social responsibility" is now a significant and effective way to not only solve current problems, but also assist with the future strategic decisions of tourism enterprises and the tourism industry as a whole during the COVID-19 crisis (11).

As we write this paper, the coronavirus is ongoing. Considering its novelty, few studies have studied its impact on "corporate social responsibility." Moreover, there are few studies that have examined this epidemiological catastrophe from the "corporate social responsibility" in public health perspective. In this article, preliminary ideas are discussed on how the quarantine hotel has demonstrated "corporate social responsibility" by assisting Chinese communities, particularly the HCW, and its potential implications on marketing strategies during and after the pandemic.

THE QUARANTINE HOTEL IS AN ADJUSTED OPERATIONS MODEL WHICH ALSO PROVIDES A MODEL FOR "CORPORATE SOCIAL RESPONSIBILITY"

"Corporate social responsibility" is often used as a comprehensive term to describe a variety of issues relating to the responsibilities of business (12). "Corporate social responsibility" has developed into a new global governance model to promote the ability to reach collective decisions on transnational subjects (13). The COVID-19 crisis has tested companies on their commitment to ethical business conduct and "corporate social responsibility" (14). For example, some companies have donated funds, personal protective equipment, hand sanitizer, respiratory systems and testing kits to hospitals.

As a result of the COVID-19 pandemic and the impact of new challenges to the hotel industry, hoteliers adjusted their operations to overcome obstacles, such as redundancies. Post-pandemic accomplishment over fighting the virus will build an organization's genuine "corporate social responsibility" and provide a more superior relationship with the general public. Previous hotel industry literature actively promotes their "corporate social responsibility" efforts and focusses on the perceptions of the hospitality industry's environmental practices (15). Now, the quarantine hotel is not only an important ally in the fight against the COVID-19 pandemic, it also provides another "corporate social responsibility" within the public health model.

"CORPORATE SOCIAL RESPONSIBILITY" INITIATIVES OF THE QUARANTINE HOTEL

How will stakeholders be involved in the quarantine hotel's "corporate social responsibility" activities and what does it mean to them?

Medical HCW

Due to the high contagiousness of COVID-19, healthcare professionals are occupationally exposed to high biological risk (16). The protection of health care professionals is of great concern and importance during the COVID-19 pandemic (17). In Italian, for Infection control and provided a specific early detection programme, HCW staffs can be hosted safely in hotel facilities during the COVID-19 pandemic (8). Taking care of the mental health of quarantine employees is a critical part of the public health response and is also a "corporate social responsibility" (18). Quarantine hotels provide their premises to house medical staff when dealing with COVID-19 patients. Supporting HCW in all aspects of health and safety is important to sustain a healthy workforce and is pivotal in protecting them against the virus. A report discovered that the provision of rest areas and basic physical needs, such as food, resulted in greater satisfaction among HCW (19).

In order to prevent transmission of the virus and protect their parents or children from the pandemic, some HCW have temporarily quarantined themselves from their family. The quarantine hotels provided the much-needed private space to rest or self-isolate, making life a little less stressful for those battling COVID-19.

Travelers or Residents From Abroad

Governments worldwide have enforced that all travelers or residents returning from overseas must be quarantined in designated accommodation (quarantine hotels) for 14 days from the day they arrive in the country. Hoteliers are helping to prevent the spread of COVID-19 by complying with the quarantine order and providing travelers and residents with accommodation for the 14-day quarantine period. As a result, there is now a large proportion of travelers and residents living in quarantine hotels.

Hotel Employees

The hospitality industry supports millions of livelihoods; however, job losses have resulted from the devastating impact of the COVID-19 pandemic. Providing quarantine space is a smart business move, as quarantine packages will provide some economic relief for the hospitality industry. As a quarantine hotel, the adjusted operations model guarantees staff will keep their jobs and ensures wages will still be paid.

Staff of quarantine hotels will also receive extra medical education to identify microbiological characteristics and perform diagnosis, disinfection and self-protection technology. They are also trained in operation guides, complying with anti-epidemic and disinfection standards, and implementing quarantine services. Quarantine hotels will help organizations navigate workforce shifts through agile workforce strategies.

Although the roles of the hotel staff have been adjusted, their new skills will prevail. Underlying core skills, along with new skills in medical education, anti-epidemic and disinfection standards are the new currency and will be the key to building resilient workforces in the future. Moving forward, it will provide staff with the additional skills and new mindsets needed to obtain high-demand jobs in either health care or other businesses. For example, kitchen and cleaning staff could move on to work in an elderly care center, long-term care facilities and/or nursing homes. Thus, hoteliers are also helping staff achieve long-lasting workforce resilience.

Shareholders and Investors of the Quarantine Hotel

As the COVID-19 pandemic continues, more countries require both citizens and foreign visitors arriving from abroad to

enter a mandatory 14-day isolation period at a quarantine hotel. Hence, there is an increasing demand for this facility. In Malaysia, anyone traveling into the country will have to pay the full cost, US$34.50 a day, for their compulsory quarantine hotel. In Taiwan, in addition to the income from the quarantine travelers, as a designated quarantine hotel the hotelier will also receive some compensation from the government. Offering quarantine packages slightly relieves the financial pressures caused by the COVID-19 outbreak, which will benefit shareholders and investors.

Government

By offering quarantine accommodation during the COVID-19 pandemic, the hospitality industry is working with the government to support their quarantine requirements policy. This solves the problem of tourists requiring quarantine accommodation and also minimizes potential leaks in the government's outbreak prevention efforts.

MARKETING STRATEGIES IN THE HOSPITALITY INDUSTRY DURING AND AFTER THE PANDEMIC

The public health crisis caused by the COVID-19 pandemic provides a significant opportunity for the hospitality industry to actively participate in various "corporate social responsibility" initiatives. Mid-pandemic, as the hospitality industry introduces the quarantine hotel, their "corporate social responsibility" quickly adopts the market-driven strategy to control, educate and manage the basic services in demand. The designated quarantine hotel is a short-term "corporate social responsibility" strategy in the fight against the COVID-19 pandemic. It also potentially accelerates a new era of development of "corporate social responsibility" in the long-term marketing strategy.

This article implicates that some short-term marketing strategies that change consumer habits can lead to a long-term marketing philosophy. First, enhance the insertion of robotics technology and artificial intelligence (AI) into the hotel industry. The increased emphasis on physical social distancing and decreasing personal contact are significant measures to reduce transmission of diseases. The quarantine hotel provides three meals a day via services that avoid contact with guests. In the future, hotels can apply AI and robotics technology to positions such as bellboy, busboy and room service to avoid personal contact, while still maintaining service standards.

Second, because the COVID-19 virus can spread through contact with contaminated surfaces, cleanliness and hygiene are paramount (20). Hoteliers should focus their attention on hygiene and cleanliness and promote this message via social media e.g., "*We have high standards of cleanliness and hygiene*." As the quarantine hotel employees have been trained and educated on essential preparatory and prevention measures, ranging from hygiene measures that includes increased frequency of cleaning and sanitizing, to guidelines on how to handle suspected or confirmed cases of COVID-19 and implementing quarantine services, customers will feel comfortable and safe during their stay at the hotel.

CONCLUSION

The present paper is an opinion article which studies the impact of COVID-19 on "corporate social responsibility" within public health from the quarantine hotel perspective. The goal of this opinion article is to enrich the understanding of COVID-19's impact on corporate social responsibility in public health, and to suggest avenues for quarantine hotels' actions from social enterprise perspective, during and post COVID-19 in order to mitigate its effects. Academically, the contribution of this study is to examine the impact of COVID-19 on corporate social responsibility within public health, this paper will help broaden the scope of corporate social responsibility research in the COVID-19 crisis and provide some insights for hoteliers. Thus, this study provides a pioneer reference for similar studies in the future.

From a practical implications point of view, the outbreak of COVID-19 has disturbed the daily operation and even survival of hotels worldwide. The quarantine hotel volunteered to house HCW or those requiring quarantine, which is a positive CSR way for hotels to open their doors and give back to society during this public health crisis. This demonstrates altruism and egoism, which is a win-win corporate social responsibility marketing strategy. While COVID-19 drives the hotel industry's CSR strategy in the short term, researchers need to explore and discover effective marketing strategies which will bring beneficial corporate social responsibility to their stakeholders in the long term.

After the COVID-19 pandemic, what are the opportunities and challenges for corporate social responsibility in the long term? Post-pandemic, researchers should strive to reinforce the theory and epistemology of the hospitality industry to help them become more resilient and attain effective post-disaster recovery. Hospitality practitioners and scholars should carefully investigate the empirical influence of the COVID-19 crisis and seek to improve hoteliers' corporate social responsibility, and a new era marketing strategy for hospitality industry operations from the stakeholders' perspective. In future research, scholars should include in-depth interviews, surveys, or a mixed-methods approach to research to gather data on the topics raised in related articles.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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A Plea for the Need to Investigate the Health Effects of Gig-Economy

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Keywords: gig-economy, biomarkers, unstable jobs, stress, biological age

INTRODUCTION

The gig economy is a rising phenomenon globally, where gig workers present "alternative work arrangements" (1) for pieces of jobs ("gigs") or more generally short-term contract, which are mainly agreed upon via digital platforms (2) for different services, including food delivery or transportation. The gig job is a platform-based evolution of the "piece paid" job of the "80's, likewise transferring employers" economic risk-taking and responsibilities to individuals without a real reciprocal potential for gains in the form of increased pay or job security. Although there are generally empowering aspects of self-employment, including freedom of choosing gigs, the gig workers typically have little or no say on how much work is available. Under this kind of contracts, the work organization results in job instability, a risk of poor job quality and often low salaries (3). For these reasons, gig-workers represent a vulnerable population that is likely to be most exposed to stress.

Despite the difficulties in capturing these evolving work characteristics, there is evidence that the numbers of gig-workers are growing in U.S. and E.U. In 2016, Mc Kinsey (4) estimated that in U.S. 20–30% of the working-age population and the E.U. up to 162 million individuals, were engaged in some form of independent work, defined in the MC Kinsey report by: high degree of autonomy, payment by task, assignment, or sales and a short-term relationship between worker and client. In this generalization, the report included: "*free agents, who actively choose independent work and derive their primary income from it; casual earners, who use independent work for supplemental income and do so by choice; reluctants, who make their primary living from independent work but would prefer traditional jobs; and the financially strapped, who do supplemental independent work out of necessity.*" (4) In 2018, it was reported (5) that 36% of all the workers in the U.S. have alternative work arrangements and that by 2027, could increase up to 50% (6). In the U.K., between 2016 and 2019 numbers have doubled, while in Europe (7) 11% of the working population has performed some gig-work.

GIG-ECONOMY STUDIES STATE OF ART

We have only a very partial picture of the health effects of the gig economy on workers, as data on gig jobs are fragmentary and research on health effects has only begun. However, some patterns and profiles are emerging. Gig work may be more prevalent in urban settings and among young people and immigrants at phases of entering the labor force. In the UK (8–10) a report conducted among 2,184 online respondents, indicated that the majority of gig workers are London based; half of them are 18–34 years old with educational attainment similar to that of the whole population. Fourteen percentage of gig workers have worked for more than 2 years and 38% between 6 months and 2 years in the gig market system. Overall, individual satisfaction is correlated with their employment status, i.e., negatively correlated when the gig-work is the primary source of income (9) and positively otherwise. Differences among types of gig workers and across countries have been reported (11)

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and governmental policies implemented to safeguard gig-workers' rights vary substantially. What is evident, from a public health perspective, is that the flexibility of such jobs goes hand-in-hand with *existential instability* (i.e., narrowing other domains of life, hampering partnering and starting families with potential for other adversities in individual adult life course), which is exacerbated among those who rely entirely on "gigs" for their income.

The gig economy may involve high work stress such as "job strain" or "effort-reward imbalance" as well as job insecurity that has been shown to have adverse effects on health (12–14). In a pooled analysis (n = 124,808) (15) job strain, the most widely studied form of work stress was associated with an increased risk for type 2 diabetes (16) in men and women independently of lifestyle factors. A meta-analysis (17) of published and unpublished results found that coronary risk disease was associated with job strain dimensions of job demand and job content, and with an attributable population risk for job strain of 3.4%. Job strain was found to be significantly increasing the risk of death in men with a cardiometabolic disease (18), independently of conventional clinical risk and lifestyle factors. The study authors concluded that "targeting conventional risk factors is therefore unlikely to mitigate the mortality risk associated with job strain in this population" (18). In the effort-reward imbalance model, stress is generated by the recurrent experience of a failed reciprocity between the effort spent at work and the rewards received in turn, material and non-material. Dragano et al. (19) have found, using a multicohort study of 90,164 employed individuals, that the effort-reward imbalance at work is associated with an increased risk of coronary disease. Mutambudzi et al. (20) found an association between effort-reward imbalance with an increased risk of diabetes incidence for subjects that worked 55 or more hours per week and had no insurance coverage than those working in blue-collar jobs. Both associations were independent of job strain. Job insecurity and job loss and discontinuous employment have also been found to affect health outcomes.

Research in the "1970 British Cohort Study" (21) confirms that those who have experienced a job loss while aged between 30 and 42 years showed increased risks of diabetes and hypertension, that worsened in the presence of debts. In the U.S. (22), women in "piece rate" jobs self-reported more frequent adverse health outcomes than salaried female workers. Changes in employment history for individuals who were unemployed, ejected or in precarious occupational positions led to a higher risk of developing poor health conditions (23), in particular during the economic crisis between 2007 and 2012. While it is known that financial crises affect the health status of those without a permanent contract, job stress impacts workers in permanent positions too. Bruner et al. (24) found a dose-response relationship between work stress and risk of obesity among civil servants, while no association was found between job strain and an increased risk of obesity (25). The picture that emerges is that job-related sources of stress like job demand, job content, effort-reward imbalance, insecurity, job loss, and unemployment contribute in different and possibly independent ways to well-being.

THE ROLE OF BIOMARKERS

Recently, epidemiological studies have started to evaluate the role of biomarkers as both internal indicators (e.g., allostatic load) of the health status and predictors for adverse health outcomes.

According to WHO (26), a biomarker is "*any measurement reflecting an interaction between a biological system and a potential hazard, which may be chemical, physical, or biological. The measured response may be functional and physiological, biochemical at the cellular level, or a molecular interaction.*"

The allostatic load is defined "*as the cost of chronic exposure to fluctuating or heightened neural or neuroendocrine response resulting from repeated or chronic environmental challenge that an individual reacts to as being particularly stressful.*" (27) These indicators are useful because they allow to monitor and evaluate the health status before adverse health events occur. This characteristic makes them suitable in studies where the exposed population is relatively young, like gig workers.

Different types of biomarkers have been found associated with job characteristics, including work-related stress. In 2017, Siegrist and Li (28) summarized the literature findings, linking stressful work with a broad range of biomarkers. They found a robust association with heart rate variability, altered blood lipids, risk of metabolic syndrome, increased blood pressure, altered immune function, inflammation, and increased cortisol release. This study highlighted that altered biomarkers are involved in pathways associated with disadvantaged working conditions and stress-related conditions.

Economic insecurity has been investigated in the U.K. Household Longitudinal Study (29). Those who were consistently economically insecure (defined as a subjective measure of the perceived insecurity and inability to afford monthly expenses) had altered levels of high-density lipoprotein (HDL)-cholesterol, triglycerides, C reactive protein (CRP), fibrinogen and glycated hemoglobin, compared to the economically secure. The same dataset was used to compute the allostatic load, an indicator composed of 12 biomarkers representing multiple biological systems. The authors (30) compared the allostatic load for people who were unemployed with those recently re-employed. Results indicated that those who were re-employed and rated their job quality as poor (based on indicators including job anxiety, insecurity, dissatisfaction, and low pay) presented a higher allostatic load compared to the unemployment group. Different biomarkers have also been proven to play a role in the regulation of inflammatory and immune pathways, which, in turn, are associated with environmental stressors (31).

Besides clinical and blood-related biomarkers, newer epigenetic biomarkers, based on DNA methylation, have become available. Bakusic et al. (32) conducted a systematic review of human and animal studies on work stress, burnout and depression. They reported different methylation patterns of the brain-derived neurotrophic factor gene (*BDNF*) and increased global methylation in relation to aspects of mental health. This opens new avenues for estimating the role of gig economy in relation to epigenetic changes due to work stress factors.

Among epigenetic biomarkers, "epigenetic clocks" based on a combination of DNA methylation CpG sites rather than

single-gene sites, have been shown to be reliable and promising indicators of biological age. "Age acceleration" assessed through DNA methylation has been found to predict all-cause mortality, frailty, several physical functions, psycho-social stress (31) and cancer (33, 34). Epigenetic clocks have been suggested to behave as an intermediate biological mechanism linking environmental exposures (including socioeconomic position) and late-life poor health outcomes and mortality. Fiorito et al. (35) found that the effects of low socioeconomic position are detectable through epigenetic clocks, which mediate the socioeconomic position effects on aging, starting early in life. However, the traditional measures of socioeconomic position need to be further developed in order to adequately distinguish the gig workers from other types of self-employed and employed individuals and to be able to compare and untangle the peculiar gig working characteristics and the induced health effects.

DISCUSSION

With governments supporting little or no measures for workers in the gig economy, the future of these workers looks uncertain and their health at risk. The recent COVID-19 pandemic has significantly impacted the economy of an estimated 70% of gig-workers (36) worsening their already precarious situation. The gig-worker population is still quite young, hence hard health outcomes are less likely to be expected in the short term, except under extreme circumstances. Likewise, the fragmented nature of these jobs, with workers rosters not easily accessible and the difficult to detect health effects, make epidemiological studies challenging. We believe that future research should concentrate on these two main paths:

1. Research on developing DNA-based biomarkers as stable and consistent indicators.
2. Research to understand how interventions using moderators (e.g., primary source of income, government policies) can improve working conditions that will promote long-term health benefits.

A starting point for these investigations could be access to a national cohort that combines detailed job and employment history and health data assessment, including DNA assays. For example, in the United Kingdom, the U.K. Household Longitudinal Study and in Finland, the Northern Finland Birth Cohort (NFBC) in 1966 and 1986 collect work data and biological samples.

In conclusion, we suggest that focusing on the health effects among gig workers is of great public health relevance and that biomarker studies represent an important and viable approach to conducting epidemiological investigations of health outcomes in this young and highly unstable population. Such epidemiological information could better inform policies to design and implement preventive health measures.

AUTHOR CONTRIBUTIONS

AF-S drafted the paper. VS conducted the bibliography research. Both authors contributed to the final version.

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Third Follow-Up of the Study on Occupational Allergy Risks (SOLAR III) in Germany: Design, Methods, and Initial Data Analysis

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Introduction: Asthma and allergies are complex diseases affected by genetic and environmental factors, such as occupational and psychosocial factors, as well as interactions between them. Although childhood is a critical phase in the development of asthma and allergies, few cohort studies on occupational outcomes followed up participants from childhood onwards. We present design, methods, and initial data analysis for the third follow-up of SOLAR (Study on Occupational Allergy Risks), a prospective and population-based German asthma and allergy cohort.

Methods: The SOLAR cohort was initially recruited in 1995–1996 for Phase II of the German branch of the International Study of Asthma and Allergies in Childhood (ISAAC II) and followed up three times since, in 2002–2003, 2007–2009, and 2017–2018. During the third follow-up (SOLAR III), participants were between 29 and 34 years old. Since SOLAR focuses on occupational exposures, follow-ups were conducted at important points in time of the development of participants' career. To evaluate the potential of selection bias, responders and non-responders were compared based on variables from earlier study phases. In responders, frequency and pattern of missing values were examined and compared within the subsets of paper and online versions of the used questionnaires.

Results: In total, 1,359 participants completed the questionnaire of the third follow-up (47.3% of eligible participants). Initially, the cohort started with 6,399 participants from the ISAAC II questionnaire study. A selection process led to a study population that is more female, higher educated, smokes less and has a higher proportion of certain asthma and allergy symptoms (also in their parents) than the initial cohort. Pattern and frequency of missing values were different for paper and online questionnaires.

Discussion: The third follow-up of the SOLAR cohort offers the opportunity to analyze the course of asthma and allergies and their associations to environmental, occupational and psychosocial risk factors over more than 20 years from childhood to adulthood. Selection processes within the cohort might lead to bias that needs to be considered in future analyses.

Keywords: asthma, occupational asthma, atopic dermatitis, rhinitis, epidemiological methods, cohort study

INTRODUCTION

Asthma and allergies are complex diseases affected by environmental and genetic factors as well as interactions between them (1, 2). In addition, different phenotypes of asthma have been established, based for example on the time of onset. One important type of adult-onset asthma is work-related asthma, which is associated with workplace exposures (3). So far only few cohort studies on occupational outcomes follow up participants from childhood onwards. Nevertheless, the inclusion of childhood is important since it is a critical phase in the development of asthma and allergies and because childhood symptoms might affect later job choices (4). To investigate the course of asthma and allergies from childhood to adulthood elucidating especially the role of occupational risk factors, the SOLAR study (Study on Occupational Allergy Risks) was established based on the German part of the International Study of Asthma and Allergies in Childhood Phase II (ISAAC II). Three follow-up studies have been conducted since, with a total follow-up time of more than 20 years.

The third follow-up of the Study on Occupational Allergy Risks (SOLAR III) aims to:

- further investigate the course of asthma and allergies from childhood to adulthood;
- continue the collection of data on occupational, environmental and psychosocial risk factors and investigate associations with asthma and allergies;
- study risk factors in relation to participants' age.

This article presents design and methods of SOLAR III and reports processes and results from its initial data analysis (IDA). IDA is an essential part of the study process within the conduction of observational studies. It connects data collection and analysis including the set-up of metadata, data cleaning, and data screening. IDA is necessary to obtain an analyzable data set and to identify aspects that influence interpretation and future analyses (5).

METHODS

Study Design

The SOLAR cohort was initially recruited in 1995–1996 for Phase II of the German branch of the International Study of Asthma and Allergies in Childhood (ISAAC II). ISAAC II aimed to find potential determinants for asthma and allergy occurrence and severity around the world (6). For this, community-based random samples of children aged 9–11 years were drawn in the two study centers Munich and Dresden. An additional goal of the German branch was to investigate differences in asthma and allergies between east (Dresden) and west (Munich) of the recently reunified Germany (7). In total, 7,498 children were invited to participate and fill in a questionnaire. For both study centers, 6,399 children and their parents participated (85.3%). A random subset of children (n = 4,018) was also invited to clinical examinations including spirometry, tests for bronchial hyperresponsiveness using nebulized hypertonic saline, skin prick tests, specific IgE tests in blood serum, and standardized skin examinations.

In 2002–2003, the first phase of SOLAR (SOLAR I) followed-up the initial German ISAAC II cohort. Of 4,893 invited adolescents aged 16–18 years who could be re-contacted, 3,785 (77.4%) completed the questionnaire and agreed to link the data with the information from ISAAC II. Additionally, 3,053 participants (62.4%) agreed to be re-contacted for subsequent studies. In 2007–2009, 2,051 participants (70.6% of the eligible 2,904 participants) aged 19–24 years filled in the questionnaire for the second follow-up (SOLAR II). SOLAR II also included clinical examinations, comprising e.g., physical examinations, skin prick tests, and spirometry (8).

All participants who agreed to be re-contacted in SOLAR I and for whom either an e-mail or postal address was available were invited to complete a questionnaire for the third follow-up (SOLAR III), which means that cohort members were also asked to participate in SOLAR III if they did not participate in SOLAR II without actively refusing re-contact. No clinical examinations were conducted in the third follow-up. During the field phase in 2017–2018, the participants were between 29 and 34 years old. In total, 1,359 participants completed the questionnaire (**Figure 1**).

All study phases were approved by the Ethical Committees of the Medical Faculty of the University of Dresden and the Bavarian Chamber of Physicians. Written informed consent, also for linking data from all study phases, was obtained from all participants (SOLAR I to III) and their legal guardians (ISAAC II, SOLAR I).

Questionnaire Instruments

The SOLAR III questionnaire (121 items) included validated questions on:

- socio-demographics (six items)

Abbreviations: ETS, Environmental tobacco smoke; IDA, Initial data analysis; ISAAC, International Study of Asthma and Allergies in Childhood; ISCO, International Standard Classification of Occupations; JEM, Job-exposure-matrix; PA, Physical activity; SES, Socio-economic status; SOLAR, Study on Occupational Allergy Risks; TICS, Trier Inventory of the Assessment of Chronic Stress.

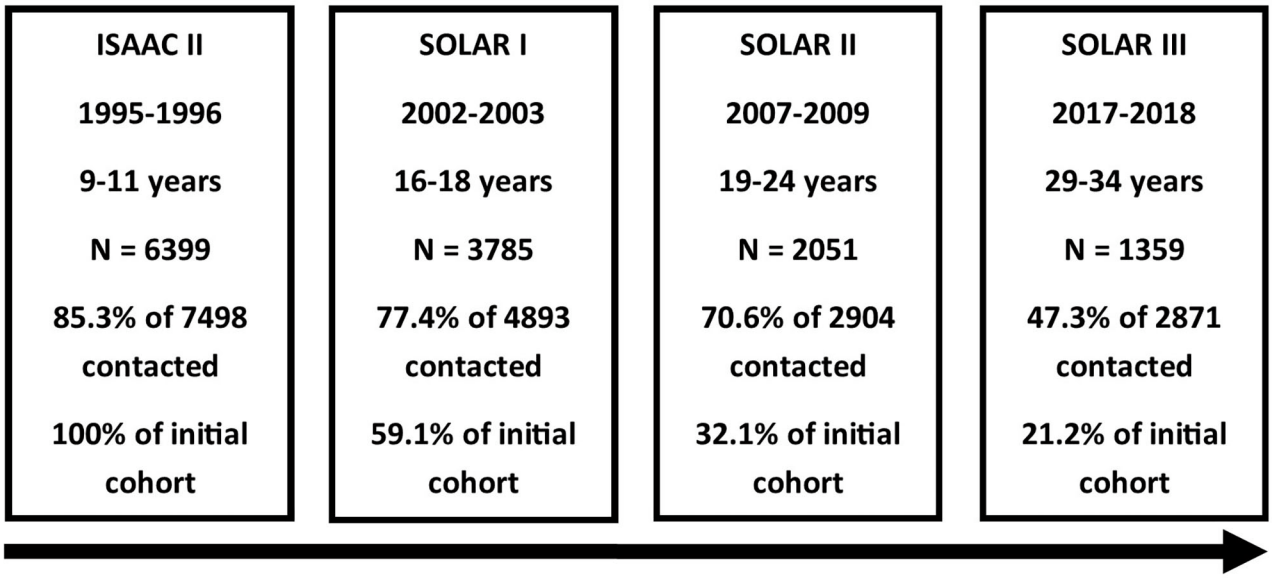

FIGURE 1 | Flowchart of the SOLAR study phases. From top to bottom: study phase, time period of data collection, age of participants, number of participants, response based on number of invited participants, and proportion of ISAAC II cohort remaining.

- respiratory symptoms and disease (including asthma and wheeze) (15 items)
- rhinoconjunctivitis and hay fever (7 items)
- atopic dermatitis and hand eczema (13 items)
- domestic exposures, use of skin care products, use of disinfectants (14 items)
- smoking, exposure to environmental tobacco smoke (13 items)
- occupation (19 items)
  - level of education and job type
  - job history for all jobs held for at least 1 month and for at least 8 h a week
  - occupational diseases and risk factors
- physical activity and use of entertainment electronics (5 items)
- body height and weight (2 items)
- use of oral contraceptives, number of pregnancies (3 items)
- depression (PHQ-2) (2 items) (9)
- work-related stress [TICS (Trier Inventory of the Assessment of Chronic Stress)] (22 items) (10, 11).

Throughout the study phases, the same questions on respiratory symptoms and disease as well as on atopic dermatitis and hand eczema were used. Those questions were originally in English and translated with back-translation into German for ISAAC (6). Questions on exposures and other variables were also kept as similar as possible throughout the study phases and came for example from the ECRHS (12) and the GA^{2}LEN survey (13). Compared to the second follow-up, questions on water pipe and electronic cigarette use (water pipe questions were modified for electronic cigarettes) (14), discrimination and harassment at work (15), working conditions (16), and depression screening (9) were added in SOLAR III. Questions on job choice, accidents involving steam, gas, or smoke, state of residence, glove material, and frequency of washing hands that were still in the second follow-up questionnaire were left out in phase III. Some questions on symptoms of asthma and rhinitis were no longer kept either in order to keep the length of the questionnaire acceptable for participants. Removed questions were either not relevant anymore because of participants' age or had many missing values in earlier study phases. The questionnaire used is available as **Supplementary Material**.

After assessment of face validity, the content validity of the newly added questions were evaluated in a pre-test. The seven pre-test participants were sampled based on convenience and were of both genders, between 27 and 35 years old, and had low to high level of education to represent the demographic characteristics of participants (17). They were no participants of ISAAC or SOLAR and were asked to explain the presented questions to the investigator. In case of difficulties understanding the meaning of the questions, the questionnaire was revised accordingly before the pilot study.

We additionally offered the possibility to complete the questionnaire online. The open source software LimeSurvey (LimeSurvey GmbH, Hamburg, Germany) was used for setting up the online version. The survey was hosted on servers of the University Hospital, LMU Munich (Munich, Germany) to ensure data protection.

Recruitment Methods

A pilot study including 25 participants from each study center indicated that the planned recruitment processes (e-mail and mail) worked out well. Participants for whom an e-mail address was available were contacted via e-mail with study information and were invited to fill in the online questionnaire. The

remaining participants received a letter including the paper questionnaire, an informed consent form, study information, and an envelope for sending the questionnaire back free of charge. In order to ensure written informed consent as requested by the data protection representative, all participants of the online questionnaire had to print-out and send-in the signed written consent form by fax, e-mail, or postal mail. Participants were reminded twice, firstly 1 week after the initial contact and secondly one (e-mail) or two (mail) weeks later. Letters were sent out on Thursdays and, e-mails on Fridays to ensure that participants received the questionnaire toward the weekend. Because a substantial proportion of participants already had children, school holidays were avoided for the contact phase. As an incentive, participants who completed the questionnaire had the chance of winning one of ten 200€ shopping vouchers.

When e-mail addresses were invalid or e-mail invitations remained unanswered, the participants were re-contacted via postal mail. When postal addresses were outdated, the local population registries were asked for the current address. Additionally, participants without informed consent form (mainly online participation, 85.8% in study center Munich and 98.4% in Dresden) were reminded via postal mail and, if no response was registered after 21 days, by telephone. The letter contained a ready-to-sign consent form and a post-paid envelope. Thereby, 92.0% (Munich) and 83.5% (Dresden) of the missing forms were received.

Data Processing and Cleaning

Paper questionnaires were entered manually by two independent staff members. Differences between both entries were compared to the paper questionnaire and changed accordingly. Every change was documented to assure the possibility of replication. Concordant entries were assumed correct. Missing values were coded either "missing" or "not applicable" depending on what applied.

Plausibility checks were conducted to obtain a dataset as error-free as possible. Questions filtering subsequent questions were checked for plausible values. If plain text answers contained options that were selectable in the corresponding single or multiple-choice questions, these options were assigned.

Job histories were coded manually by two independent staff members according to the International Standard Classification of Occupations 88 (ISCO-88) classification (18). Afterwards, differing codes were compared in an expert re-evaluation step. Exposure to potential occupational risk factors for asthma and allergies was assessed by linking exposure profiles from the asthma-specific job-exposure-matrix (JEM) by Le Moual and colleagues (19) with the ISCO-88 codes.

All steps of crude data processing and cleaning were documented either in R software (20) scripts, tables, or the data dictionary. This ensures that the cleaned, final dataset can be reproduced from the original variables.

Data Screening and Evaluation of Selection Bias

In order to identify relevant aspects that influence interpretation and future analysis (5), frequency and pattern of missing values were examined and compared within the subsets of answers given by paper and online questionnaires.

To evaluate the potential of selection bias, responders and non-responders were compared in two different ways: First, all SOLAR III responders were compared with ISAAC II participants not responding in SOLAR III with regard to sex, parental history of asthma, parental history of asthma or allergies, and parental socio-economic status (SES). These variables were measured in ISAAC II. Second, all SOLAR III responders were compared with SOLAR I participants not responding in SOLAR III in terms of the outcomes 12-months prevalence of wheezing, asthma, allergic rhinitis, and atopic dermatitis, life-time prevalence of doctor diagnosed asthma, participants own SES, smoking, physical activity (PA), work-related stress, and occupational exposure to potential occupational risk factors for asthma and allergies measured at SOLAR I. SOLAR I results were considered rather than SOLAR II results as they included a larger number of SOLAR III non-respondents.

Parental history of asthma was defined as present if at least one parent reported ever having had asthma. Parental history of asthma or allergies was defined as present if at least one parent reported ever having had asthma, hay fever, or dermatitis. Parental as well as participant's SES were considered high for 12 or more years of education (for at least one parent for parental SES). Twelve-months prevalence of asthma was defined as symptoms of wheezing within the last 12 months prior to the survey and a doctor diagnosis of asthma or multiple doctor diagnoses of asthmatic bronchitis (7). Twelve-months prevalence of allergic rhinitis was defined as having problems with sneezing or a runny blocked nose without having a cold during the last 12 months that were accompanied by itchy-watery eyes. Twelve-months prevalence of atopic dermatitis was defined as ever having had eczema for at least 6 months with symptoms during the 12 months prior to study and the itchy rash at any time affecting any of the following places: the folds of the elbows, behind the knees, in front of the ankles, in the face, or around the neck (21). Participants were defined as smokers if they smoked at least 20 packs in their life or at least one cigarette per day or one cigar per week for 1 year (22). PA was classified as no PA (never doing physical exercise), low PA (physical exercise between less than once a month and once a week), and high PA (physical exercise more than once a week). Work-related stress was measured by the TICS (10, 11). The items of two scales, work overload and work discontent, were summed up separately and translated to an age-specific T-value. For each scale, a binary variable was created which was defined as positive if the T-value and its 95% confidence interval exceeded the value of 50 (10). Occupational exposure to potential occupational risk factors for asthma and allergies was defined as present if the participant ever had a job that was linked to a relevant exposure by an asthma-specific job-exposure-matrix (23).

RESULTS

Response

In total, 3,053 participants, who agreed to be re-contacted in the first follow-up, were asked to participate in the SOLAR III study (**Table 1**). Of those, 153 could not be contacted because of missing e-mail and postal addresses, 15 had died, and 14 had actively refused to be re-contacted. Of the remaining 2,871 SOLAR I participants, 1,359 answered the questionnaire (47% of the eligible sample). Response was considerably higher in the study center Dresden (56%) compared to Munich (39%). Of the 1,359 participants in SOLAR III, 216 had not participated in SOLAR II (22% of SOLAR II non-responders).

Non-participation

A higher proportion of SOLAR III participants was female (61 vs. 47%) and had a high parental SES (59 vs. 46%) compared to ISAAC II participants not participating in SOLAR III (**Table 2**). While no difference was found for parental history of asthma, a higher proportion of SOLAR III participants had parents with a history of asthma or allergies (46 vs. 39%).

Compared to SOLAR I participants not participating in SOLAR III, participants' SES was also higher at SOLAR I (60 vs. 44%). In addition, during SOLAR I, SOLAR III participants were more likely to report symptoms of atopic dermatitis than SOLAR I participants not responding in SOLAR III (11 vs. 8%), and less likely to be ever smokers (29 vs. 38%). No differences were seen for the other variables under study (**Table 3**).

Missing Data Pattern

In the total SOLAR III dataset, 3% of values were missing. Questions with the highest proportion of missing values were on environmental tobacco smoke (ETS) (11%), quitting jobs because of symptoms of asthma or allergies (6%), doctor diagnosis of respiratory outcomes (6%), skin-straining activities at home, including cleaning without gloves, construction or renovation, gardening or farming, or other tasks that could be straining for the skin due to wet conditions, chemicals or other factors (6%), wheezing (6%) or symptoms of rhinoconjunctivitis (5%) due to an occupation, and duration of glove use (5%).

Generally speaking, online questionnaires had lower proportions of missing values in the first half of the questionnaire, while paper questionnaires had lower proportions of missing values in the second half (**Figure 2**). Questions with the highest difference in the proportions of missing values were on wheezing (9%-points) or symptoms of rhinoconjunctivitis (8%-points) due to an occupation, use of gloves (8%-points), including duration (8%-points), declaration of occupational disease, including its reason (8%-points), with a lower proportion of missing values for paper questionnaires, and on ETS (6%-points) and indoor mold (6%-points) with a lower proportion of missing values for online questionnaires.

TABLE 1 | Participation in the SOLAR study phases.

	Total *n* (%)	Munich *n* (%)	Dresden *n* (%)
ISAAC Phase II (Questionnaire study)	6,399 (85.3)[a]	3,354 (87.6)	3,045 (83.0)
SOLAR I	3,785 (77.4)[b]	2,043 (81.5)	1,742 (73.0)
Agreed to be re-contacted	3,053 (80.7)	1,534 (75.1)	1,519 (87.2)
SOLAR II	2,051 (70.6)[c]	1,008 (69.6)	1,043 (71.1)
SOLAR III			
Contacted	3,053 (100.0)	1,534 (100.0)	1,519 (100.0)
Lost participants	182 (6.0)	46 (3.0)	136 (9.0)
No valid address available	153 (5.0)	33 (2.2)	120 (7.9)
Deceased	15 (0.5)	6 (0.4)	9 (0.6)
Participant refused further contact	14 (0.5)	7 (0.5)	7 (0.5)
Eligible sample	2,871 (94.0)	1,488 (97.0)	1,383 (91.0)
Response	1,359 (47.3)[d]	585 (39.3)	774 (56.0)
of these			
Participation in SOLAR II	1,143 (84.1)	496 (84.8)	647 (83.6)
No participation in SOLAR II	216 (15.9)	89 (15.2)	127 (16.4)
Online questionnaire	787 (57.9)	323 (55.2)	464 (59.9)
Paper questionnaire	572 (42.1)	262 (44.8)	310 (40.1)

[a] *6,399 of 7,498 invited children.*
[b] *3,785 of 4,893 invited adolescents who could be re-contacted.*
[c] *2,051 of 2,904 invited adults who could be re-contacted.*
[d] *1,359 of 2,871 eligible participants.*

DISCUSSION

We present design, methods, and results from the initial data analysis for the third follow-up of a German prospective and population-based asthma and allergy cohort. SOLAR started with the German ISAAC II participants in two study centers. We followed this cohort for more than 20 years from elementary school until the early thirties. The follow-ups were placed at important points in time of the participant's career: around the transition from school to work or university, around the transition from university to work, and after being settled in working life. Because of the long follow-up time, the study offers the opportunity to link (occupational) information from adulthood to data from childhood.

In the presented follow-up, no clinical examinations were feasible. Although examinations might decrease errors for example in asthma measurement, it would have negatively affected the feasibility of the study and probably also the willingness of cohort members to further participate. In addition to the initial examination in the ISAAC II study phase, an examination was conducted in the second follow-up when participants had already reached adulthood. Back then, only 40% of the eligible study population participated in the clinical part (8). Because validated questions were used throughout the study, we came to the conclusion that accuracy is maximized best by focusing on reaching a high response in the questionnaire study.

Many cohort studies investigating work-related asthma recruited workers from a specific occupation to investigate effects of a certain exposure. Often these cohorts had a few hundred participants and were followed for a time period between a few months and several years (24). Usually, eligible workers were either already exposed for a certain time or enrolled at the beginning of their job. To focus on new and therefore unexposed

TABLE 2 | Non-responder-analysis comparing all SOLAR III participants to ISAAC II participants not responding in SOLAR III based on baseline data.

	Responders SOLAR III *N* = 1,359		**ISAAC II participants not responding in SOLAR III *N* = 5,040**	
	Available responses *n* (%)	**% (95%-CI)**	**Available responses *n* (%)**	**% (95%-CI)**
Female	1,359 (100.0)	60.5 (57.9–63.1)	5,036 (99.9)	46.5 (45.1–47.9)
Parental history of asthma[a]	1,243 (91.5)	9.5 (7.9–11.1)	4,466 (88.6)	9.9 (9.0–10.8)
Parental history of asthma or allergies[b]	1,346 (99.0)	46.0 (43.3–48.7)	4,932 (97.9)	39.3 (37.9–40.7)
Parental SES (high)[c]	1,338 (98.5)	59.3 (56.7–61.9)	4,789 (95.0)	45.8 (44.4–47.2)

[a] *At least one parent reported ever having had asthma.*
[b] *At least one parent reported ever having had asthma or hay fever or dermatitis.*
[c] *12 or more years of education for at least one parent.*

TABLE 3 | Non-responder-analysis comparing all SOLAR III participants to SOLAR I participants not responding in SOLAR III based on SOLAR I characteristics.

	Responders SOLAR III *N* = 1,359		**SOLAR I participants not responding in SOLAR III *N* = 2,570[a]**	
	Available responses *n* (%)	**% (95%-CI)**	**Available responses *n* (%)**	**% (95%-CI)**
Symptoms of wheezing within the last 12 months	1,354 (99.6)	14.7 (12.8–16.6)	2,547 (99.1)	15.0 (13.6–16.4)
Doctor diagnosis of asthma	1,334 (98.2)	7.2 (5.8–8.6)	2,515 (97.9)	8.1 (7.0–9.2)
12-months prevalence of asthma[b]	1,346 (99.0)	4.2 (3.1–5.3)	2,534 (98.6)	5.2 (4.3–6.1)
12-months prevalence of allergic rhinitis[c]	1,342 (98.7)	22.4 (20.2–24.6)	2,529 (98.4)	22.1 (20.5–23.7)
12-months prevalence of atopic dermatitis[d]	1,345 (99.0)	10.9 (9.2–12.6)	2,529 (98.4)	7.6 (6.6–8.6)
Participant's SES (high)[e]	1,351 (99.4)	59.5 (56.9–62.1)	2,548 (99.1)	44.1 (42.2–46.0)
Smoking[f]	1,346 (99.0)	29.1 (26.7–31.5)	2,546 (99.1)	37.9 (36.0–39.8)
Physical activity (high)[g]	1,353 (99.6)	50.3 (47.6–53.0)	2,554 (99.4)	48.9 (47.0–50.8)
Physical activity (low)[h]		44.3 (41.7–46.9)		42.2 (40.3–44.1)
Work overload[i]	1,348 (99.2)	27.7 (25.3–30.1)	2,516 (97.9)	25.7 (24.0–27.4)
Work discontent[i]	1,347 (99.1)	46.2 (43.5–48.9)	2,516 (97.9)	49.2 (47.2–51.2)
Exposure to any potential occupational risk factors for asthma and allergies[j]	1,335 (98.2)	14.2 (12.3–16.1)	2,450 (95.3)	13.8 (12.4–15.2)

[a] *The analysis for this table is based on all 3,929 SOLAR I participants including those, who did not give consent for linking the data to data from other study phases.*
[b] *Symptoms of wheezing within the last 12 months and a doctor diagnosis of asthma or multiple doctor diagnoses of asthmatic bronchitis.*
[c] *Having problems with sneezing or a runny blocked nose without having a cold during the last 12 months that were accompanied by itchy-watery eyes.*
[d] *Ever having had eczema for at least 6 months with symptoms during the 12 months prior to study and the itchy rash at any time affecting any of the following places: the folds of the elbows; behind the knees; in front of the ankles; under the buttocks; or around the neck, ears, or eyes.*
[e] *12 or more years of education.*
[f] *Smoked at least 20 packs in their life or for a year at least one cigarette per day or one cigar per week.*
[g] *Physical exercise more than once a week.*
[h] *Physical exercise between less than once a month and once a week.*
[i] *Age-specific T-value of item sum of corresponding scale and its 95% confidence interval exceeded the value of 50.*
[j] *Ever having had a job that was linked to a relevant exposure by an asthma-specific job-exposure-matrix.*

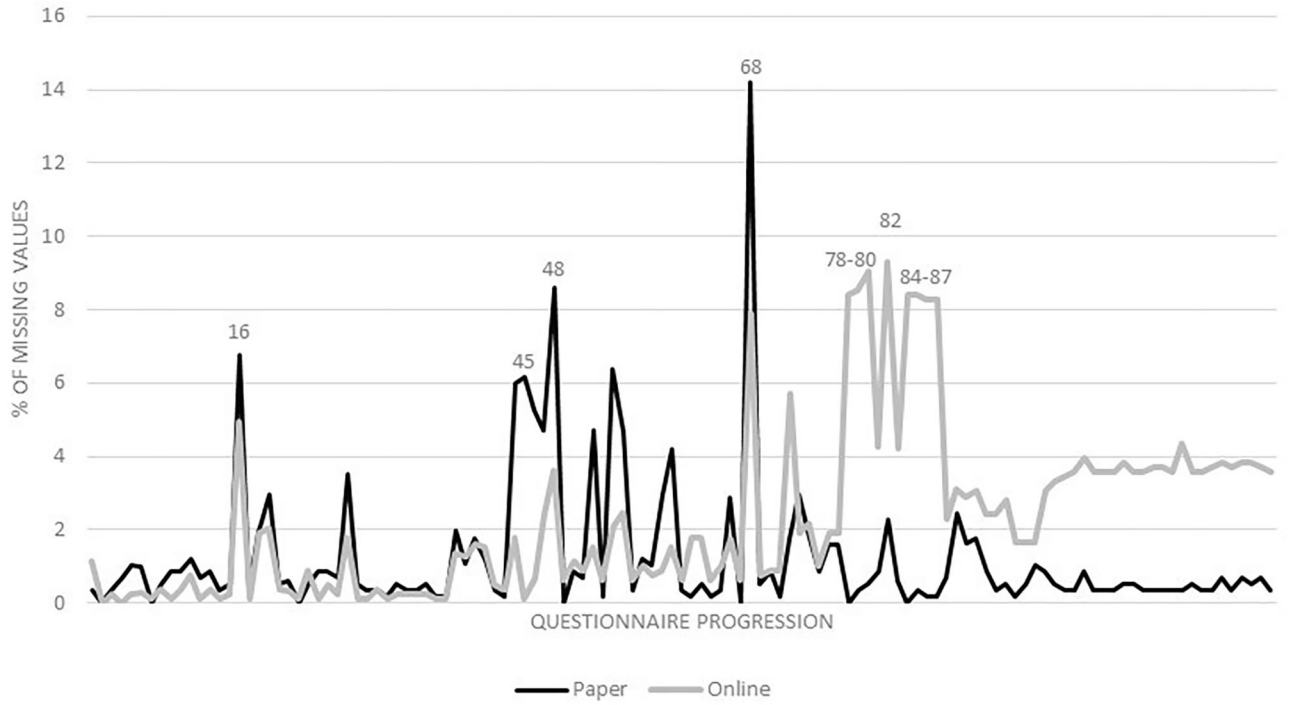

FIGURE 2 | Percentage of missing values for paper and online questionnaires from first to last questionnaire item. Question numbers: 16: doctor diagnosis of respiratory outcomes; 45: indoor mold; 48: skin-straining activities at home; 68: ETS; 78–79: symptoms of rhinoconjunctivitis due to an occupation; 80: wheezing due to an occupation; 82: quitting jobs because of symptoms of asthma or allergies; 84: use of gloves; 85: duration of glove use; 86: declaration of occupational disease; 87: reason of declaration of occupational disease.

workers, some cohorts recruited apprentices and followed them during their training (25). Other cohorts focused on estimating asthma incidences attributable to workplace exposures (26, 27). In contrast to the mentioned studies, SOLAR tries to investigate the course of asthma and allergies, including work-related phenotypes, from childhood to adulthood.

Although the initial cohort was population-based, a selection process led to a study population that is more female, higher educated, smokes less, and has a higher proportion of people with atopic dermatitis at the end of childhood. The proportion of participants with at least one parent that reported ever having had asthma, hay fever, or dermatitis was increased as well. The selection process was already present in earlier follow-ups (8). In the initial ISAAC cohort, however, participants and non-participants of clinical examinations were similar regarding atopic diseases in children and parents, parental education, family size, passive smoke exposure, and sex (28). Regarding the 1,099 invited children that didn't participate at all, no information on potential selection was available. It implies the potential of selection bias that needs to be considered carefully in analyses of follow-up data. Depending on the research question, the available information will be used to obtain less biased results, e.g., by adjusting estimates or multiply imputing missing values.

Since the cohort underwent a selection process over the years of follow-up, the generalizability of the study's results might be limited if selection bias affects the internal validity of the study. However, since the study's goal is the investigation of associations between occupational, environmental, and psychosocial exposures and asthma and allergy outcomes, this selection process does not affect the generalization of results on the basic association to other populations as long as the internal validity is not substantially affected. Nevertheless, asthma and allergies are complex diseases for which reason associations might vary for different genotypes, age groups and exposure histories. Therefore, genetic background and age of participants as well as environmental factors that might interact need to be considered when generalizing the results of the SOLAR study to other populations. After all, comparisons of future results to other cohorts is necessary for drawing conclusions about associations.

A strength of the SOLAR study is its still relatively high sample size after more than two decades of follow-up. This response could be reached using several methods to increase participation, including incentives, e-mail, postal, and telephone reminders as well as envelopes for returning study documents free of charge. Since e-mail addresses were collected in earlier study phases for a substantial part of the cohort, a valid postal address was not necessary for reaching these participants. An online version of the questionnaire was used to simplify participation for individuals with known e-mail addresses. One drawback of the online version was the difficulty to get informed consent, since it was necessary for the participants to conduct an extra step of

printing and sending the signed consent form. The number of missing forms and therefore of excluded questionnaires could be reduced substantially by sending out postal reminders, which made it necessary to get a valid postal address for some of the participants with known e-mail addresses after all.

The questions with higher proportions of missing values in the subset of online questionnaires mentioned earlier were all asked in the second half of the questionnaire. This might indicate that some participants quit before finishing and that 121 items are therefore too many for an online questionnaire. An alternative explanation for these differences might be that the questionnaire was too long in general and that we just received more incomplete online questionnaires than incomplete paper questionnaires as those were not sent-in.

In general, the online questionnaire was a good addition, because including logical links that made it possible to skip questions that were not applicable, and making it mandatory for continuing to answer certain questions, led to less missing values than in the paper version for most questions in the first half of the questionnaire. Apart from that, the use of online questionnaires saved time (of participants and the research team) and money for sending invitations and data entry. Although the proportion of missing values is not too high in total, multiple imputation methods should be used to limit potential biases. The information on the type of questionnaire (paper vs. online) should be included in the imputation process since it is a potential cause or correlate of missingness (29).

In conclusion, the third follow-up of the SOLAR cohort offers the opportunity to analyze the course and risk factors of asthma and allergies over more than 20 years from childhood to adulthood. The focus on the occupational environment, including the participants' full job histories, makes it possible to investigate occupational exposures in particular. The use of online questionnaires contributed to the feasibility of conducting a third follow-up and still yielding an adequate size of the study population. However, selection processes within the cohort might lead to sources of bias that need to be considered in future analyses.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because of data protection reasons. Requests to access the datasets should be directed to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Ethical Committees of the Medical Faculty of the University of Dresden (EK 163042015) and the Bavarian Chamber of Physicians (mb BO 17015). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

FF drafted the manuscript. Data acquisition was coordinated by FF, SK, and LW. Data was interpreted by FF, JG, and KR. CV, JG, LW, TW, KR, DN, BS, EM, SK, and FF contributed substantially to the conception and design of the study. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2021.591717/full#supplementary-material

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Gender Differences in Job Satisfaction and Work-Life Balance Among Chinese Physicians in Tertiary Public Hospitals

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Background: Gender has been associated with job-related experience, including job satisfaction and work-life balance. This study aimed to identify gender differences in job satisfaction and work-life balance among Chinese physicians in a large, nationally representative sample.

Methods: A national cross-sectional survey was conducted between March 18 and 31, 2019, using an anonymous online questionnaire. The questionnaire included the short-form MSQ (Chinese version) and a work-life balance item. The demographic and job-related factors were also collected.

Findings: In total, 22,128 physicians (9,378 males and 12,750 females) from 144 tertiary public hospitals completed the survey. The overall MSQ score (job satisfaction) was 70.31 ± 12.67, and it was 69.89 ± 13.24 in males, and 70.63 ± 12.22 in females, respectively ($p < 0.001$). Only 931 (4.21%) physicians were very satisfied with WLB (421 males, 510 females), and 2,534 (11.45%) were rated as satisfied. Age, education, monthly income, working hours, specialty, and professional titles were significantly associated with job satisfaction; while number of children, specialty, professional titles, monthly income, age, working hours were significantly associated with WLB. No significant gender differences were observed in job satisfaction or WLB after controlling confounding factors (both $p > 0.05$).

Interpretation: While many demographic and work-related factors are significantly associated with job satisfaction and WLB, we found no significant gender differences, which is different from many other studies. To improve Chinese physicians' job satisfaction and work-life balance, interventions should be focused on certain specialties and on other modifiable factors, such as income, working hours.

Keywords: job satisfaction, work-life balance, gender difference, hospitals, China

INTRODUCTION

Job satisfaction can be defined as the attitudes resulting from one's job experience (1, 2). Previous studies have identified a series of factors associated with physicians' job satisfaction, such as age, gender, marital status, professional title, and educational background etc (3–9). Many studies have examined gender differences of job satisfaction in physicians. While some did not find significant gender differences (10–15), and a few other studies even found the opposite, that male physician reported higher job satisfaction (16, 17).

Work-life balance (WLB) is a common concept with no universally accepted definition. It can be roughly defined as the state of equilibrium degree of how a person equally prioritizes the demands of his/her career and the needs of his/her personal life, with a minimum role conflict at work and at home life (18). A good WLB improves job satisfaction, psychosocial well-being, and overall quality of life (19, 20). On the contrary, a work-life imbalance (bad WLB) often leads to psychological strain, lower life and job satisfaction, depression, burnout, and family conflict, and other health problems (21–25).

Gender is associated with many job-related factors, and the relationship between gender and WLB has recently attracted much interest. As gender refers to the culturally defined roles and responsibilities in given settings, traditional gender roles prescribe different emphases for men and women: work for men and family responsibility for women (26). Although gender systems could be equitable, gender inequality in WLB have often been reported in past decades. Many studies showed that gender differences existed in job satisfaction with medical practice. In most cultures, especially Asian cultures, female workers are expected to share more household responsibilities than their male counterparts. They are more likely to reach the "glass ceiling" of career (27, 28). A series of studies demonstrated that gender plays a vital role in WLB (29–33).

In the healthcare field, several previous studies investigated gender difference in WLB, but got inconsistent results (34–39). One study showed that WLB varied significantly among healthcare specialties, length of work time and work settings (18). The situation also understandably varies across different cultures, and some believe this situation may be worse in Eastern countries due to the long history of sexism (40). However, there have been few studies examining gender differences in WLB among Chinese physicians. Therefore, this study aimed to investigate gender differences in physicians' job satisfaction and WLB in Chinese tertiary public hospitals.

DATA AND METHODS

Study Design and Samples

The study was a part of a national survey conducted in 2019, the China National Healthcare Improvement Initiative Survey (41). The National Health Commission of China approved and sponsored this survey. The project was completed between March 18 to 31, 2019. We purposely involved 144 tertiary public hospitals in the capital cities of each province in mainland China, including 59 general hospitals, 37 Traditional Chinese Medicine (TCM) hospitals, 33 maternal and children's hospitals, five stomatological hospitals, four cancer hospitals, and six other specialty hospitals. These hospitals accounted for 6.45% of all the tertiary hospitals, delivered 12.28% of the inpatient care among tertiary hospitals, 10.90% of all physicians in tertiary hospitals (42). In the Chinese healthcare system, tertiary hospitals play a critical role.

Based on their employee's ID codes on the hospital staff lists, physicians were sampled through a systematic sampling method in each participating hospital. We invited 170 physicians from each hospital to participate. The survey was conducted anonymously through WeChat, a widely used online social media application in China.

Ethics Statement

The Ethics Committee (IEC) of the Emergency General Hospital in Beijing approved the study protocol. All participated physicians signed the informed consent before they proceeded to respond to the questionnaires. The informed consent statement explained the purpose of the survey, ensured that the data would be de-identified before analysis and that the hospitals' administrators would have no access to their responses.

Measures

The online questionnaire collected their demographic information, including gender, age, marital status, number of children, educational level, department (specialty), professional title, average monthly income, average working hours per week, hospital type, and location (geographical region).

Job satisfaction was measured through the short version of the Minnesota Satisfaction Questionnaire (MSQ) (Chinese version), which has been widely used and has demonstrated good reliability and validity (43, 44). Work-life balance was measured using the following question: "How are you satisfied with the balance of your work and your family?" (30, 36). They were used as the outcome measure in this study.

The items for MSQ and WLB were 5-point Likert scale responses: very dissatisfied-1, dissatisfied-2, neither-3, satisfied-4, and very satisfied-5. The responses for WLB were dichotomized into two groups: Dissatisfied WLB (very dissatisfied/dissatisfied) and non-Dissatisfied WLB (neither/satisfied/very satisfied).

Statistical Analysis

Descriptive analyses were conducted for the variables. Continuous variables were shown with mean and standard deviation, while categorical variables were shown with numbers and percentages. Ages, average working hours per week, MSQ scores were treated as continuous variables. Ages, average working hours between male and female physicians were tested by ANOVA. Chi-square tests were used to examine other characteristics.

As the physicians were nested in 144 hospitals, the null model demonstrated that the intra-class correlation was more than

TABLE 1 | Characteristics of physicians in tertiary public hospitals.

Characteristic	Total ($N = 22128$)		Male ($N = 9378$)		Female ($N = 12750$)		Statistics	
	N	%	*N*	%	*N*	%	χ^2	*p*
Marital status							111.164	**<0.001**
Single	3244	14.66	1135	12.10	2109	16.54		
Married	18261	82.52	8033	85.66	10228	80.22		
Divorced or widowed	623	2.82	210	2.24	413	3.24		
Children							185.063	**<0.001**
None	5822	26.31	2111	22.51	3711	29.11		
One	12782	57.76	5489	58.53	7293	57.20		
More than one	3524	15.93	1778	18.96	1746	13.69		
Educational level*							206.736	**<0.001**
Bachelor degree or below	5628	25.43	2256	24.06	3372	26.45		
Master's degree	10440	47.18	4084	43.55	6356	49.85		
Doctorate degree	6060	27.39	3038	32.39	3022	23.70		
Department/Specialty							2.6e+03	**<0.001**
Internal medicine	6576	29.72	2369	25.26	4207	33.00		
Surgery	7281	32.90	4582	48.86	2699	21.17		
Ob/Gyn**	3099	14.00	368	3.92	2731	21.42		
Pediatrics	2229	10.07	760	8.10	1469	11.52		
Emergency	1030	4.65	431	4.60	599	4.70		
Miscellaneous others***	1913	8.65	868	9.26	1045	8.20		
Professional title							188.044	**<0.001**
Junior	6247	28.23	2266	24.16	3981	31.22		
Middle	8202	37.07	3445	36.73	4757	37.31		
Associate senior	4889	22.09	2359	25.15	2530	19.84		
Senior	2790	12.61	1308	14.82	1482	11.62		
Average monthly income							173.051	**<0.001**
<5000 RMB	5917	26.74	2267	24.17	3650	28.63		
5000–9999 RMB	6252	28.25	2468	26.32	3784	29.68		
10,000–20,000 RMB	7290	32.94	3264	34.80	4026	31.58		
>20,000 RMB	2669	12.06	1379	14.70	1290	10.12		
Hospital type							638.724	**<0.001**
General hospitals	8865	40.06	4373	46.63	4492	35.23		
TCM general hospitals	6098	27.56	2829	30.17	3269	25.64		
Specialty hospitals	7165	32.38	2176	23.20	4989	39.13		
Location/Region							17.443	**<0.001**
East China	9553	43.17	4128	44.02	5425	42.55		
Central China	5240	23.68	2285	24.37	2955	23.18		
West China	7335	33.15	2965	31.62	4370	34.27		
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	***T***	***p***
Age (years)	37.94	8.13	38.86	8.15	37.27	8.05	14.516	**<0.001**
Working hours/week	55.85	15.10	57.31	15.68	54.77	14.56	12.466	**<0.001**

**In China, medical school graduates are awarded with a bachelor degree of medicine (similar to the European and Russian systems). Some obtained a master's or doctorate degree in addition to their medical degree.*

***Ob/Gyn: obstetrics-gynecology.*

****Including oncology department, rehabilitation department, reproductive health department, geriatrics department, etc.*

Bold value for $p < 0.05$.

10%, so we used multi-level linear and logistic regression models to examine gender differences in MSQ and WLB, respectively (45). Participants with missing data were rare (<1%) and were excluded from the analyses.

All statistical analyses were conducted using the statistical software Stata 15 (StataCorpLP, College Station, TX, USA). All statistical analysis tests were two-sided, and the statistical significance was defined as $p < 0.05$.

RESULTS

Description of Sample Characteristics and Related Factors

In total, 24,480 physicians were invited to participate, and 22,416 responded (response rate = 91.57%). After removing 288 participants with incomplete data, data from 22,128 physicians (22128/22416, 98.72%) were included in the final analysis. Their socio-demographic and job-related characteristics are shown in **Table 1**. There were 9,378 male (42.4%) and 12,750 (57.6%) female physicians. The average weekly working hours were 55.85 ± 15.10 h in this sample. The gender differences in demographic factors (age, marriage status, number of children, education), work-related factors (specialty, professional title, income, hospital type, working-hours, and regions) were all significant (**Table 1**).

The MSQ score was 70.31 ± 12.67 overall, and 69.89 ± 13.24 in male physicians, 70.63 ± 12.22 in female physicians, respectively ($p < 0.001$). Univariate analysis demonstrated that all other demographic factors (age, marriage status, number of children, education) and work-related factors (specialty, professional title, income, hospital type, working-hours, and regions) were significantly associated with MSQ scores (**Table 2**).

In the multi-level linear regression analysis model, we found that physicians with doctorate degrees, in Ob/Gyn and "Miscellaneous departments" (which included oncology department, rehabilitation department, reproductive department, geriatrics department, etc.), with senior professional titles, with a monthly income of more than 10,000 RMBs, in specialty hospitals, had higher MSQ scores, with middle and associate senior professional titles, elder, longer working hours were significantly associated with lower MSQ scores. Although there was a trend that female physicians had a little higher MSQ scores than males, it was not statistically significant ($p = 0.057$) (**Table 3**).

In the whole sample, only 931 (4.21%) physicians were very satisfied with WLB (421 males, 510 females), 2,534 (11.45%) rated as satisfied (1,030 males and 1,504 females), 8,140 (36.79%) rated as neither satisfied nor dissatisfied (3,295 males and 4,845 females), 6,288 (28.42%) as dissatisfied (2,624 males and 3,664 females), 4,235 (19.14%) as very dissatisfied (2,008 males and 2,227 females). In short words, only 15.70% of physicians were satisfied or very satisfied with their WLB.

After regrouping the reported WLB into a categorical variable, 10,523 (47.56%) were classified as dissatisfied with WLB and 11,605 (52.44%) as non-dissatisfied with WLB. Among them, 49.39% of male and 46.20% of female physicians were classified as dissatisfied WLB, respectively ($p < 0.001$). All other demographic and work-related factors were significantly associated with WLB in univariate analysis (details see **Table 4**).

In the multi-level logistic regression model, we found physicians with one (OR = 1.52) or more than one child (OR = 1.77), middle (OR = 1.36) or associate senior professional title (OR = 1.35), monthly income of 5,000–9,999 RMBs (OR = 1.10), longer working hours/week (OR = 1.06) were more likely to have dissatisfied WLB. While physicians in surgery (OR = 0.85) or "Miscellaneous departments" (OR = 0.80), older (OR = 0.99) were less likely to have dissatisfied WLB. Similar to the analysis with job satisfaction, we failed to observe significant gender differences in WLB after controlling for confounding factors (**Table 5**).

DISCUSSION

To our best knowledge, this study was among the first studies focusing on gender differences in job satisfaction and WLB based on a nationally representative physician sample in China, covering a wide range in terms of specialty, hospital types, and geographical regions. While we replicated some of the findings reported by others, one unique finding is that no significant gender differences were found in physician job satisfaction and WLB.

Gender differences are a longstanding phenomenon and an important research topic, in which job satisfaction and WLB are two aspects that have gained research attention in recent years. Job satisfaction describes the level of contentment and fulfillment that employees derive from their jobs. Studies suggested that different job expectations, values and many other factors may contribute to the differences in job satisfaction between men and women (17). In the healthcare field, studies of WLB have mostly centered on "role" and the conflicts between work and family as the main sources of poor WLB. The society often has double expectations for women, this is particularly true in China, where most people believe in the traditional sex role assignment. On one side, women are expected to perform well in their career; on the other side, they are also expected to be a "good wife and good mother" and take most household responsibilities. Therefore, career women often suffer more conflicts between work and family and bad WLB (Shui et al., 2020). To add to the problem, most career women in China work full time.

Our finding that there was no significant association between gender and job satisfaction is in line with several previous reports involving different samples from several countries. For example, the surveys of 2,584 Canadian physicians (10), of 248 American obstetrician/gynecologists (11), and of other physician samples (12–15), no significant gender differences were found in job satisfaction. In the meantime, some studies have found significant gender differences. For example, Saperstein et al. surveyed 186 Navy family physicians with one self-developed item, and found that males had more positive job satisfaction (16). While in 1,472 doctors from rural areas in West China, the authors reported that female doctors had better job satisfaction than males, based on a self-developed questionnaire (17).

In our study, only 4.21% of the participants were very satisfied with WLB, and 11.45% were satisfied; both were much lower than that reported in other studies. For example, Starmer et al. showed that 17% American pediatricians were very satisfied with their WLB (39); another survey demonstrated that 10.6% US physicians were strongly satisfied and 30.3% satisfied (36); Streu et al. found that 52% U.S. plastic surgeons were satisfied with their WLB (35). The considerable gap suggests much improvement is needed. To improve the status, hospital administrations and policymakers should pay more attention to the job-related risk factors and target risk subgroups, such as surgeons and physicians working in the "miscellaneous

TABLE 2 | Univariate analysis of MSQ.

Characteristic	Total ($N = 22128$) Mean	SD	Statistics F/T	p
Gender			18.25	**<0.001**
Male	69.89	13.24		
Female	70.63	12.22		
Marital status			4.43	**0.012**
Single	70.54	12.55		
Married	70.32	12.67		
Divorced or widowed	68.89	13.19		
Children			4.83	**0.008**
None	70.67	12.44		
One	70.09	12.66		
More than one	70.53	13.06		
Educational level			61.33	**<0.001**
Bachelor degree or below	69.18	12.56		
Master's degree	70.12	12.62		
Doctorate degree	71.71	12.73		
Department/specialty			13.61	**<0.001**
Internal medicine	69.50	12.44		
Surgery	70.26	12.79		
Ob/Gyn	71.62	13.13		
Pediatrics	70.32	12.27		
Emergency	70.45	12.73		
Miscellaneous	71.12	12.47		
Professional title			55.49	**<0.001**
Junior	71.23	12.79		
Middle	69.61	12.59		
Associate senior	69.19	12.52		
Senior	72.31	12.55		
Average monthly income			152.87	**<0.001**
<5000 RMB	68.91	12.44		
5000–9999 RMB	68.90	12.47		
10,000–20,000 RMB	71.22	12.54		
>20,000 RMB	74.28	12.91		
Hospital type			121.05	**<0.001**
General hospitals	69.39	12.34		
TCM general hospitals	69.41	12.31		
Specialty Hospitals	72.22	13.15		
Location/region			64.02	**<0.001**
East China	71.05	12.48		
Central China	70.88	13.12		
West China	68.95	12.48		

	Correlation coefficient	p
Age (years)	−0.0208	**0.002**
Working hours/week	−0.2057	**<0.001**

Bold value for p<0.05.

departments" (including oncology, reproductive departments, etc.), those with middle or associate senior professional titles, and those with lower-income, and longer working hours.

TABLE 3 | Multi-level linear regression examining factors associated with MSQ.

	Coef.	95.0% CI (Lower)	95.0% CI (Upper)	p
Gender (ref. Male)	0.32	−0.01	0.65	0.057
Marital status (ref. Single)				
Married	0.42	−0.17	1.01	0.162
Divorced or widowed	−0.74	−1.79	0.32	0.170
Children(ref. None) One	−0.34	−0.85	0.17	0.193
More than one	−0.14	−0.75	0.47	0.650
Educational level (ref. Bachelor's degree or below)				
Master's degree	0.31	−0.11	0.73	0.143
Doctorate degree	1.18	0.65	1.72	**<0.001**
Department(ref. internal medicine)				
Surgery	0.26	−0.16	0.68	0.225
Ob/Gyn	0.60	0.01	1.18	**0.046**
Pediatrics	0.27	−0.31	0.86	0.353
Emergency	0.39	−0.37	1.15	0.314
Miscellaneous	1.17	0.58	1.76	**<0.001**
Professional title (ref. Junior)				
Middle	−1.60	−2.05	−1.15	**<0.001**
Associate senior	−1.43	−2.08	−0.77	**<0.001**
Senior	1.88	0.98	2.78	**<0.001**
Average monthly income (ref. <5000 RMB)				
5000–9999 RMB	−0.13	−0.54	0.29	0.547
10,000–20,000 RMB	1.41	0.99	1.84	**<0.001**
>20,000 RMB	3.17	2.55	3.79	**<0.001**
Hospital type (ref. General hospitals)				
TCM general hospitals	0.01	−1.85	1.86	0.993
Specialty Hospitals	1.82	0.08	3.56	**0.040**
Location(ref. East China)				
Central China	1.00	−0.87	2.87	0.293
West China	−0.17	−1.90	1.56	0.847
Age	−0.14	−0.18	−0.11	**<0.001**
Working hours/week	−0.15	−0.16	−0.14	**<0.001**

Bold value for $p < 0.05$.

Furthermore, our finding of no significant gender difference in WLB, from a large sample of Chinese physicians, is also different from most studies in physicians. Literature review shows that four surveys in the U.S. found that female physicians had a significantly lower WLB than male physicians (34–39). Two other U.S. studies found no significant gender difference in physician WLB. In a survey of 127 American faculty surgeons, Baptiste et al. found that there was no significant gender difference in the overall work life balance (mean 2.6 for female vs. 2.9 for male, $p = 0.3$) (37). Similarly, in a sample of 433 physicians in South Dakota, 54.7% of male physicians and 55.4% female physicians were satisfied with their WLB, without significant gender difference (37). Although no gender differences were found in this study, the moderating role of gender in the relationship between organizational behaviors and outcomes should be examined in the future.

Cultural factors, social policies and role expectations have been found to be associated with work-life balance (46, 47).

TABLE 4 | Univariate analysis of WLB.

	Not bad WLB (11605)		Bad WLB (10523)		Statistics	
Characteristic	***N***	**%**	***N***	**%**	χ^2	***p***
Gender					22.02	**<0.001**
Male	4746	50.61	4632	49.39		
Female	6859	53.80	5891	46.20		
Marital status					22.53	**<0.001**
Single	1826	56.29	1418	43.71		
Married	9455	51.78	8806	48.22		
Divorced or widowed	324	52.01	299	47.99		
Children					100.16	**<0.001**
None	3322	57.06	2500	42.94		
One	6643	51.97	6139	48.03		
More than one	1640	46.54	1884	53.46		
Educational level					38.27	**<0.001**
Bachelor degree or below	3147	55.92	2481	44.08		
Master's degree	5393	51.66	5047	48.34		
Doctorate degree	3065	50.58	2995	49.42		
Department					71.43	**<0.001**
Internal Medicine	3284	49.94	3292	50.06		
Surgery	3940	54.11	3341	45.89		
Ob/Gyn	1582	51.05	1517	48.95		
Pediatrics	1096	49.17	1133	50.83		
Emergency	593	57.57	437	42.43		
Miscellaneous	1110	58.02	803	41.98		
Professional title					139.98	**<0.001**
Junior	3506	56.12	2741	43.88		
Middle	3972	48.43	4230	51.57		
Associate senior	2482	50.77	2407	49.23		
Senior	1645	58.96	1145	41.04		
Average monthly income					17.83	**<0.001**
<5,000 RMB	3119	52.71	2798	47.29		
5,000–9,999 RMB	3188	50.99	3064	49.01		
10,000–20,000 RMB	3808	52.24	3482	47.76		
>20,000 RMB	1490	55.83	1179	44.17		
Hospital type					90.93	**<0.001**
General hospitals	4306	48.57	4559	51.43		
TCM general hospitals	3315	54.36	2783	45.64		
Specialty Hospitals	3984	55.60	3181	44.40		
Location					65.14	**<0.001**
East China	5251	54.97	4302	45.03		
Central China	2778	53.02	2462	46.98		
West China	3576	48.75	3759	51.25		
	Mean	**SD**	**Mean**	**SD**	***T***	***p***
Age(years)	38.25	8.70	37.61	7.44	5.85	**<0.001**
Working hours/week	50.98	12.91	61.21	15.51	53.50	**<0.001**

Bold value for p<0.05.

The fact that we did not observe significant gender differences in this sample could also mean more gender equity in family responsibilities in China, especially among married physicians.

TABLE 5 | Multi-level Logistic regression examining factors associated with WLB (Dissatisfied WLB vs. non-Dissatisfied WLB).

	OR	95.0% CI (Lower)	95.0% CI (Upper)	*p*
Gender (ref. Male)	0.98	0.92	1.04	0.520
Marriage status (ref. Single)				
Married	0.92	0.82	1.03	0.149
Divorced or widowed	1.05	0.86	1.29	0.627
Children(ref. None)				
One	1.52	1.38	1.68	**<0.001**
More than one	1.77	1.57	1.99	**<0.001**
Educational level (ref. Bachelor degree or below)				
Master's degree	1.05	0.96	1.14	0.279
Doctorate degree	1.10	0.99	1.21	0.079
Department (ref. Internal Medicine)				
Surgery	0.85	0.79	0.93	**<0.001**
Ob/Gyn	0.99	0.89	1.11	0.897
Pediatrics	1.11	0.99	1.24	0.082
Emergency	0.97	0.84	1.13	0.732
Miscellaneous	0.80	0.72	0.90	**<0.001**
Professional title (ref. Junior)				
Middle	1.36	1.24	1.48	**<0.001**
Associate senior	1.35	1.19	1.53	**<0.001**
Senior	1.10	0.93	1.31	0.265
Average monthly income(ref. <5000 RMB)				
5,000–9,999 RMB	1.10	1.01	1.19	**0.026**
10,000–20,000 RMB	1.08	0.99	1.17	0.073
>20,000 RMB	1.00	0.88	1.12	0.951
Hospital type(ref. General hospitals)				
TCM general hospitals	0.91	0.75	1.10	0.326
Specialty hospitals	0.90	0.75	1.08	0.268
Location(ref. East China)				
Central China	0.88	0.73	1.07	0.213
West China	1.10	0.91	1.31	0.327
Age (years)	0.99	0.98	1.00	**0.015**
Working hours/week	1.06	1.05	1.06	**<0.001**

Bold value for $p < 0.05$.
Dissatisfied WLB was defined as 1 and non-Dissatisfied WLB as 0.

As suggested by some authors, the rapid economic growth and social progress have pushed more gender equity in employment opportunities and career development (48, 49).

Several limitations about our study need to be mentioned. First, as in all cross-sectional studies, the causal relationship of different factors cannot be established. Second, the participating hospitals were tertiary public hospitals, which often mean they have more cases and also more resources than lower-level hospitals, so the results may not be generalized to all hospitals. Third, although we have some data about the participants' marital status and number of children, we did not collect other important data on their home or personal life, such as the time they spent taking care of chores or other home responsibilities, time for pleasure and relaxation, and these factors are likely associated with WLB (50). Finally, the WLB in our survey was measured by a single item instead of a standardized instrument, which may be limited in reliability and validity.

CONCLUSIONS

In conclusion, while we found that many demographic and job-related factors are significantly associated with job satisfaction and work-life balance, we did not find significant gender differences in either of the assessments between male and female physicians in China, which is different from many other studies. To improve physicians' job satisfaction and WLB in China, interventions should focus on certain specialties and on modifiable factors, such as work hours and income.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by The Ethics Committee (IEC) of the Emergency General Hospital in Beijing approved the study protocol. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

DL, YW, FJ, MW, YL, and Y-LT: conceptualization. YW: data curation and investigation. FJ: data analysis. YL: funding acquisition. FJ and Y-LT: methodology. DL: wrote an original draft. DL, YL, and Y-LT: wrote revision & editing. All authors contributed to the article and approved the submitted version.

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BRIEF RESEARCH REPORT
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Musculoskeletal Disorders in Portuguese Welders: Effects on Bodily Pain and Health-Related Quality of Life

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Background: Musculoskeletal disorders in welders may influence their health-related quality of life. However, few studies have addressed this issue and their results were inconclusive. This study investigates whether there are musculoskeletal disorders with a higher incidence in welders compared to non-welders, and whether these disorders lead to an increase in bodily pain which in turn decreases their health-related quality of life.

Methods: *A priori* analyses of statistical power were conducted to determine the sample size needed to find medium to large statistical effects, for a 0.05 alpha, and critical sampling, combined with snowball sampling, was carried out. The study was cross-sectional, and participants were asked to respond to a survey using validated instruments ($N_{welders} = 40$, $N_{non-welders} = 42$).

Results: As expected, a higher incidence of symptoms of musculoskeletal disorders in the cervical, dorsal, lumbar, and wrists and hands was found in welders in comparison to non-welders. Furthermore, the presence of musculoskeletal disorders, particularly in the lumbar area, was related to an increased bodily pain and decreased health-related quality of life.

Conclusion: Welders are exposed to a higher incidence of musculoskeletal disorders that decrease their quality of life. It is essential to increase the awareness of welders, organizations, and regulatory institutions toward this issue in order to motivate the development and implementation of prevention strategies. The need for primary and secondary prevention-type strategies, which have already proven their effectiveness in the context of welding, is highlighted.

Keywords: bodily pain, lumbar, quality of life, musculoskeletal disorders, welding

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INTRODUCTION

Welders comprise a large occupational group that works for long hours in forced postures. The welding activities often imply that the workers remain statically, in the same posture, for long periods of time. It is often carried out by hand, requiring work in various positions, angles, and rotations to ensure high standards of product quality in accordance with the ISO standards. Maintaining an awkward posture can lead to work-related musculoskeletal disorders [e.g., (1–3)].

Musculoskeletal disorders represent a problem not only for the individual, but also for the organization and society. At a European level, the occurrence of musculoskeletal and connective tissue disorders represented over 17 million euros of losses in production (i.e., costs of lost production based on labor costs) in 2016 and more than 30 billion euros in the gross added value loss (i.e., loss of labor productivity) (4). To improve the quality of life of these individuals, as well as the sustainability of organizations and social security systems, it is essential to continuously assess and understand to what extent these professional activities and challenges influence the health-related quality of life of welders and to further invest in prevention strategies.

A substantial body of studies indicates that musculoskeletal disorders are associated with welding activities. For example, welders, in general, and professional divers working as welders have an increased risk of musculoskeletal complaints that are related to heavy physical demands at work (5). A study in the UK calculated the standardized incidence rate ratios for construction workers using work-related ill-health cases for individual job titles returned to The Health and Occupation Reporting network by clinical specialists and UK population denominators (6). A significant increase in the incidence of work-related ill-health cases was found, compared with other workers in the same major Standard Occupational Classification (i.e., workers with similar levels of qualifications, training, skills, and experience) for many conditions, including musculoskeletal disorders in welders.

Studies are not always consistent with the areas indicated as more prone to musculoskeletal disorders. For instance, a study conducted in Sweden comparing welders to office clerks and fishermen illustrated that welders have more musculoskeletal disorders overall, but particularly in the shoulder, using both self-reported data and objective signs of musculoskeletal disorders (2). In Iran, a study using self-reported data illustrated that 88% of the welders had musculoskeletal problems, predominantly on the knees, neck, and back (3). Another study in Iran illustrated that arc welders had significantly more musculoskeletal problems on the neck and wrists/hands regions than gas welders (7). In Shanghai, a study comparing welders to non-dust workers using self-reported measures indicated that welders have a more pronounced discomfort on their cervical vertebra and low back pain (8). These different results demonstrate the need for further research, as well as the need to consider the effects of anthropometric differences between countries.

The World Health Organization (WHO) defines health as a state of physical, mental, and social well-being, and not just the absence of disease or infirmity. Likewise, quality of life is the individual's perception of their position in life, according to their culture and value systems, taking into consideration their objectives, expectations, and concerns (9). The interest in the concept of quality of life in the health area is relatively recent and emerges from the new paradigms that have influenced practices and policies in the health sector in the last decades. Knowing an individual's own perception of health-related quality of life has become an important component of health surveillance, generally considered as a valid indicator for measuring care needs and monitoring the outcome of interventions [e.g., (8)]. Few studies have focused on the impacts of welding on the health-related quality of life. A cross-sectional study in the UK compared professional divers who had worked as a welder, professional welders who had not dived, and offshore oil field workers who had neither dived nor welded, but no differences were found in their physical quality of life. However, in the study conducted in Shanghai, authors found that the health-related quality of life was significantly worse in welders compared to non-dust workers (8). The authors suggest this difference occurred because the instrument they used to measure the health-related quality of life is commonly used and probably has a higher validity, namely the 36-item Short Form Health Survey, SF-36 (10). Of relevance for the present study, bodily pain was one of the dimensions that was significantly worse in welders (8).

This study had two main goals. The first was to analyze the musculoskeletal impacts of welding in Portuguese welders, comparing with a general population sample with similar sociodemographic characteristics. We expected to find a higher incidence of symptoms of musculoskeletal disorders among welders (Hypothesis 1). The second was to understand if the musculoskeletal disorders influenced the health-related quality of life due to bodily pain. To the best of our knowledge, this has not been analyzed in previous studies. We expected that musculoskeletal disorders with a higher incidence in welders decreased their health-related quality of life given that musculoskeletal disorders increase bodily pain (Hypothesis 2).

MATERIALS AND METHODS

Sample Determination

A priori analyses of statistical power were carried out to determine the adequate sample size for a 0.05 alpha using the GPower software (11). To test Hypothesis 1, the total sample required for a chi-square test was 145 participants to find a medium effect and 52 participants to find a large effect (welders and not welders). To test Hypothesis 2, the total sample required for a linear regression model with two predictors was 107 welders to find a medium effect and 48 welders to find a large effect. Therefore, we defined that the minimum sample size would be 48 welders and 48 non-welders. A critical sampling process of welders was conducted, combined with snowball sampling, to recruit Portuguese welders and afterwards, to recruit a sample of non-welders with similar sociodemographic characteristics. Due to the ongoing pandemic, data collection was forced stop at 40 welders and 42 non-welders. To compensate, bootstrapping was used to test Hypothesis 2 given that this technique has a relatively more power to detect smaller statistical effects.

Participants and Procedure

Forty welders and 42 non-welders employed by multiple Portuguese organizations read the informed consent and agreed to participate in the study. Critical and snowball sampling procedures were used to gather the sample: welding industries were initially identified then the welders were contacted by email and social media networks, and they were kindly asked to forward the study to other welders after responding to the survey. Most welders were male (95.0%), aged between 30 and 40 years old

(40.0%), had a medium level education (97.5%), and technical training in welding (72.5%). They were mostly employed in (a) manufacturing industries (35.0%), (b) wholesale and retail trade; repair of motor vehicles and motorcycles (30.0%), and (c) electricity, gas, steam, hot and cold water, and cold air industries (22.5%).

The sample of non-welders was recruited online in various internet groups. We sought to recruit a sample of non-welders with similar sociodemographic characteristics. Therefore, the admission criteria for the non-welders were the following: an active worker, male, between 30 and 40 years old, and has a medium level of education. As a result, all non-welders were male and aged between 30 and 40 years old. However, only 83.3% had a medium level of education, with 16.7% indicating to have a higher-level education, most likely because they were completing their education at the time of the study. The study data was collected between February and October 2020.

Measures

The survey for welders was composed of three sections: musculoskeletal disorders, bodily pain, and health-related quality of life. The survey for non-welders measured only the musculoskeletal disorders.

Musculoskeletal Disorders

A Portuguese version (12) of the Dutch Musculoskeletal Questionnaire (13) was used to identify which areas were most affected due to musculoskeletal disorders. To facilitate the identification of the anatomical zones, the questionnaire included a body diagram, highlighting the body regions, and participants were asked to mark which areas they felt discomfort, on a dichotomic scale of *yes* or *no*.

Bodily Pain

The bodily pain dimension of SF-36 (10, 14) was used to measure the intensity of the bodily pain and its effect on daily life ($\alpha = 0.69$). It is composed of two items (e.g., *"During the last 4 weeks, how the pain has interfered with your normal work")*, which participants responded on a scale that ranged from *1*, *absolutely nothing*, to *5*, *immensely*.

Health-Related Quality of Life

Health-related quality of life was measured using the SF-36 (10, 14). In this study, we used the following dimensions: physical function, social function, physical performance, and general health. To reduce the length of the questionnaire, we opted not use all the items of the survey as our aim was to use a composite measure of the health-related quality of life, not to study its dimensions. The physical function dimension (10 items) refers to the individual's ability to perform daily tasks, studying the impact of perceived limitations on the quality of life [e.g., "*Does your health now limit you in these activities (e.g., Lifting or carrying groceries)? If so, how much?"], with a* response scale ranging from *1*, *Yes, limited a lot*, to *5*, *No, not limited at all.* The original response scale that ranged from 1 to 3 was adapted for this purpose so that all scales had the same range. The social function (one item) evaluates the amount and level of difficulty to carry out the usual social activities ("*During the past 4 weeks, to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbors, or groups*?"), with a response scale ranging from *1*, *not at all*, to *5*, *extremely*. Physical performance (four items) assesses the limitation on the physical health to perform daily or professional tasks [e.g.,, "*During the past 4 weeks, have you had any of the following problems (e.g., accomplished less than you would like) with your work or other regular daily activities as a result of your physical health*?], with a response scale ranging from *1*, *yes*, or *2*. General health (five items) rates the overall health consciousness of the individual (e.g., "*In general, would you say your health is*"), with a response scale ranging from *1, excellent*, to *5*, *fair*. A composite measure of the health-related quality of life was created and revealed an adequate level of internal consistency ($\alpha = 0.85$).

The summary of participants and procedure is presented in **Table 1**.

TABLE 1 | Summary of participants and procedure.

Description	Sample	
	Welder ($N = 40$)	**Non-welder ($N = 42$)**
Sociodemographic		
Male	95%	100%
Age between 30 and 40	40%	100%
Medium level of education	97.5%	83.3%
Survey measures		
Musculoskeletal disorders	Yes	Yes
Bodily pain	Yes	No
Health-Related Quality of Life	Yes	No

RESULTS

Musculoskeletal Disorders: Comparisons Between Welders and Non-welders

The qui-square test was used to compare the frequency of musculoskeletal disorders between welders and non-welders. As predicted, a higher incidence of symptoms of musculoskeletal of disorders was found in welders (Hypothesis 1). In particular, data shows that there is a higher incidence of musculoskeletal disorders in the cervical [$\chi^2 = (1, N = 82) = 19.90$, $p > 0.001$; $\phi = 0.493$], lumbar [$\chi^2 = (1, N = 82) = 3.95$, $p = 0.047$, $\phi = 0.220$], dorsal [$\chi^2 = (1, N = 82) = 14.58$, $p < 0.001$, $\phi = 0.422$], and in the wrists and hands [$\chi^2 = (1, N = 82) = 7.74$, $p = 0.005$, $\phi = 0.307$] areas. Among non-welders, there was no incidence of musculoskeletal disorders in any body areas. To control for possible age effects, we further ran the Cochran–Mantel–Haenszel test, distinguishing among the participants below and above 35 years old. The same trend of results emerged. The percentage of welders and non-welders that reported musculoskeletal disorders in those areas is presented in **Figure 1**.

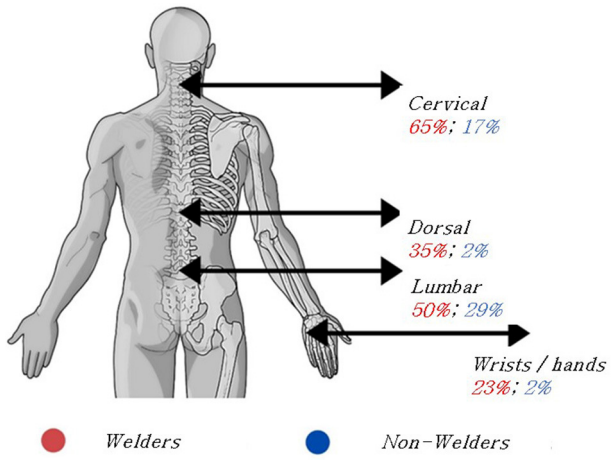

FIGURE 1 | Percentage of incidence of symptoms of musculoskeletal disorders in the areas that were significantly different between welders and non-welders.

Effects of Musculoskeletal Disorders on the Health-Related Quality of Life of Welders, Mediated by Bodily Pain

In average, welders showed a medium level of bodily pain (*Mean* = 3.30, *Standard Deviation* = 1.30) and health-related quality of life (*Mean* = 3.30, *Standard Deviation* = 1.30; both scales ranged between 1 and 5). Most welders reported having two musculoskeletal disorders (35%). To further explore these results, we first calculated the Pearson coefficient to estimate the correlation between quantitative variables and the point-biserial coefficient to estimate the correlation between quantitative and dichotomous variables (i.e., musculoskeletal disorders). The matrix of correlations between variables is presented in **Table 2**. Only musculoskeletal disorders in the lumbar area were significantly related to higher levels of bodily pain. Bodily pain was very strongly related to a lower health-related quality of life. All musculoskeletal disorders, with the exception of the dorsal area, were related to a significantly lower perception of quality of life.

It was expected that musculoskeletal disorders in welders would cause bodily pain which, in turn, would decrease their health-related quality of life, that is, bodily pain would mediate the relation between musculoskeletal disorders and health-related quality of life in welders (Hypothesis 2). To test the mediation model, we used the bootstrapping method, as it has a relatively higher power for detecting smaller effects. In specific, we used the PROCESS macro for SPSS version 3.5 (15), which is based on the ordinary least square regression and path analysis. The number of bootstrap samples for the percentile bootstrap confidence intervals was 5,000.

The bodily pain was entered as a mediator of the relation between the musculoskeletal disorders in welders (independent variable) and their health-related quality of life (dependent variable). We ran four separate models using as independent variables the musculoskeletal disorders in the cervical, dorsal, lumbar, and in the hands and wrists areas. Hypothesis 2 was partially corroborated. As it was to be expected from the matrix of correlations, we only found a mediation effect of bodily pain on the relation between the incidence of musculoskeletal disorders and health-related quality of life for the lumbar area. In particular, the mediation model explained 54% of the variance of health-related quality of life, $F(2,37) = 21.59$, $p < 0.001$. The indirect effect of bodily pain on the relation between musculoskeletal disorders in the lumbar area and health-related quality of life was significant, −0.55, 95% CI [−0.89, −0.22].

TABLE 2 | Correlation between musculoskeletal disorders, bodily pain, and health-related quality of life.

Variable	1	2	3	4	5	6
1. MD cervical	-					
2. MD dorsal	−0.12	-				
3. MD lumbar	0.21	0.42**	-			
4. MD wrists/hands	0.14	−0.02	0.18	-		
5. Bodily pain	0.27	0.14	0.47**	0.14	-	
6. Quality of life	−0.35*	−0.11	−0.43**	−0.31*	−0.73***	-

*MD, musculoskeletal disorders; *p < 0.050; **p < 0.010; ***p < 0.001.*

To explore the potential cumulative effects of musculoskeletal disorders in all areas, we computed a new measure that aggregated all musculoskeletal disorders except the lumbar area (cervical, dorsal, and wrists and hands). This new variable varied between 0 (absence of musculoskeletal disorders) and 1 (presence of musculoskeletal disorders in all three areas). A model entering the aggregated measure as an independent variable significantly explained 58% of the variance of health-related quality of life, $F(2,37) = 25.20$, $p < 0.001$. The indirect effect of bodily pain on the relation between the musculoskeletal disorders in all areas, except the lumbar area, and health-related quality of life was significant and slightly higher than the effect obtained in the previous model, −0.69, 95% CI [−1.31, −0.01].

This suggests that the musculoskeletal disorder that has more impact on the health-related quality of life due to the effect of bodily pain is located in the lumbar area. However, when considering the cumulative effects of musculoskeletal disorders in the cervical, dorsal, and wrists and hands areas, these were also related to an increase of bodily pain and have a very negative impact on the health-related quality of life. The results of the two mediation models are presented in **Figure 2**. Of relevance, the relation between musculoskeletal disorders in the cervical, dorsal, and wrists and hands areas and quality of life was only partially mediated by bodily pain. When the mediator is considered in the model, the relation remained significant, though its strength is significantly diminished (from −1.45 to −0.76). This suggests that the other variables that were not considered can further explain the relation between musculoskeletal disorders in those three areas and health-related quality of life.

DISCUSSION

Welders are exposed to multiple occupational hazards in their workplaces. However, only a few studies have been addressing their health status and quality of life. This study contributes

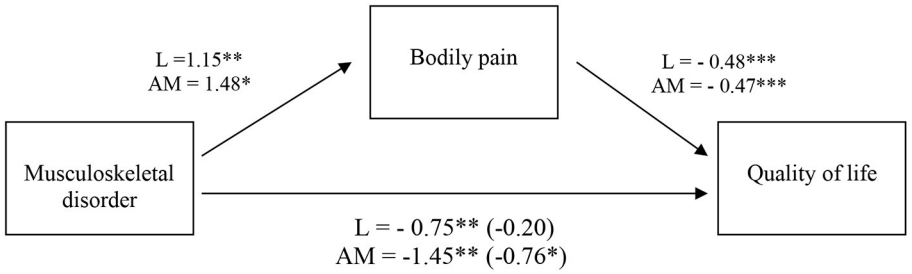

FIGURE 2 | Indirect effect of bodily pain on the relation between musculoskeletal disorders and health-related quality of life. The coefficient for musculoskeletal disorder and health-related quality of life controlling for bodily pain is shown in parenthesis. All values represent unstandardized coefficients. L, lumbar. AM, aggregated measure of musculoskeletal disorders in the cervical, dorsal, and hands and wrists areas. $^{*}p < 0.050$, $^{**}p < 0.010$, $^{***}p < 0.001$.

to filling this literature gap by identifying the musculoskeletal disorders in a sample of Portuguese welders and understanding its effects on welders' bodily pain and health-related quality of life. Our findings suggest that welders have a higher incidence of musculoskeletal disorders in the cervical, lumbar, dorsal, and wrists and hands areas than non-welders. These results are only partially convergent with the studies conducted in other countries (2, 3, 8). Although, some of these differences might have to do with the differences in the methods that were used, and differences between arc and gas welding, it is likely that the differences are also linked to the average anthropometric differences between countries. These differences need to be further understood to be considered in the setup of workstations and in the size, weight, and relative dimensions of the welding equipment.

We also found that musculoskeletal disorders in the lumbar area alone, and in the cervical, dorsal, and wrists and hands areas combined, diminished the welders' health-related quality of life. The relation between musculoskeletal disorders in the lumbar area and health-related quality of life was explained by the increased bodily pain. Bodily pain in the lumbar area is a matter of the upmost relevance. The Global Burden of Diseases, Injuries, and Risk Factors Study (16) estimated that low back pain continues to be, since 1990, the fourth leading cause of disability-adjusted life-years (DALYs; i.e., represents the loss of the equivalent of 1 year of full health) for people between 25 and 49 years old (the same age groups of our sample of welders), and has been increasing in other age groups. Pain medication can play an important part in enabling welders to continue working without feeling pain or decreasing their health-related quality of life. However, the widespread use of opioids for the treatment of moderate or severe acute and chronic pain has become a public health problem due to the physical and psychological dependence and tolerance they produce. The increasingly higher doses that patients require may reach toxic levels or lead to accidents, including fatalities (17). Therefore, primary prevention, such as exercise training programs (1, 18), and secondary prevention, as improving the ergonomic design of the welders workstations (19, 20), should be privileged in the future.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

LL and SL contributed to conception and design of the study. LL collected the data, performed the statistical analyses and wrote the first draft of the manuscript. SL performed statistical analyses, and wrote sections of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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Identifying the Subtypes and Characteristics of Mental Workload Among Chinese Physicians in Outpatient Practice: A Latent Profile Analysis

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Objective: The purpose of this study is to investigate the mental workload level of physicians in outpatient practice since the normalization of prevention and control of the COVID-19 pandemic in China and explore the subtypes of physicians regarding their mental workload.

Methods: A cross-sectional survey of 1,934 physicians primarily in 24 hospitals in 6 provinces in Eastern, Central, and Western China was conducted from November 2020 to February 2021. A latent profile analysis was performed to identify clusters based on the six subscales of the Chinese version of physician mental workload scale developed by our research team. Chi-square tests were performed to explore the differences in demographic characteristics of the subtypes among the subgroups, and multinomial logistic regression analysis was further conducted to identify the determinants of the subtypes of physicians.

Results: Overall, the participating physicians reported high levels of task load but with high self-assessed performance (68.01 ± 14.25) while performing communication work tasks characterized by direct patient interaction in outpatient clinics. About 33.8% of the participating physicians were identified as "high workload and high self-assessment" subtype, compared to 49.7% "medium workload and medium self-assessment" subtype and 16.4% "low workload and low self-assessment" subtype. Physicians in "high workload and high self-assessment" subtype had the highest mean mental workload score. Physicians who were female, younger, married, worse health status, those who had lower educational level and an average monthly income of 5,001–10,000 RMB, those who worked in tertiary A hospitals, more hours per week and more than 40 h per week in outpatient clinics, and those who saw more outpatients per day, and spent more time per patient but with higher outpatient satisfaction were more likely to belong to "high workload and high self-assessment" subtype.

Conclusion: Our findings can help provide a solid foundation for developing targeted interventions for individual differences across physicians regarding their mental workload.

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We suggest the hospital managers should pay more attention to those physicians with characteristics of the "high workload and high self-assessment" subtype and strengthen the management of the workload of this subtype of physicians to reduce the risks of their mental health, and to maintain their high work performance in outpatient clinics.

Keywords: COVID-19, latent profile analysis, mental workload, mental health, physicians, outpatient care, communication, China

INTRODUCTION

Workload

Internationally, there has been a focus on the topic of the relationship between physicians' workload and their health (1), and their physical and mental health is closely related to their workload (1, 2), especially during the current ongoing COVID-19 (3). Excessive workload not only impacts physicians' health (2, 4), but also contributes to an inferior quality of care service (5) and thereby affects patient satisfaction and safety (6, 7). During the current COVID-19 pandemic, the high workload of healthcare workers on the frontline is a major concern for efficient health care, patient safety, and fatigue, burnout, the physical and mental health of healthcare workers (8, 9). Compared to SARS-CoV in 2003 and MERS-CoV in 2012, a higher infectivity and transmissibility of SARS-CoV-2 might further increase the workload burden for healthcare workers on the frontline, thereby threating their mental health even more (10).

Workload is generally thought to be a multidimensional and multifaceted construct, as the ratio of demands to available resources (11). Apart from the objective workload, one aspect of workload includes the subjective psychological experiences of the human operator while performing a task under a specific environmental or operational condition, namely mental workload (11). The assessments and management of mental workload was recommended by the European Pact for Mental Health and Welfare to promote physical and mental well-being (12). The National Aeronautics and Space Administration Task Load Index (NASA-TLX) provides the most widely accepted and validated theoretical framework (including mental demand, physical demand, temporal demand, effort, own performance, and frustration level) to measure subjective workload that an individual perceives (13), and is also used to quantify perceived workload of healthcare workers (2). Given that there was an urgent demand for managing the variety of human factors that influence the mental health of healthcare workers and that thus compromise pandemic control (14), most current studies have predominantly addressed the assessments of the mental workload of frontline health workers, especially for frontline nurses aiding the COVID-19 pandemic, especially in pandemic regions, in turn, to provide targeted guidance for developing interventions for the government and hospital mangers to facilitate the mental health of frontline healthcare workers and the quality of care in the COVID-19 pandemic, however, the mental workload level and its associated with factors among frontline physicians likewise aiding in the COVID-19 pandemic were rarely reported separately (6, 15, 16). A high mental workload is a psychological stress factor taking up part of an individual's naturally limited working memory, and ultimately leads to fewer cognitive resources being available. Hence, accurate assessment of physician mental workload is also of great importance to manage stressors, and thereby improve work performance.

Background

As the national epidemic prevention and control battle against the COVID-19 pandemic has achieved phased success, the China's epidemic prevention and control entered a "normalization" stage since April 29, 2020 (17), and subsequently, Chinese physicians including frontline physicians aiding in the COVID-19 pandemic have gradually returned to the normal role of the delivery of medical services for patients in outpatient clinics. According to the new data from National Health Commission of the People's Republic of China, the total number of annual outpatient visits nationwide in China in 2020 has decreased 11.2% than that in 2019, whereas the medical service requirements of patients suppressed by the COVID-19 pandemic lasted for at least 5 months (18), demonstrating that a great number of accumulated medical demands of patients might have been releasing in traditional hospitals after the rest of the time in 2020, although domestic internet hospitals have been devoted to meeting the demands of patients for light inquiry services during the pandemic; and hence, physicians may have to undertake heavier outpatient workloads than over the same period before the pandemic, since the normalization of prevention and control of the COVID-19 pandemic in China. In addition, there being still a trend of Chinese patients tending to go to high-level hospitals for high-quality medical services even for mild symptoms to date, and a trend of the increasing utilization of medical services by patients (19), might further contribute to increased outpatient workload burden for these physicians in high-level hospitals. Heavy outpatient workload can not only affect physicians' health, resulting in burnout, fatigue or anxiety, but also further lead to an inferior quality of medical services to outpatients, ultimately affecting patient satisfaction as well as patient safety. Also, opportunely assessing physician workload is an important issue in managing their workload and stressors, as well as further developing targeted interventions to support them. Hence, this study focused on the assessment of physician workload in outpatient clinics.

Previous studies often simply adopted several objective workload indicators (for example, the number of patient visits, daily visits per physician, weekly work hours) for assessments of

Chinese physicians' workload (20–22), while ignoring physicians' mental workload, an important part of physicians' workload. Mental workload has been regarded as one of the most critical occupational risk factors resulting in burnout or anxiety (11). However, there has been little research on the mental workload level and its characteristics among physicians in outpatient clinics to date, especially in China, though several studies addressed the development of mental workload scale for Chinese physicians (2, 23). Mental workload is also used as a more comprehensive indicator than the simple quantity of work tasks for predicting the mental health and work performance of frontline healthcare workers aiding in the current COVID-19 epidemic (8). If we also wish to reduce the risk factors affecting these physicians' mental health and to improve their work performance in outpatient clinics, we need a more accurate understanding of their mental workload. When drawing insights from previous studies that have provided a solid basis for the present study, we should also seek to go a step further to identify the different subtypes of mental workload among these physicians, and determine the characteristics and determinants of the different subtypes to, in turn, to develop targeted interventions for individual differences across physicians to facilitate their mental health and improve their work performance in outpatient practice. Hence, whether there exist different mental workload clusters in physicians and how to identify these clusters are rather worthwhile to explore. However, little is also known about the subtypes and its characteristics of mental workload among physicians, especially in outpatient practice in previous studies. According to the human-based archetype of mental workload proposed by Jafari et al., resource supply, task demand and individual characteristics were the key factors influencing mental workload (24). Therefore, related individual characteristics related to the mental workload of physicians might be vital for identifying the characteristics of the subtypes.

Study Aims

The main objective of this study is to investigate the level of mental workload among physicians in outpatient clinics in China, and to identify the subtypes of mental workload among these physicians through latent profile analyses, a rather novel method in the mental workload research among physicians. The specific objective is to identify the characteristics of subtypes and determine the factors associated with these subtypes mainly based on the demographic variables the demographic questionnaire. Our current understanding about the subtypes of mental workload among physicians is quite limited. Previous studies often adopted a variable-centered analytical approach for assessments of physicians' mental workload (25, 26). Such kind of study, although important, has failed to reveal the different facets of mental workload among physicians. This study fills the gap in the literature by employing latent profile analyses, which can help increase the understanding of the mental workload of Chinese physicians in outpatient clinics, and further identify the different subtypes of physicians who would otherwise be missed in single indicators.

METHODS

Study Design

Study Sampling

This study used stratified convenience sampling to select physicians in Eastern, Central, and Western China. To ensure sufficient representativeness, two provinces were selected in the Eastern, Central, and Western regions at the time of sampling, respectively, that is, a total of six provinces were selected. Specifically, Guangdong and Zhejiang provinces were selected in Eastern China, and Hubei and Henan provinces were selected in Central China. In Western China, Chongqing municipality and Guangxi Zhuang autonomous region were selected. In the selected provinces, typical sampling was then applied to select two tertiary public hospitals and two secondary public hospitals in each province. That is, a total of 24 public hospitals were mainly selected nationwide in China, including 12 tertiary and 12 secondary public hospitals. Among the selected hospitals, internal, surgical, obstetrics and gynecology, and pediatrics were further selected as main research departments, where targeted physicians were selected by random sampling.

Study Population

Given that the main purpose of this survey study was to investigate the mental workload level of physicians in outpatient practice, the setting of the research was confined to the consulting room in outpatient clinics, and therein all participating physicians who just provided medical services to outpatients in outpatient clinics after the COVID-19 pandemic were included in this survey. Moreover, the target population included physicians who had to have been working for at least 4 months in the outpatient clinics, and those who had to be employed full-time for at least 1 year in their current medical institution; whereas physicians who provided medical services to outpatients in outpatient clinics for <4 months, those who only provided inpatient service, and those who were graduate students or trainees were excluded in this study.

In the consulting room, the work tasks physicians performed, associated with their workload mainly included "communication work tasks" and "non-communication work tasks" (27); and compared to non-communication work tasks characterized by paperwork, communication work tasks characterized by direct patient interaction that mainly require physicians' brain resources, might be more highly correlated with their mental workload. Given that different types of workload resulting from different demands ("task load") and resources (28), this study mainly investigated the workload physicians perceived while performing communication work tasks in outpatient clinics, to reflect their actual or perceived workload in outpatient practice. In our prior study, these communication work tasks mainly consisted of inquiry of medical history, explanation of medical examinations, explanation of outpatient treatment, explanation of health conditions, health guidance, and provision of information about procedures of admission/outpatient operation (27).

Measurement Tool of Mental Workload

Mental workload data were obtained using the Chinese version of physician mental workload scale developed by our research team in 2018 based on the combination of dimensions of the NASA-TLX and Subjective Workload Assessment Technology (SWAT) frameworks (2). The Chinese version of physician mental workload scale has been verified to have good reliability and validity, indicating a reliable tool for measuring or diagnosing the mental workload of Chinese physicians that comprises six dimensions and 12 items regarding different aspects of workload (mental demands, physical demands, temporal demands, perceived risk, frustration level, and performance) (2). In this scale, all items are rated on a 10-point bipolar scale that ranges from 0 to 100. For five of the six dimensions, i.e., mental demands, physical demands, temporal demands, perceived risk, and frustration level, a score of 0 indicates the lowest task load, whereas the dimension of performance is reverse-scored, with a score of 0 indicating the most successful performance of the task and the highest level of satisfaction with his/her performance, and the lowest task load. In this study, the average score of all items of a corresponding dimension was the dimension score, whereas each dimension score was multiplied by the weight of the corresponding dimension (that is, weight dimension score), and the sum of the scores was the total score of mental workload.

Specifically, the measurement tool included three parts in this study. The first part included 6 dimensions and 12 items of the above physician mental workload scale; these dimensions were further compared two by two making the participants able to select the dimension with the most impact on their workload to collect the weights of each dimension in the second part, and therein the weight of each dimension was equal to the number of times that dimension was selected divided by 15. The third part was designed to collect the demographic information of the participants, including gender, age, marital status, educational level, average monthly income, professional title, working years, working years in the current medical institution, area, hospital level, hospital nature, personnel, department, working hours per week, outpatient working hours per week, number of outpatients serviced per day, amount of time spent per patient, self-rated health status, and self-rated outpatient satisfaction. Self-rated health status was measured by the question on a scale of 1 (very poor) through 5 (very good) that "how do you rate your overall health status?" Self-rated outpatient satisfaction was measured based on the question on a 20-point bipolar scale that ranges from 0 to 100 with 0 indicating the lowest outpatient satisfaction, that is, "how many scores you perceive that your outpatients rate for your outpatient services?" and we further divided those with a score of 30 and below into the low satisfaction group, 40–60 into the medium satisfaction group, and 70 or more into the high satisfaction group based on the 0-to-10 numeric pain rating scale (29).

Then, we performed a pilot survey on site in October 2020, to validate the measurement tool in 10 physicians who just finished the provision of the outpatient services in the outpatient clinic of a tertiary public hospital in Wuhan, Hubei. They made comments on the scale, the clarity and level of detail of the outpatient work tasks, and the general design of the survey. Subsequently, context-specific adjustments were made to improve the accuracy and clarity of the questionnaire according to the feedback from the pilot survey. Due to the impact of the COVID-19 pandemic in 2020, we further used the web-based survey tool called wenjuanxing, to create an electronic questionnaire with which to survey physicians.

Data Collection

This survey was carried out from November, 2020 to February, 2021. To improve the efficiency of data collection in the selected hospitals, a unique two-dimensional code of the electronic questionnaire was generated for each hospital. Prior to the beginning of the survey, an informed consent of the outpatient managers in each selected hospital was requested and obtained, and they were invited and volunteered to play the role of the project manager in their hospitals in this survey. To recruit physicians in main research departments selected in this study, we then sent the unique two-dimensional code of the electronic questionnaire to these outpatient managers of the corresponding hospital, and subsequently, they sent the two-dimensional code to the targeted department groups of physicians via WeChat or Tencent QQ group, and physicians who met the inclusion criteria for the targeted population were further invited to participate in this survey. Participants could scan the two-dimensional code of the electronic questionnaire using their phones to access and complete the electronic questionnaire. Before the survey, we introduced the purpose of the survey, provided the definition of mental workload and its outpatient work tasks involved, and guaranteed that the survey data would not be used for other purposes. After an individual's consent was obtained, the survey was conducted accordingly. A WeChat or Tencent QQ account and mobile Internet Protocol address could be used to complete the questionnaire only once. Moreover, to improve the scale of the targeted physicians, these physicians who completed the questionnaire were also encouraged to share the survey website link to their Wechat Circle of Friends, WeChat or Tencent QQ group, where some physicians who met the inclusion criteria for the targeted population could participate in this survey. The study was approved by the Ethics Committee of Tongji Medical College of Huazhong University of Science and Technology (No. IORG0003571).

Statistical Analysis

Descriptive statistics were used to summarize data on demographic characteristics, mental workload and its dimensions of the participating physicians. Data were summarized as frequencies (n) and percentages (%) for categorical variables.

To identify the subtypes of mental workload among physicians, exploratory latent profile analysis (LPA) was performed using the six dimensions of mental workload in this study. LPA, a person-centered statistical approach, provides a method to group individuals with similar patterns of personal and professional characteristics, traits or behaviors into non-overlapping profiles based on their responses to a set of continuous observed indicators (30). Previous studies found that LPA was used as a reliable and feasible approach

to the identification of different facets of mental workload among individuals (31), including frontline nurses aiding in the COVID-19 pandemic (6). Therefore, LPA can be used to identify the patterns of mental workload among Chinese physicians in outpatient clinics likewise. Data for the six dimension indicators were input into the LPA, with one class initially and additional classes added incrementally, until a unique solution could not be determined with the maximum likelihood method.

We tested different models that categorized the subtypes of mental workload into one, two, three, four, five, six and seven Classes. The best fit model was mainly identified using the following model indexes: Akaike information criterion (AIC), Bayesian information criterion (BIC), sample-size Adjusted BIC (ABIC), Lo-Mendell-Rubin (LMR), adjusted likelihood ratio test and bootstrap likelihood ratio test (BLRT) and Entropy (32). A lower value of AIC, BIC and ABIC indicates better fitness of data into the estimated model (32). LMR and BLRT compare the model fit between two neighboring models (for example, k-1class model vs. k-class model), and a lower *P*-value represents that the k-class model fits the data better than the k-1-class model (32). Entropy assesses the accuracy of classification, with values closer to 1 indicating better classification (32). To avoid over-stratification, the smallest group should have a minimum of 5% of the total sample (32). A three-class model was identified in the LPA. Each participating physician was assigned into one of the classes of mental workload of physicians with the highest probability.

Chi-square (χ^2) tests were then used to explore the differences in the three classes across demographic characteristics, and the differences in mental workload and its dimensions among different Classes were tested using one-way analysis of variance (ANOVA) tests. Multinomial logistic regression analysis was applied to identify the significant factors predicting the three subtypes of physicians regarding their mental workload, and therein the demographic variables were set as independent variables. Data analyses were performed using Mplus software (version 7.0) and STATA 15.0 software. $P < 0.05$ was considered statistically significant.

RESULTS

Participant Characteristics

In total, 2,038 responses were received; of these, 104 responses were excluded because the time taken to answer the questionnaire was <60 s, or because they were not physicians, or they were physicians, but did not provide medical services to outpatients in outpatient clinics. Of the 1,934 participating physicians, 45.9% were female, the average age of them was 38.12 years (SD = 8.38 years, range: 20–77 years), 82.0% were currently married, and 74.9% were from tertiary hospitals. Furthermore, among these participating physicians, 51.9% had a postgraduate degree or higher, 38.0% were from Eastern China, 54.9% worked 41–60 h per week and 35.8% worked more than 60 h per week; the average time per week working in outpatient practice was 19.50 h (SD = 14.18 h, range: 3.5–60 h) and the physician saw an average of 43.20 (SD = 24.81, range: 10–160) patients per day in outpatient clinics. In addition, almost half (46.6%) of the participating physicians rated health status as moderate, and 87.9% of them rated outpatient satisfaction as high. Detailed demographic characteristics of the 1,934 participating physicians

TABLE 1 | Demographic characteristics of the participating physicians (*N* = 1,934).

Characteristics	Number (%)	Characteristics	Number (%)
Gender		Hospital level	
Male	1,047 (54.1)	Tertiary A hospital	1,234 (63.8)
Female	887 (45.9)	Tertiary B hospital	215 (11.1)
Age (years)		Secondary hospital	447 (23.1)
20–30	433 (22.4)	First-tier hospital	38 (2.0)
31–40	852 (44.1)	Department	
41–55	587 (30.4)	Internal	585 (30.2)
>55	62 (3.2)	Surgical	481 (24.9)
Marital status		Obstetrics and gynecology	192 (9.9)
Unmarried	305 (15.8)	Pediatrics	163 (8.4)
Married	1,585 (82.0)	Other	513 (26.5)
Divorced	36 (1.9)	Working hours per week	
Widowed	8 (0.4)	≤40	180 (9.3)
Educational level		41–60	1,062 (54.9)
PhD	228 (11.8)	>60	692 (35.8)
Postgraduate	776 (40.1)	Outpatient working hours per week	
Undergraduate	857 (44.3)	≤8	584 (30.2)
Junior college	59 (3.1)	8–16	440 (22.8)
Other	14 (0.7)	16–24	440 (22.8)
Average monthly income (RMB)		24–40	268 (13.9)
≤5,000	376 (19.4)	>40	202 (10.4)
5,001–10,000	903 (46.7)	Number of outpatients serviced per day	
10,001–15,000	406 (21.0)	≤25	497 (25.7)
>15,000	249 (12.9)	26–40	582 (30.1)
Professional title		41–50	381 (19.7)
Senior	212 (11.0)	>50	474 (24.5)
Deputy senior	548 (28.3)	Amount of time spent per patient (minutes)	
Intermediate	699 (36.1)	≤5	601 (31.1)
Junior	450 (23.3)	5–10	867 (44.8)
Other	25 (1.3)	10–15	274 (14.2)
Working years in the current medical institution		>15	192 (9.9)
1–5	596 (30.8)	Self-rated health status	
6–10	503 (26.0)	Very poor	23 (1.2)
11–15	335 (17.3)	Poor	105 (5.4)
16–20	206 (10.7)	Fair	902 (46.6)
>20	294 (15.2)	Good	624 (32.3)
Area		Very good	280 (14.5)
Eastern China	735 (38.0)	Self-rated outpatient satisfaction	
Central China	685 (35.4)	Low	24 (1.2)
Western China	514 (26.6)	Medium	210 (10.9)
		High	1,700 (87.9)

are presented in **Table 1**. Moreover, the total mean score of workload the participating physicians perceived ranged from 17.11 to 100.00 while performing communication work tasks characterized by direct patient interaction, and the mean score was 68.01 (SD = 14.25) and therein the highest weighted score in six dimensions was mental demands, followed by the perceived risk, temporal demands, frustration level, physical demands, and performance (seen from **Table 2**).

Identification of Different Subtypes of Physicians

According to model indexes, the best fitting LPA was the three-class model (**Table 3**), which had lower AIC (97069.375), BIC (97214.126) and ABIC (97131.523). The *p*-values of the LMR test (0.0017) and BLRT (<0.001) indicate this model was statistically significant at the $\alpha = 0.05$; and a higher Entropy value (0.796) and proportion of physicians in the least class (16.4% > 10%) indicate the model was reliable and valid. In the three-class model, the average profile probabilities of physicians in each category ascribed to corresponding potential category ranged from 0.901 to 0.908, which further supports that the results of the three-class model were reliable and valid.

Figure 1 shows the subtypes of physicians (Classes 1, 2, and 3), their proportion (16.4, 33.8, 49.7%, respectively), and the mean levels of the mental workload and its dimensions, which can be distinguished as having relatively low (Class 1), medium (Class 3) and high (Class 2) levels of mental workload. The diagrams for Classes 3 and 1 shared similar patterns for the six dimensions of the physician mental workload scale. The scores for the dimensions of performance and frustration level were much lower than the other dimension scores in each subgroup. Specifically, Class 2 presented the highest task load and highest self-assessment of performance, named the "high workload and high self-assessment" subtype. Class 3 demonstrated medium levels of the six workload dimensions, named the "medium workload and medium self-assessment" subtype. However, Class 1 had the lowest scores in task load and the lowest self-assessment level of satisfaction with performance, named the "low workload and low self-assessment" subtype.

Characteristics of Different Subtypes of Physicians

Chi-square tests (**Supplementary Table S1**) showed that there was a significant difference in the three subtypes for gender ($\chi^2 = 15.925$, $p < 0.001$), marital status ($\chi^2 = 12.726$, $p = 0.013$), educational level ($\chi^2 = 38.810$, $p < 0.001$), average monthly income ($\chi^2 = 16.635$, $p = 0.011$), professional title ($\chi^2 = 18.501$, $p = 0.018$), hospital level ($\chi^2 = 21.519$, $p = 0.001$), personnel ($\chi^2 = 16.768$, $p = 0.010$), working hours per week ($\chi^2 = 54.940$, $p < 0.001$), outpatient working hours per week ($\chi^2 = 24.806$, $p = 0.002$), number of outpatients serviced per day ($\chi^2 = 17.179$, $p = 0.009$), amount of time spent per patient ($\chi^2 = 17.714$, $p = 0.007$), self-rated health status ($\chi^2 = 60.977$, $p < 0.001$), and self-rated outpatient satisfaction ($\chi^2 = 45.659$, $p < 0.001$). However,

TABLE 2 | Mean mental workload scores ($n = 1{,}934$).

Dimensions	Minimum	Maximum	Mean ± SD	Dimensions	Minimum	Maximum	Mean ± SD
Mental demands	6.67	100.00	80.58 ± 15.17	Mental demands*	0.00	33.33	18.16 ± 8.67
Physical demands	5.00	100.00	72.28 ± 19.27	Physical demands*	0.00	33.33	8.36 ± 7.57
Temporal demands	0.00	100.00	72.81 ± 18.39	Temporal demands*	0.00	33.33	12.95 ± 7.15
Perceived risk	0.00	100.00	74.20 ± 20.15	Perceived risk*	0.00	33.33	15.51 ± 7.51
Frustration level	0.00	100.00	60.83 ± 23.14	Frustration level*	0.00	33.33	9.48 ± 7.83
Performance	0.00	100.00	27.79 ± 17.19	Performance*	0.00	33.33	3.55 ± 4.43
Total score*	17.11	100.00	68.01 ± 14.25				

**Weighted score.*

TABLE 3 | Latent profile analysis models and fit indices.

Model	AIC	BIC	ABIC	Entropy	LMR, *p*-value	BLRP, *p*-value	Proportion of physicians in the least class
1	100945.121	101011.929	100973.805	–	–	–	–
2	98017.551	98123.331	98062.967	0.801	<0.001	<0.001	44.1%
3	97069.375	97214.126	97131.523	0.796	0.0017	<0.001	16.4%
4	96704.665	96888.388	96783.546	0.791	0.0089	<0.001	5.7%
5	96420.200	96642.894	96515.813	0.785	0.0390	<0.001	7.3%
6	96218.657	96480.323	96331.003	0.799	0.0251	<0.001	3.4%
7	96033.153	96333.790	96162.231	0.788	0.1847	<0.001	3.3%

AIC, Akaike Information Criterion; BIC, Bayesian Information Criterion; ABIC, Sample-size-adjusted Bayesian Information Criterion; LMR, Lo-Mendell-Rubin Adjusted Likelihood Ratio Test; BLRT, Bootstrap Likelihood Ratio Test.

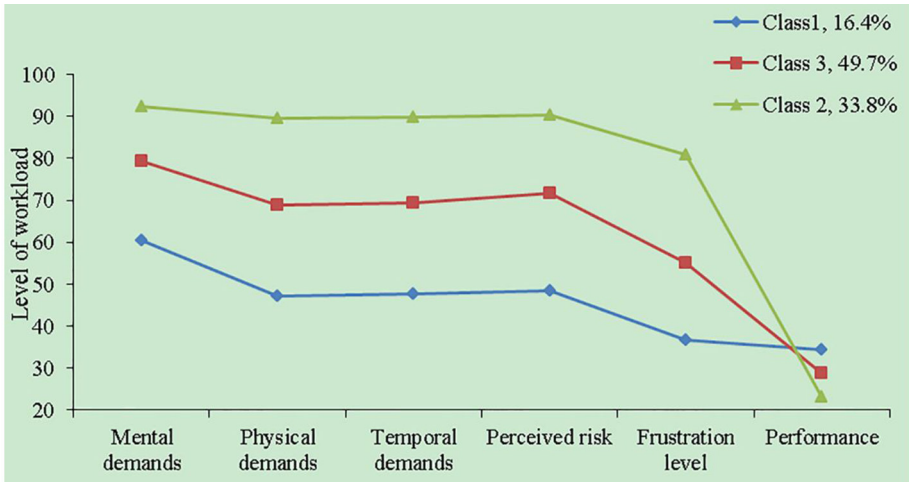

FIGURE 1 | The latent profiles of the dimensions of the Chinese version of physician mental workload scale.

TABLE 4 | Comparisons of the different subtypes by mental workload.

Dimensions	Class 1 (*N* = 318) (Mean ± SD)	Class 3 (*N* = 962) (Mean ± SD)	Class 2 (*N* = 654) (Mean ± SD)	*P*[a]-value			
				Overall	Class 1 vs. Class 3	Class 1 vs. Class 2	Class 3 vs. Class 2
Mental demands	60.45 ± 15.77	79.24 ± 10.49	92.32 ± 7.77	<0.001	<0.001	<0.001	<0.001
Physical demands	47.26 ± 15.09	68.79 ± 13.31	89.57 ± 10.3	<0.001	<0.001	<0.001	<0.001
Temporal demands	47.77 ± 14.58	69.45 ± 11.69	89.92 ± 9.04	<0.001	<0.001	<0.001	<0.001
Perceived risk	48.43 ± 18.3	71.72 ± 14.8	90.38 ± 11.04	<0.001	<0.001	<0.001	<0.001
Frustration level	36.79 ± 16.44	55.19 ± 17.65	80.82 ± 16.36	<0.001	<0.001	<0.001	<0.001
Performance	34.32 ± 17.60	28.72 ± 14.99	23.24 ± 18.74	<0.001	<0.001	<0.001	<0.001
Total score	48.55 ± 8.20	65.96 ± 8.62	80.49 ± 10.62	<0.001	<0.001	<0.001	<0.001

Class 1, "low workload and low self-assessment" subtype; Class 3, "medium workload and medium self-assessment" subtype; Class 2, "high workload and high self-assessment" subtype.

[a]*ANOVA and post-hoc pairwise Bonferroni tests for the dimension indicators with a normal distribution.*

there was no significant difference in the three subtypes for area ($\chi^2 = 0.722, p = 0.949$) and department ($\chi^2 = 13.024, p = 0.111$).

When compared with those in the other subtypes, physicians in "high workload and high self-assessment" subtype tended to be those who were female, married, and personnel agency, those who had a postgraduate or undergraduate degrees, lower average monthly incomes, intermediate or deputy senior professional titles, worse self-rated health status, and better self-rated outpatient satisfaction, and those who worked in tertiary hospitals, worked more hours per week, saw more outpatients per day, spent more time on per patient and worked more hours per week in outpatient clinic.

Table 4 also presents the significant differences in mental workload and its dimensions among the three subtypes. The "high workload and high self-assessment" subtype was characterized by the highest scores on the dimensions of mental demands, physical demands, temporal demands, perceived risk, and frustration level, and the most successful performance of the task and the highest level of satisfaction with his/her performance. The "low workload and low self-assessment" subtype further distinguished itself from the "medium workload and medium self-assessment" subtype through lower scores on the five dimensions except for the performance dimension. Also, the "high workload and high self-assessment" subtype had the highest mean mental workload, followed by the "medium workload and medium self-assessment" subtype, and "low workload and low self-assessment" subtype, which can also be named "high mental workload" group, "medium mental workload" group and "low mental workload" group in turn.

Factors Associated With the Subtypes of Physicians

Multinomial logistic regression was used to identify the significant factors that influenced the subtypes of physicians in their mental workload. Using "high workload and high self-assessment" subtype (that is, "high mental workload" group) as the base outcome (reference), we had following results (**Table 5**).

Female physicians were less likely to belong to "low workload and low self-assessment" [Relative Risk Ratio (RRR) = 0.597, $p = 0.003$] or "medium workload and medium self-assessment" (RRR = 0.770, $p = 0.039$) subtypes as compared with the odds of "high workload and high self-assessment" subtype. Physicians

TABLE 5 | Multinomial logistic regression results: significant determinants of the subtypes of physicians in mental workload.

Variables	"Low workload and low self-assessment" subtype			"Medium workload and medium self-assessment" subtype		
	β	Relative risk ratio (95% confidence interval)	*p*-value	*β*	Relative risk ratio (95% confidence interval)	*p*-value
Gender (ref: Male)						
Female	−0.515	0.597 (0.424, 0.842)	0.003***	−0.261	0.770 (0.601, 0.987)	0.039**
Age (ref: 20–30years)						
31–40	0.824	2.279 (1.320, 3.935)	0.003***	0.302	1.352 (0.909, 2.011)	0.137
41–55	0.945	2.575 (1.290, 5.140)	0.007***	0.474	1.606 (0.967, 2.667)	0.067*
>55	0.326	1.385 (0.483, 3.976)	0.544	−0.354	0.702 (0.314, 1.569)	0.389
Marital status (ref: Unmarried)						
Married	−0.529	0.589 (0.351, 0.987)	0.044*	−0.277	0.758 (0.517, 1.111)	0.155
Divorced	−0.620	0.538 (0.170, 1.70)	0.290	−1.030	0.357 (0.147, 0.869)	0.023**
Widowed	N/A	N/A	N/A	N/A	N/A	N/A
Educational level (ref: PhD)						
Postgraduate	−0.630	0.533 (0.315, 0.900)	0.019**	−0.414	0.661 (0.442, 0.987)	0.043**
Undergraduate	−0.800	0.449 (0.250, 0.807)	0.007***	−0.186	0.831 (0.537, 1.285)	0.405
Junior college	2.554	1.291 (0.462, 3.610)	0.626	0.0972	1.102 (0.464, 2.615)	0.826
Other	N/A	N/A	N/A	N/A	N/A	N/A
Average monthly income (ref: 10,001–15,000 RBM)						
≤5,000	−0.239	0.787 (0.447, 1.387)	0.408	−0.252	0.777 (0.521, 1.160)	0.217
5,001–10,000	−0.324	0.723 (0.472, 1.107)	0.136	−0.381	0.682 (0.504, 0.924)	0.013**
>15,000	0.0499	1.051 (0.619, 1.785)	0.854	−0.0844	0.919 (0.617, 1.368)	0.678
Working years in the current medical institution (ref: 1–5 years)						
6–10	−0.454	0.635 (0.395, 1.020)	0.060*	−0.108	0.898 (0.635, 1.269)	0.542
11–15	−0.413	0.662 (0.380, 1.152)	0.145	−0.237	0.789 (0.524, 1.186)	0.254
16–20	−1.034	0.356 (0.179, 0.705)	0.003***	−0.659	0.518 (0.318, 0.843)	0.008***
>20	−0.563	0.569 (0.284, 1.143)	0.113	−0.327	0.721 (0.428, 1.216)	0.220
Hospital level (ref: Tertiary A hospital)						
Tertiary B hospital	0.262	1.300 (0.752, 2.246)	0.348	−0.240	0.787 (0.523, 1.185)	0.251
Secondary hospital	0.434	1.543 (1.007, 2.363)	0.046**	0.0822	1.086 (0.802, 1.470)	0.595
First-tier hospital	0.603	1.827 (0.593, 5.634)	0.294	−0.136	0.873 (0.336, 2.271)	0.781
Working hours per week (ref: ≤40)						
41–60	−0.884	0.413 (0.244, 0.699)	0.001***	−0.372	0.689 (0.440, 1.080)	0.104
>60	−1.599	0.202 (0.115, 0.356)	<0.001***	−0.682	0.505 (0.317, 0.805)	0.004***
Outpatient working hours per week (ref: ≤8)						
8–16	0.236	1.266 (0.829, 1.934)	0.275	0.364	1.439 (1.060, 1.955)	0.020**
16–24	0.269	1.309 (0.832, 2.058)	0.244	0.359	1.432 (1.036, 1.980)	0.029**
24–40	−0.0852	0.918 (0.540, 1.561)	0.753	0.0840	1.088 (0.741, 1.596)	0.668
>40	−0.598	0.550 (0.293, 1.035)	0.064*	0.0169	1.017 (0.682, 1.518)	0.934
Number of outpatients serviced per day (ref: ≤25)						
26–40	−0.848	0.428 (0.282, 0.651)	<0.001***	−0.341	0.711 (0.523, 0.966)	0.029**
41–50	−0.602	0.548 (0.343, 0.874)	0.0012***	−0.397	0.672 (0.476, 0.951)	0.025**
>50	−0.817	0.442 (0.271, 0.719)	0.001***	−0.413	0.661 (0.464, 0.941)	0.022**
Amount of time spent per patient (ref: 10–15min)						
≤5	0.383	1.467 (0.870, 2.474)	0.151	0.432	1.540 (1.051, 2.251)	0.026**
5–10	0.278	1.320 (0.817, 2.134)	0.256	0.431	1.538 (1.089, 2.171)	0.014**
>15	−0.0633	0.939 (0.499, 1.765)	0.844	0.364	1.439 (0.909, 2.278)	0.121
Self-rated health status (ref: Very good)						
Very poor	N/A	N/A	N/A	N/A	N/A	N/A
Poor	−1.377	0.252 (0.118, 0.541)	<0.001***	−0.642	0.526 (0.308, 0.899)	0.019**
Fair	−0.964	0.381 (0.247, 0.590)	<0.001***	−0.244	0.784 (0.556, 1.105)	0.164
Good	−0.163	0.850 (0.543, 1.329)	0.475	0.349	1.418 (0.986, 2.038)	0.060*
Self-rated outpatient satisfaction (ref: High)						
Low	2.376	10.758 (1.944, 59.521)	0.006***	1.266	3.547 (0.709, 17.471)	0.123
Fair	1.303	3.680 (2.320, 5.836)	<0.001***	0.548	1.730 (1.188, 2.518)	0.004***

*Base outcome: "high workload and high self-assessment" subtype; *p < 0.1, **p < 0.05, ***p < 0.01.*

with higher age were more likely to belong to "low workload and low self-assessment" subtype; compared to those aged 20–30 years old, physicians aged 31–40 years old or 41–55 years old had a higher likelihood of belonging to "low workload and low self-assessment" subtype (RRR = 2.279, $p = 0.003$; RRR = 2.575, $p = 0.007$, respectively). Physicians being married were less likely than those being unmarried to belong to "low workload and low self-assessment" subtype (RRR = 0.589, $p = 0.044$). For educational level, physicians with lower education level were less likely to belong to "low workload and low self-assessment" subtype; compared to those with a PhD degree, physicians with postgraduate or undergraduate degrees had a lower likelihood of belonging to "low workload and low self-assessment" subtype (RRR = 0.533, $p = 0.019$; RRR = 0.449, $p = 0.007$, respectively), and physicians with a postgraduate degree also had a lower likelihood of belonging to "medium workload and medium self-assessment" subtype (RRR = 0.661, $p = 0.043$).

Physicians with an average monthly income of 5,001–10,000 RMB were less likely than those with an average monthly income of 10,001–15,000 RMB to belong to "medium workload and medium self-assessment" subtype (RRR = 0.682, $p = 0.013$) as compared with the odds of "high workload and high self-assessment" subtype. Compared to those who worked in the current medical institution for 1–5 years, physicians working 16–20 years in the current medical institution had a lower likelihood of belonging to "low workload and low self-assessment" (RRR = 0.356, $p = 0.003$) or "medium workload and medium self-assessment" (RRR = 0.518, $p = 0.008$) subtypes. Physicians in secondary hospitals were more likely than those in tertiary A hospitals to belong to "low workload and low self-assessment" subtype (RRR = 1.543, $p = 0.046$). For working hours per week, physicians who worked more hours per week were less likely to belong to "low workload and low self-assessment" or "medium workload and medium self-assessment" subtypes; compared to those with no more than 40 working hours per week, physicians with 41–60 or more than 60 working hours per week had a lower likelihood of belonging to "low workload and low self-assessment" subtype (RRR = 0.413, $p = 0.001$; RRR = 0.202, $p < 0.001$, respectively), and physicians who worked more than 60 h per week were less likely to belong to "medium workload and medium self-assessment" subtype (RRR = 0.505, $p = 0.004$).

For outpatient working hours per week, physicians who worked more than 40 h per week in outpatient clinics were less likely than those with no more than 8 outpatient working hours per week to belong to "low workload and low self-assessment" subtype (RRR = 0.505, $p = 0.064 < 0.10$), whereas physicians who worked 8–16 or 16–24 h per week in outpatient clinics had a higher likelihood of belonging to "medium workload and medium self-assessment" subtype (RRR = 1.439, $p = 0.020$; RRR = 1.432, $p = 0.029$, respectively) as compared with the odds of "high workload and high self-assessment" subtype. For number of outpatients serviced per day, physicians with more outpatients serviced per day were less likely to belong to "low workload and low self-assessment" or "medium workload and medium self-assessment" subtypes; compared to physicians with no more than 25 outpatients serviced per day, physicians who saw more than 25 outpatients per day had a lower likelihood of belonging to "low workload and low self-assessment" (RRR = 0.428, $p < 0.001$; RRR = 0.548, $p = 0.0012$; RRR = 0.442, $p = 0.001$, respectively) or "medium workload and medium self-assessment" (RRR = 0.711, $p = 0.029$; RRR = 0.672, $p = 0.025$; RRR = 0.661, $p = 0.022$, respectively) subtypes. For amount of time spent per patient, physicians with less time spent per patient were more likely to belong to "medium workload and medium self-assessment" subtype; compared to physicians with 10–15 min spent per patient, physicians with no more than 5 or 5–10 min spent per patient had a higher likelihood of belonging to "medium workload and medium self-assessment" subtype (RRR = 1.540, $p = 0.026$; RRR = 1.538, $p = 0.014$, respectively).

For self-rated health status, physicians with worse self-rated health status were less likely to belong to "low workload and low self-assessment" subtype; compared to physicians who rated health status as "very good," physicians who rated health status as "poor" or "fair" had a lower likelihood of belonging to "low workload and low self-assessment" subtype (RRR = 0.252, $p < 0.001$; RRR = 1.538, $p < 0.001$, respectively), and physicians who rated health status as "poor" were less likely to belong to "medium workload and medium self-assessment" subtype (RRR = 0.526, $p = 0.019$) as compared with the odds of "high workload and high self-assessment" subtype. However, physicians with lower self-rated outpatient satisfaction were more likely to belong to "low workload and low self-assessment" subtype; compared to physicians who rated outpatient satisfaction as "high," physicians who rated outpatient satisfaction as "low" or "fair" had a higher likelihood of belonging to "low workload and low self-assessment" subtype (RRR = 10.758, $p = 0.006$; RRR = 3.680, $p < 0.001$, respectively), and physicians who rated outpatient satisfaction as "fair" had a higher likelihood of belonging to "medium workload and medium self-assessment" subtype (RRR = 1.730, $p = 0.004$). We also calculated the variance inflation factor to test the collinearity problem, and the variance inflation factor was <10 (1.07–2.65), indicating that there was no collinearity problem, and that the results of the model were reliable.

DISCUSSION

Principal Findings

Overall, this survey study indicated a medium level of mental workload but with a relatively higher performance and self-rated outpatient satisfaction among Chinese physicians while performing communication work tasks characterized by direct patient interaction in outpatient clinics since the normalization of prevention and control of the COVID-19 pandemic in China compared to previous studies. About 33.8% of the participating physicians were identified as "high workload and high self-assessment" subtype, compared to 49.7% "medium workload and medium self-assessment" subtype and 16.4% "low workload and low self-assessment" subtype. The "high workload and high self-assessment" subtype with the highest level of mental workload, was characterized by the highest task load but the most successful performance of the task and the highest level of satisfaction with his/her performance. Previous studies often simply classify the mental workload groups using single indicators (overall mental workload) (25, 26).

Gender, age, marital status, educational level, average monthly income, working years in the current medical institution, hospital level, working hours per week, outpatient working hours per week, number of outpatients serviced per day, amount of time spent per patient, self-rated health status, and self-rated outpatient satisfaction were all significantly associated with the subtypes of mental workload among physicians while performing communication work tasks characterized by direct patient interaction in outpatient clinics.

Comparison to Prior Studies

Mental Workload of Physicians

This survey study, to our knowledge, was an early study investigating the level of the mental workload of physicians and delineating the characteristics of the subtypes of these physicians in outpatient practice since the normalization of prevention and control of the COVID-19 pandemic in China. Current studies mainly addressed the assessments of mental workload of frontline nurses aiding in the COVID-19 epidemic; however, the mental workload level and its associated factors or characteristics among physicians likewise aiding in the COVID-19 pandemic, or working in outpatient settings after the pandemic were rarely reported (6, 9, 10). This study revealed that the total mean score of workload physicians perceived was 68.01 (SD = 14.25) while performing communication work tasks, which indicates a medium level of mental workload. The classes divided by the LPA showed that the total mean mental workload score in Class 2 ("high workload and high self-assessment" subtype, which accounted for 33.8% of the total sample) was 80.49 (SD = 10.62), which suggests a much higher level of mental workload than the mental workload reported not only in a study by Mazur et al. with radiation oncology professionals including physicians in America (range: 40–52) (26), and in a study conducted by Weigl et al. with hospital physicians in Germany (46.45 ± 17.29) (33) and in a study of Ariza et al. with general practitioners in England (28.7, 95% CI 23.3–34.0) (34) but also in a study by Ma et al. with physicians in outpatient departments in China (69.7 ± 11.5) (23) and in recent study conducted by Du et al. with frontline healthcare workers aiding in the COVID-19 pandemic in China (69.7 ± 16.4) (35). Regarding the objective workload, the latest data from National Health Commission of the People's Republic of China showed that the total number of annual outpatient visits in 2020 decreased 11.2% than that in 2019, whereas the medical service requirements of patients suppressed by the COVID-19 pandemic lasted for at least 5 months (18), indicating that a great number of accumulated medical demands may have been releasing in traditional hospitals after the rest of the time in 2020, and hence, the workloads physicians would undertake might be increased significantly over the same period since the normalization of prevention and control of the COVID-19 pandemic in China. Some physicians in outpatient practice might be exposed to the infection risks due to the sporadic outbreaks of COVID-19 in China, and might fear to infect their family, colleagues, and friends, and thus suffer from psychological pressure, anxiety and depression. Therefore, the challenges of the higher workloads and potential infection might seem sufficiently severe to increase the mental workload of physicians in outpatient practice.

As the graphs in the three-class model show, the scores for the dimensions of performance and frustration were much lower than the other dimension scores in each subgroup, whereas the dimensions of mental demands, perceived risk and temporal demands were main contributors of mental workload in this study, which contributed to the overall higher mental workload than that reported in previous studies (23, 26, 33–35). Another possible reason might be relevant to the fact that according to the definition of mental workload, mental workload could be determined by characteristics of the work task, the operator, and the environmental context or operational condition, where the work task was performed (11); and thus, communication work tasks characterized by direct patient interaction that mainly require physicians' brain resources, high-pressure workplace in outpatient clinics, and the participating physicians in this study mainly from high-level hospitals, where they tend to have heavy outpatient workloads (36), could together result in a higher level of mental workload reported in this study.

Determinants of Different Subtypes of Physicians

Findings of this study on determinants of the three subtypes of physicians showed that gender, age, marital status, educational level, average monthly income, working years in the current medical institution, hospital level, working hours per week, outpatient working hours per week, number of outpatients serviced per day, amount of time spent per patient, self-rated health status, and self-rated outpatient satisfaction were all the factors significantly associated with the subtypes of mental workload (that is, mental workload group) among physicians while performing communication work tasks characterized by direct patient interaction in outpatient clinics. A study by Du et al. also found that frontline health care workers aiding in the COVID-19 epidemic who perceived higher mental workload, tended to have higher education level and longer working years (35), and another study of Shan et al. revealed that frontline nurses with lower incomes were more likely to have a relatively low level of mental workload (8), and these two studies further suggested that there was no significant correlation between gender and mental workload, and similar conclusions were reported in several studies (37, 38). However, this study found that female physicians were more likely than male physicians to have a higher likelihood of belonging to those with high mental workload (that is, "high workload and high self-assessment" subtype) in outpatient practice; one possible reason for this difference might be relevant to the fact that compared to males, females among the participating physicians in this study might have longer outpatient working hours, when such a workload was combined with housework, children, and elderly care (39), which is supported by the finding from this study that physicians being married were more likely to have a high level of mental workload; another possible reason might be that female physicians showed more patience than male physicians in communication with their patients in clinics (40), thereby resulting in more consumption of their brain resources.

This study indicated that younger physicians (aged 20–30 years old) were more likely than other older groups (aged 31–55 years old) to have a relatively high level of mental workload while performing communication work tasks in outpatient practice; one possible explanation was that on the one hand, younger physicians, due to relative lack of experience, tended to have increased perceived workload (41), and on the other hand, these younger physicians in China were often likely to have lower professional titles, and thus to provide general outpatient services with a greater number of patients and have longer working hours, and moreover, the work pressure of scientific research owing to professional title assessment might also contribute to their workload to some extent (42).

Our study also found that physicians who saw more outpatients per day tended to have a relatively high level of mental workload while perform communication work tasks in outpatient clinics. Similar conclusions were reported in primary healthcare physicians by Orozco and Garcia (43) and in emergency department physicians by Prints et al. (44). Moreover, physicians with more time spent per patient in outpatient clinics were more likely to have a high level of mental workload, which is supported by the finding from Khori et al. that a longer mean consultation time of general physicians in Iran was significantly associated with their higher workload (45), however, another study conducted by Petek et al. found that physicians with absence of high workload in general practice in Slovenia tended to have longer consultation time (46); one possible explanation was that these physicians with more time spent per patient in this study might have higher professional titles, and mainly provide expert outpatient services for patients with intractable diseases, in which a greater number of their own brain resources were demanded while performing communication work tasks characterized by direct patient interaction in outpatient clinics. Compared to physicians in secondary hospitals, physicians in high-level hospitals (tertiary A hospitals) were more likely to have a higher likelihood of belonging to those with a high level of mental workload, because physicians in high-level hospitals on the one hand, tended to undertake a greater number of outpatient services, and on the other hand, provided higher quality medical services for outpatients (47), which means that a greater number of brain resources were demanded.

Health condition of physicians is a heated social problem in China. Previous studies have repeatedly emphasized the highly significant correlation between physicians' workload and their health (1, 2), and excessive mental workload can lead to not only serious health problems [for example, lower sleep quality (48), cardiovascular diseases and so on] for physicians (2) but also an inferior quality of care service (5) and further medical errors (49), thereby threatening patient safety. Our findings also showed that physicians with worse health status were more likely to have a relatively high level of perceived workload while performing communication work tasks characterized by direct patient interaction in outpatient clinics, indicating a major concern that should be focused on in this study. However, it was reported that there was a trend of dramatically increased workload for Chinese physicians from 1998–2016, potentially threatening their health and the quality of patient services (21). The analysis indicated that physicians with more working hours per week, and more working hours per week in outpatient clinics tended to have a high level of mental workload. Surprisingly, physicians had a higher level of mental workload but with better self-assessed performance in this study. These findings remind that hospital managers should further pay more attention to the effects of physicians' workload on their health to, in turn, prevent and reduce the risks of negative health outcomes, burnout and fatigue among physicians, and thereby improve the quality of medical services and patient safety in outpatient practice.

Characteristics of Different Subtypes of Physicians

Our findings also indicated the characteristics of the different subtypes of physicians in their mental workload, which could provide an opportunity for hospital mangers to develop targeted interventions for individual differences across physicians to prevent negative physical and psychological outcomes of physicians and improve their performance in outpatient clinics. Among the classes, Class 2 was referred to as the "high workload and high self-assessment" subtype, as these individuals tended to be female, married, younger, worse health status, have lower educational level and an average monthly income of 5,001–10,000 RMB, work in high-level hospitals and 16–20 years in the current medical institution, work more hours per week, work more hours in outpatient clinics, see more outpatients per day and spend more time per patient but with higher outpatient satisfaction. These characteristics represent that these individuals who had greater objective workloads in outpatient clinics were more likely to perceive a high level of mental workload, but with worse health condition. Meanwhile, their frustration level was high (80.82 ± 16.36). It can be speculated that the physical and psychological stress owing to heavier objective workload experienced by these physicians, and the nature of communication work tasks characterized by direct patient interaction that mainly require physicians' brain resources in outpatient practice may also result in job burnout. However, the mean self-reported outpatient work performance score was the lowest for this class, indicating that these physicians were the most successful in their performance or the most satisfied with their performance. Research indicated that there was a decreased consultation time (46) and self-rated performance (50), and an increased rate of severity grade of medical errors with increasing workload of physicians (51). These findings suggest that hospital managers should consider paying attention to physicians in "high workload and high self-assessment" subtype, monitor their workloads in real time and take measures to strengthen the management of their workload to, in turn, prevent and reduce negative physical and psychological outcomes of physicians and maintain their high work performance in outpatient practice. In addition, a study regarding the comparing the psychological impact of the COVID-19 outbreak between frontline and non-frontline medical workers in China reported that compared to non-frontline medical workers, frontline medical workers were more likely to suffer from mental health problems (i.e., anxiety, insomnia, and depressive symptoms) (9), and another study concerning factors associated with mental health outcomes among frontline and non-frontline healthcare workers in Oman

during COVID-19 found that frontline healthcare workers were more likely than non-healthcare workers to report anxiety, stress and insomnia (52), and similar conclusions were reported in a narrative review regarding COVID-19-related mental health effects in the workplace that mental health problems, such as anxiety, depression, post-traumatic stress disorder (PTSD), suicidal ideas, and sleep disorders were more likely to affect the healthcare workers, especially those on the frontline (53); and a survey regarding mental health in frontline medical workers during the 2019 Novel Coronavirus Disease epidemic in China reveled that compared to those in other regions, frontline medical workers in Hubei Province (the epidemic center of the COVID-19 outbreak in 2019 in China) reported a high rate of symptoms of depression, anxiety, and insomnia, respectively (54). Moreover, some factors related to the risk of contagion in the organizational workplace and the adoption of preventive procedures [such as the lack personal protective equipment (PPE), the conflict between safety procedures and the desire to provide support, increased and heavy workload with multitasking as well as longer working hours, negative emotion of patients, distance of families, and fears of infection for themselves and their families] can deeper affect the mental well-being of these frontline healthcare workers during the COVID-19 epidemic (14, 53); and in response, when selecting interventions aimed at supporting frontline health workers' mental health, organizational, social, personal, and psychological factors might all be important reported in a systematic review (55), and thus, multiple organizational and work-related interventions (such as improvement of workplace infrastructures, the adoption of correct and shared anti-contagion measures), psychological support interventions (such as counseling and psychology services) and multifaceted interventions were recommended to help mitigate this scenario (53, 55). Furthermore, a systematic review further revealed that young age, and female gender, and heavy workload were the factors increasing the risks of suffering from post-traumatic stress symptoms in healthcare workers dealing with the COVID-19 pandemic (56), whereas negative mental health outcomes were associated with diminished work performance (57), and therefore, hospital managers should also pay more attention to these physicians in "high workload and high self-assessment" subtype, who were younger, female, participated in aiding in the COVID-19 pandemic, and even experienced mental health problems during the COVID-19 pandemic.

As for Classes 1 and 3 of the LPA model, both classes showed a similar pattern for the six dimensions of the Chinese version of physician mental workload scale. Class 1 showed the highest score in the performance dimension and the lowest task load, i.e., the "low workload and low self-assessment" subtype, whereas Class 3 showed a medium level for all mental workload dimensions, i.e., the "medium workload and medium self-assessment" subtype. Compared to those in Class 2, physicians in the two classes had a relatively low level of mental workload, and mainly shared the characteristics of being male, unmarried, older age, better health status, having higher educational level, working in the current medical institution for 1–5 years, working fewer hours per week, working fewer hours per week in outpatient clinics, seeing fewer outpatients per day, but with lower outpatient satisfaction, which indicates that these individuals were more likely to have relatively low outpatient workloads with a lot of room for work performance improvement. According to the characteristics in Classes 1 and 3, hospital managers should consider on the one hand distributing and increasing workloads for these physicians (especially in Class 3), especially when healthcare workers were urgently demanded for participating in aiding in the COVID-19 pandemic, and on the other hand, taking incentive measures to motivate these physicians to improve their work performance and the quality of medical services in outpatient practice.

LIMITATIONS

This study has several limitations. First, although stratified convenient sampling was mainly used to recruit participants, due to the impact of the COVID-19 pandemic, we only employed an online questionnaire platform to collect data, and lower responsiveness was received in some selected hospitals, which may have impacted the generalizability of our conclusions, and thus, we generated a unique two-dimensional code of the electronic questionnaire for each hospital, and the outpatient managers in each selected hospital were invited and volunteered to play the role of the project manager in their hospitals in this survey. Second, data collection was self-reported by participating physicians via the online survey, and as a result, there was no guarantee that the participating physicians filled out the questionnaire just after finishing the provision of the outpatient services in outpatient practice, which might have a recall bias. Third, it is impossible to compare the differences in mental workload and its subtypes between frontline and non-frontline physicians since the question about whether physicians have participated in aiding in the COVID-19 pandemic in China, was not set up in the questionnaire. Fourth, the factors considered to differentiate the three subgroups were mainly based on the demographic variables in the demographic questionnaire, and therefore, further research should consider including more related factors to precisely identify the subtypes of mental workload among physicians.

CONCLUSION

In general, participating physicians in our survey reported high levels of task load but good self-assessed performance while performing communication work tasks characterized by direct patient interaction in outpatient clinics since the normalization of prevention and control of the COVID-19 pandemic in China. About 33.8% of the participating physicians were identified as "high workload and high self-assessment" subtype, compared to 49.7% "medium workload and medium self-assessment" subtype and 16.4% "low workload and low self-assessment" subtype. Great individual variation among distinctive subtypes of mental workload of physicians exists. These findings can help provide a solid foundation for developing targeted interventions for individual differences across physicians regarding their mental

workload. Therefore, we suggest that hospital managers should pay more attention to those physicians with the characteristics of the "high workload and high self-assessment" subtype and strengthen the management of the workload of this subtype of physicians to, in turn, reduce the risks of their mental health problems and maintain their high work performance in outpatient clinics. For physicians in other subtypes, we also suggest that the hospital managers should consider distributing and increasing workloads for these physicians (especially in "low workload and low self-assessment" subtype), especially when healthcare workers were urgently demanded for participating in aiding in the COVID-19 pandemic.

DATA AVAILABILITY STATEMENT

The datasets used and/or analyzed during the current study are available from the corresponding author on a reasonable request. Requests to access the datasets should be directed to hyh288@hotmail.com.

ETHICS STATEMENT

The study was approved by the Ethics Committee of Tongji Medical College of Huazhong University of Science and Technology (No. IORG0003571); written informed consent from the patients/participants or patients/participants legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

YH designed the study, obtained funding, participated in the collection, and performed revisions of the manuscript. DL contributed to the acquisition, analysis and interpretation of survey data, and drafted the manuscript. HC participated in the collection, contributed to the interpretation of the results, and performed revisions of the manuscript. XZ, XW, and JL took part in the investigation and were involved in data cleaning. ZZ and SL were involved in data cleaning and contributed to the interpretation of the results. All authors have read and approved the final version of the manuscript.

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SUPPLEMENTARY MATERIAL

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BRIEF RESEARCH REPORT
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Lower Back Pain as an Occupational Hazard Among Ugandan Health Workers

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Background: Lower back pain is a public health concern affecting 70–85% of the world's population. There is paucity of published data on the prevalence, disability and risk factors for lower back pain among health workers in Uganda.

Objective: To determine the frequency rate (note that is it implicit that frequency is a rate like incidence so including rate seems redundant here. This is bounded by zero and infinity. In contrast, prevalence is bounded by 0 and 1 and is thus a proportion not a rate) of lower back pain and its associated risks amongst health professionals in the Arua District of Uganda.

Methods: Cross-sectional descriptive study of 245 consecutive participants conducted during February-April 2020. We stratified risks as individual or work related and analyzed the data using IBM SPSS version 25. Chi-square was used to measure the significance of association between categorical variables at 95% confidence interval, regarding a $p \leq 0.05$ as significant.

Results: The mean age of participants was 40.87 years ± 8.74 (SD), with female predominance (69.8%). Majority were either general nurses or midwives (64.9%) and more than half had practiced for over 6–10 years. The frequency rate of lower back pain was 39.6% ($n = 97$). Individual factors associated with LBP were; cigarette smoking ($X^2 = 33.040$; $P \leq 0.001$), alcohol consumption ($X^2 = 13.581$; $P \leq 0.001$), age ($X^2 = 14.717$; $P = 0.002$), and female gender ($X^2 = 4.802$; $P = 0.028$). The work related factors significantly associated with lower back pain were: being a nurse/midwife ($X^2 = 9.829$; $P = 0.007$), working in the outpatient department ($X^2 = 49.752$; $P \leq 0.001$), bending ($X^2 = 43.912$; $P \leq 0.001$), lifting ($X^2 = 33.279$; $P < 0.001$), over standing ($X^2 = 40.096$; $P \leq 0.001$), being in awkward positions ($X^2 = 15.607$; P=<0.001), and pushing patients ($X^2 = 21.999$; $P \leq 0.001$).

Conclusion: The frequency rate of low back pain was high amongst health workers and its main associated individual and work related factors could have been prevented. Health workers should strike a balance between caring for their personal back-health and meeting clients' needs while manually handling patients. Ergonomic structuring, job organization, back health care courses and use of assistive equipment could reduce such occupational hazards in our low resourced settings.

Keywords: injury, occupational health, sub saharan Africa, pain, backache

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INTRODUCTION

Lower back pain (LBP) is a global problem of public health importance, affecting 70–85% of the world's population (1). It is a common cause of work-related disability (2). According to Hartvigsen et al. the annual prevalence of lower back pain ranges from 15 to 45%, with a point prevalence averaging 30%. In the United States (US), back pain is the most common cause of activity limitation in people under the age of 45 years and is considered the second most frequent reason for visits to a physician (3). It is also ranked the fifth leading cause of admission to a hospital and the third leading cause of surgical procedures. As such, two percent of the US workforce is compensated for back injuries annually (3). In addition, LBP is reported to be the second leading cause of work absenteeism and results in lost productivity more than any other medical condition (4, 5). According to Hartvigsen et al. (2), the direct and indirect costs attributable to LBP are enormous in terms of loss of quality of life, productivity and employee absenteeism. This condition is thus the single largest contributor to musculoskeletal disability worldwide (6). In the US, it is estimated that over 80 billion US dollars are spent on LBP annually, accounting for over 156 million lost working days and 5.2 million disabilities of which 2.6 million are permanent (2).

In the United Kingdom, it is estimated that 116 million productive days are lost due to LBP and the resulting economic cost is estimated at 12 billion GBP annually (7) whereas in Europe, the direct costs related to LBP are estimated at 7,000 Euros per person per year in Germany (8) and 740 Euros annually in Sweden (9). There is a paucity of retrievable research evidence on economic cost of LBP in Africa. The financial impact of LBP is presumed enormous on the African continent due to its fragile health systems with limited human and infrastructural resource capacity, amidst a dual burden of infectious and non-communicable diseases. The sick leaves related to LBP exert strain on services and staff coverage with absenteeism being identified as an essential indicator of LBP related disability (10). In recent years, medical consultations due to LBP have increased significantly and LBP can be considered a "twentieth-century healthcare disaster" (2).

To date, several studies have revealed a number of risk factors associated with LBP in the general population such as: advanced age, alcohol and drug abuse, family history, gender, level of activity, obesity, poor posture and alignment, smoking; occupational factors such as prolonged standing and sitting, previous back injury plus psychological and social factors (1, 6, 11). Understanding the risk factors for LBP amongst specific population groups is key to guide preventive polices which are tailored to one's occupation. The health sector workforce is one of such special groups that deserves utmost attention, being a core building block for a functional health system. As such, hospital workers have been shown to have higher rates of LBP compared to the general population due to the physical and emotional factors such as stress involved in their occupation (2, 5).

The main occupational risk factors for LBP amongst health workers include: lifting and moving patients, frequent twisting and bending, sustained postures, improper ergonomics of work environment, anxiety, depression, stress, poor job satisfaction, shortage of staff and poor working conditions amongst others (4, 5, 12). However, there is a paucity of published data on the proportion and risks for LBP amongst health workers in low income countries despite resource constraints such as lack of assistive equipment for lifting patients, which requires manual in-patient transfers. Such heavy lifting could lead to physical injuries for instance, involving the vertebral discs, culminating in LBP and restricted movement.

In the end, the limited range of physical movements which results from LBP, can be associated with psychological distress that further intensify the pain, depending on one's coping strategy (13, 14). Indeed, LBP has been linked to psychosocial stress (15), for which cognitive behavioral therapy is being proposed as adjunct in its management (16, 17). According to Bogduk (18), when LBP persists, there is a tendency for the brain activity to switch away from pain circuits to emotional circuits, raising anxiety. Thus, the physical work challenges such as lifting patients manually in low income countries could potentially aggravate the existing psychosocial stress already posed by COVID-19 infections amongst health workers (19), yet mindfulness-based stress reduction (20) is an under-developed field of LBP control and less studied in low income settings compared to higher income (17, 21).

Despite this, few studies have been conducted on LBP amongst health workers in low income countries in the African region which implies an under-estimation of the global burden of LBP. In a systematic review on prevalence of chronic LBP worldwide, only one of the 25 original population-based cross-sectional studies were from Africa (Nigeria), the rest of studies being largely from Europe, Americas, and Asia (22). This indicates how this subject matter is under-researched on the African continent. Inadequate attention on this topic in Africa may be attributed to the outsized impact of infectious diseases which has resulted in the shift of funding priorities within health research to this area (23). According to Morris et al. (23), the mean point prevalence of LBP amongst the adult population in Africa is estimated at 39% whereas chronic LBP ranges from 51 to 63%. In addition, hospital-based statistics show that LBP accounts for 30–40% of visits to rheumatologists in Africa (24) and that much of this burden has been linked to poor back care ergonomics and unavailability of lifting equipment (25). However, the these studies have been disproportionately conducted in South Africa and West Africa (Nigeria) (23) while underrepresented in East Africa.

In Uganda, the point prevalence of LBP amongst health workers was last estimated more than a decade ago at 20% in a hospital-based study at the National Referral Hospital, Mulago (26), partly attributed this to the high levels of perceived stress. Such stress due to LBP is further aggravated by a significant reduction in activities of daily living such as recreation, sleep and sex (27). Ugandan public hospitals have shortages of health workers due to limited health care professionals training capacity and health workforce emigration to the private sector and overseas (28). This in turn, has resulted in increased workloads for staff in public health facilities, thus predisposing them to LBP. Consequently, the impact of absenteeism from duty due

to LBP of the already understaffed health workforce in Uganda, underscores the need to better address this problem. This study is therefore aimed at generating current data on the frequency rate and the specific risk factors for LPB among health workers in the Arua District of Uganda. We defined LBP as self-reported pain at the time of the study, that lasts for $\geq$ 3 months in the area between the twelfth ribs and gluteal folds. The 3-months period case definition was chosen so to minimize recall bias and had been validated in previous studies (23).

METHODS

Study Design

This was a cross-sectional descriptive study of 245 consecutively recruited health professionals who consented to the study during 1st February 2020–30th April 2020. A multi-center prospective randomized control trial would have provided more generalizable results, giving all endangered health workers equal chance to participate in the study. However, the cost-prohibitive nature this methodology and the ethical implications of consenting participants to exposure variables leading to the outcome of LBP in the present study were key constraints. On the other hand, the low accuracy of paper-based data capture health systems in Ugandan settings would significantly impact data quality for a retrospective cohort (29). Consecutive sampling while sub-optimal, was deemed suitable for our study population that was presumed to be fairly homogeneous with respect to the underrepresented group of health workers in resource limited low-income settings, to offer a narrower but clear generalizability in a context described by Jager et al. (30).

Study Settings

The study was conducted amongst health workers at Arua Regional Referral Hospital located in the Arua District of Uganda (03′001′10″N; 30′054′45″E). This is a 272 bed capacity, public tertiary and teaching hospital for Arua School of Nursing which serves 8 districts in Northern Uganda and referrals from neighboring parts of southern South Sudan and the Democratic Republic of Congo.

Eligibility Criteria

Any health worker at the Arua Regional Referral Hospital who was willing to participate in the study. We excluded health workers with a documented history of physical injuries such as those resulting from road traffic crash, falls from height and those with congenital musculoskeletal deformities such as kyphosis and scoliosis that were presumed to influence the dependent variable (LBP) (31, 32).

Sample Size Determination

To determine the frequency rate of LBP amongst health workers at the Arua Regional Referral Hospital, we used the Kish-Leslie formula (33) to determine the sample size. Based on a prevalence of LBP of 20% reported in a previous study in Uganda (26), a margin error of 5% and a standard normal deviation of (1.96) corresponding to the 95% confidence interval; the sample size that is required for validating the findings was 245 participants. To probe the potential risk factors for LBP, it was deemed unnecessary to calculate a sample size for the purposes of demonstrating a valid association between LBP with each of the individual variables of interest, since this exploratory study intended to report findings that could allow for defining possible associations with the final result (LBP) but not casual inference.

Study Procedure

Each consenting participant was asked to complete a pre-designed survey questionnaire to collect information on the independent socio-demographic variables, self-reported LBP as the dependent variable and its presumed risk factors as the other independent variables. The independent variables were stratified into two categories: personal or occupational (work-related). Personal variables included age, sex, body mass index, cigarette smoking and alcohol consumption whereas occupational factors included ergonomic structuring, job organization, department, cadre of the health personnel, ergonomics of the work environment, working hours and availability of assistive equipment to lift patients. All these factors had been previously found in the literature to be associated with LBP amongst health workers (4, 5, 12, 25).

Data Processing and Analysis

We analyzed the data using IBM SPSS 25.0 statistics for windows (Armonk, NY, USA, IBM Corp). The participants' age groups were stratified based on the fact that disability amongst patients with LBP had been highest amongst the 30–50 years age group. Galukande et al. (27). Percentages were computed to determine the frequency rate of LBP. Cross tabulation and Chi-square tests were performed to screen for potential associations with the main outcome variable LBP. Chi-square and correlation tests are known precursor to multivariate analyses in the exploratory research (34) such as the present study. Logistic regression models resulting from forward-selected stepwise procedures were used for variables with $p < 0.1$ at bivariate analysis, to determine which factors were associated with LBP. The level of significance was set at $P < 0.05$ at the 95% confidence interval.

Quality Control

The questionnaires were pre-tested amongst staff at Kampala International University Teaching Hospital in a similar setting so to ensure clarity. The questions that showed ambiguity during pre-testing were revisited and accordingly modified. A test-retest reliability coefficient of $\geq$ 0.9 was observed and considered to be excellent for this measure.

Ethical Consideration

Ethical approval was obtained from Kampala International University Western Campus, School of Biomedical Sciences, Faculty of Clinical Medicine and Dentistry (Ref: BMS/0100/151). Following approval, an introductory administrative letter was issued to the participating health facility in the Arua District. Written informed consent was obtained from the participants before their enrollment into the study. The study followed the Uganda National Council for Science and Technology (2014) guidelines on conducting research involving participating human subjects.

TABLE 1 | Sociodemographic characteristics of respondents.

Characteristics	Frequency	Percent
Age		
<30	33	13.5
30–39	54	22
40–49	126	51.4
50+	32	13.1
Gender		
Female	171	69.8
Male	74	30.2
Cadre		
Nurse/Midwife	159	64.9
Allied health	77	31.4
Doctor	9	3.7
Cigarette smoking		
No	196	80
Yes	49	20
Alcohol consumption		
No	172	70.2
Yes	73	29.8
Years of practice		
<5	85	34.7
6–10	131	53.5
>10	29	11.8
BMI		
Underweight or normal weight	123	50.2
Overweight	73	29.8
Obese	49	20

TABLE 2 | Bivariate analysis of individual factors associated with LBP.

Variables	Ever suffered		Chi-square	*P*-value
	No	Yes		
Age			14.717	0.002
<30	29 (19.6%)	4 (4.1%)		
30–39	34 (23.0%)	20 (20.6%)		
40–49	65 (43.9%)	61 (62.9%)		
50+	20 (13.5%)	12 (12.4%)		
Gender			4.802	0.028
Female	111 (75.0%)	60 (61.9%)		
Male	37 (25.0%)	37 (38.1%)		
Cigarette smoking			33.04	<0.001
No	136 (91.9%)	60 (61.9%)		
Yes	12 (8.1%)	37 (38.1%)		
Alcohol consumption			13.581	<0.001
No	91 (61.5%)	81 (83.5%)		
Yes	57 (38.5%)	16 (16.5%)		
Years of practice			3.673	0.162
<5	58 (39.2%)	27 (27.8%)		
6–10	75 (50.7%)	56 (57.7%)		
>10	15 (10.1%)	14 (14.4%)		
BMI			0.033	0.855
Underweight/Normal	63 (42.6%)	60 (61.9%)		
Overweight	48 (32.4%)	25 (25.8%)		
Obese	37 (25.0%)	12 (12.4%)		

RESULTS

A total of 245 participants responded to the survey with a response rate of 100%. The frequency rate of LBP among the sample was 39.6% ($n = 97$). The mean age of participants was 40.87 (8.74 SD) years with a majority (51.4%) in the 40–49 years age group. The participants were predominantly females (69.8%) and the majority of these were either nurses or midwives (64.9%) with the smallest proportion being doctors (3.7%). More than half of the participants had been in practice for 6–10 years (53.5%) prior to the study. The majority were neither smokers (80.0%) nor did they consume alcohol (70.2%) and around half (50.2%, $n = 123$) were either underweight or had normal weight as shown in **Table 1**.

Individual Factors Associated With Lower Back Pain

Individual factors associated with LBP were cigarette smoking ($X^2 = 33.040$; $P < 0.001$), alcohol consumption ($X^2 = 13.581$; $P < 0.001$), age ($X^2 = 14.717$; $P = 0.002$), and gender ($X^2 = 4.802$; $P = 0.028$) as shown in **Table 2**.

Work-related factors which were found to be associated with LBP included department ($X^2 = 49.752$; $P < 0.001$), bending ($X^2 = 43.912$; $P < 0.001$), lifting ($X^2 = 33.279$; $P < 0.001$), over standing ($X^2 = 40.096$; $P < 0.001$), being in awkward positions ($X^2 = 15.607$; $P < 0.001$), pushing patients ($X^2 = 21.999$; $P < 0.001$)and professional cadre ($X^2 = 9.829$; P = 0.007) as shown in **Table 3**.

Using the data reduction features of SPSS, we identified the variables which were highly correlated with each other such as alcohol and cigarette smoking and re-ran the logistic output using the forward selection feature of SPSS. When the Cox-Snell R square (0.34) and Nagelkerke R square (0.46) were below the minimum threshold value of 2.5 for flagging multi-collinearity [We should probably note that the formula that relates variance inflation to r squared are generally intended to be applicable in a multiple regression rather than logistic models which do not generate r squares but these pseudo r square tests do help support our overall argument since step-wise procedures also throw out some variables that are highly correlated with others], the individual factors (age, gender and cigarette smoking) and work related factors (ward/department, bending or twisting, lifting, and pulling or pushing) remained strongly associated with the presence/absence of LBP with $P < 0.01$ (**Table 4**).

DISCUSSION

This study established the frequency rate of LBP to be 39.6%. The individual factors (cigarette smoking, alcohol consumption, age, and female gender) and work-related factors (being a nurse/midwife, working in the outpatient department, bending, lifting, over standing, being in awkward positions, and pushing patients) were significantly associated with LBP.

TABLE 3 | Bivariate analysis of work related factors associated with LBP.

Characteristics	Ever suffered LBP		Chi-square	*P*-value
	No	Yes		
			49.752	<0.001
Ward/department				
OPD	62 (41.9%)	36 (37.1%)		
Medical ward	12 (8.1%)	13 (13.4%)		
Surgical	12 (8.1%)	12 (12.4%)		
Theatre	3 (2.0%)	21 (21.6%)		
Maternity	46 (31.1%)	3 (3.1%)		
Orthopedic	13 (8.8%)	12 (12.4%)		
Cadre			9.829	0.007
Nurse/midwife	97 (65.5%)	62 (63.9%)		
Allied health	50 (33.8%)	27 (27.8%)		
Doctor	8 (8.2%)	1 (0.7%)		
Working hours			0.033	0.855
<8 h	75 (50.7%)	48 (49.5%)		
>8 h	73 (49.3%)	49 (50.5%)		
Bending/twisting			43.912	<0.001
Yes	13 (8.8%)	44 (45.4%)		
No	135 (91.2%)	53 (54.6%)		
Lifting			33.279	<0.001
Yes	37 (25.0%)	60 (61.9%)		
No	111 (75.0%)	37 (38.1%)		
Standing for a long time			40.096	<0.001
Yes	13 (8.8%)	42 (43.3%)		
No	135 (91.2%)	55 (56.7%)		
Transferring patients			6.812	0.009
Yes	98 (66.2%)	48 (49.5%)		
No	50 (33.8%)	49 (50.5%)		
Awkward positions			15.607	<0.001
Yes	87 (58.8%)	32 (33.0%)		
No	61 (41.2%)	65 (67.0%)		
Pushing			21.999	<0.001
Yes	88 (59.5%)	28 (28.9%)		
No	60 (40.5%)	69 (71.1%)		

The frequency rate of lower back pain in this study was 39.6% which is higher than 20% previously reported by a study in Mulago Hospital, Uganda (26). Although close to the African average of 41.9% (35), the higher frequency rate of LBP in the present study might depict a rapid shift in the population aging (1), without a concurrent rise in dedicated resources to address this burden. A cross-sectional survey which analyzed work-related musculoskeletal disorders among nurses in Ibadan in South-West Nigeria found a comparable prevalence of lower back pain at 44.1% (25). However, the frequency of LBP in the present study is lower than 56.2% found in a study conducted among healthcare workers in tertiary health institutions in Sokoto, Nigeria (24). The difference in occurrence rates could be due to the fact that the researchers in Nigeria included the entire state (Sokoto) with a relatively larger sample size. High prevalence of lower back pain are reported in other studies across the globe (2, 5). This high occurrence of lower back pain reduces the efficiency of health workers.

With respect to the individual factors, this study found that age was significantly associated with lower back pain. The highest frequency rate (62.9%) was found among the respondents aged 40–49 years contrary to the study by Mitchell et al. (39) that found no association between age and LBP. However our findings concur with a study amongst health workers in Tunisia which found that occurrence of LBP increased with age, with a peak toward 36–46 years (36). The increased burden of LBP in advanced age is presumed to be related to low bone density and comorbidities in this age group, however in this particular study, this might be rather attributable to prolonged duration of exposure to the manual lifting of patients commensurate to one's working experience. This is however controversial as some studies have found higher prevalence of LBP amongst adolescents, for instance in a systematic review by Steffens et al. (11), although authors warn that such pain could persist and become chronic in old age.

On the other hand, LBP could depend on ones' level of physical activity and seating postures which vary with age, with youth spending more sedentary time on electronic devices such as computers and cell phones. In addition to aging, bone density is also significantly correlated with racial background, with persons of African descent having significantly more dense lumbar bones and thus lower rates of bone mass attrition due to aging (37). Despite this however, the occurrence of LBP in African settings is like to be comparable to well-resourced countries given under reporting (38) due to concerns of higher malnutrition and infectious diseases of the spine such as tuberculosis.

In this study, 61.9% of the respondents with LBP were females and this was significant (is there an associated *p*-value with this?). This is similar to findings of other studies (1, 3, 11). In addition, these findings are comparable to the results found in the Ugandan study of health workers at Mulago hospital that reported 68% occurrence rates for female and 32% for males, respectively. Galukande et al. (26). The high frequency rates in females could be attributed to females predominantly taking on the nursing job roles, inclusive of lifting and transfer of patients in addition to extra occupational workload of women in our cultural settings such as household chores and caring for children. Furthermore, an Australian study suggests that the difference in LBP occurrence may be related to the anatomical, physiological and structural differences between males and females (39). The female hormones such pregnancy induced relaxin and low estrogen levels that are associated with the aging process could aggravate the strain on the bony spine (40).

A higher percentage of nurses in the present study were significantly experiencing LBP as compared to other professionals (63.9 vs.36.1%; $P = 0.007$). A Nigerian study by Kehinde et al. (41) and a systematic review and meta-analysis of risk factors of musculoskeletal disorders in hospital workers reported similar results (5, 24). The higher frequency rate of LBP among nurses in this study could be attributed to the fact that nurses are more involved in the manual handling of patients while carrying out nursing roles. The nurses' job description in

TABLE 4 | Forward stepwise regression analysis of factors associated with LBP.

Selection	Variable	Model LL	Change in -2 LL	Df	Sig. of change
Individual factors					
Step 1	Cigarette smoking	−164.474	32.938	1	<0.001
Step 2	Gender	−148.005	19.846	1	<0.001
	Cigarette smoking	−162.099	48.033	1	<0.001
Step 3	Age	−138.082	5.792	1	0.016
	Gender	−146.331	22.29	1	<0.001
	Cigarette smoking	−159.667	48.962	1	<0.001
Work factors					
Step 1	Bending or twisting	−164.474	44.11	1	<0.001
Step 2	Bending or twisting	−147.708	38.943	1	<0.001
	Lifting	−142.419	28.365	1	<0.001
Step 3	Bending or twisting	−132.471	24.864	1	<0.001
	Lifting	−137.426	34.774	1	<0.001
	Pulling or pushing	−128.236	16.395	1	<0.001
Step 4	Ward/department	−120.039	13.938	1	<0.001
	Bending or twisting	−123.87	21.6	1	<0.001
	Lifting	−133.638	41.135	1	<0.001
	Pulling or pushing	−126.592	27.043	1	<0.001

LL, Log Likelihood.

Uganda involves direct patient care for instance moving and transferring patients such as from operating theaters to the wards and transporting material and medical devices (26). However, in other African settings, this might be an issue of workload with a tendency to task shifting where nurses take on both doctors' and nursing roles in the event physicians are under staffed (42).

Unlike results of a study by Oliveira et al. (43), which found LBP higher in smokers, this study found otherwise. Majority of the respondents with LBP (61.2%) had no history of smoking. Smoking is presumed to cause LBP through the effect of nicotine on nerves and mineral density but how it exactly exerts these effect is unclear (44). In a systematic review by Furlan et al. (45), it was concluded that heavy lifting and long standing were more reliable predictors of LBP than smoking. Despite conflicting results on the influence of smoking on LBP, it is generally agreed that smoking is harmful to one's health and could either way predispose to LBP (46).

Ward and department, bending and twisting, lifting patients, standing for a long time and pushing patients during transfer were all work related factors found to be significantly associated to LBP amongst health workers. In their study amongst Nigerian health workers, Sikiru (47) found that manual handling during transfer of patients was a major predictor of LBP. In our settings, most patient handling activities are performed in less than ideal space and in sub-optimal time frames. Besides, it's not uncommon to use faulty trolleys such as one with non-functional tires to transfer patient. According to Tinubu et al. (25), repeated biomechanical strain on the musculoskeletal system may eventually lead to the development of LBP. Thus, the increased proportion of participants with LBP in this study could be the result of poor working posture, the incorrect use of lifting techniques and unavailability of manual handling equipment in the health facilities such as job aids. Heavy physical work, sustained position and lifting have been earlier linked to LBP in a Nigerian study (23). In addition, according to Vermani et al. (48) the risk of developing LBP amongst Japanese nurses involved in manual handling of patients was high compared with nurses who were not involved.

This study found that the majority of respondents who had suffered from LBP were working in the outpatients department and the theater. This is in agreement with Manchikanti et al. (49) in USA who found high frequency rate of LBP among health workers in the outpatient department. This may be partly due to the fact that the outpatients department receives all volumes of patients entering the hospitals whereas theater staff transfer critically ill pre-operative and post-operative patients who need lifting or pushing on the trolleys. Poor back care ergonomics and unavailability of lifting equipment have been previously cited as major predisposing factors to LBP among health workers in Africa (25), but minimal has been done to address this issue. In Ugandan public health facilities, inadequate human resource and infrastructural capacity puts extra strain on the fewer health care providers who manually lift these patients (28), but inclusion of manual patient lifting on the nurses' job description during employment further complicates this issue. It is no doubt that nursing staff and midwives who report lifting, and bending while pushing patients such as those from theater report LBP. Other than the physical impact on their health, LPB could be a strong demotivator that can deter individuals from joining the nursing profession in the future, further limiting human resource capacity in the region.

Study Strengths

The data collection tools were pre-tested for validity. This being a cross-sectional study, the completeness of the questionnaire and overall quality of the data could be easily be controlled.

Study Limitations

The present study was not without limitations. Firstly,the study established the occurrence of LBP amongst health workers without much emphasis on its severity. Secondly, the self-reported nature of the data collection approach could have been affected by social desirability bias hence distorting the results. As such, participants could have under-reported LBP and certain aspects of their working circumstances for job security concerns such as early retirement on medical grounds or rather over report LBP in such a way as to obtain less strenuous departmental tasks. In addition cross-sectional studies like one described do not give a casual inference. Finally, the psycho-social factors that could contribute to LBP such anxiety, stress, depression, job satisfaction were beyond the scope of this study.

CONCLUSION

The frequency rate of LBP amongst health workers was high at 39.6%, mainly affecting those aged 40–49 years, females, and nurses/midwives. In addition, working in the outpatient department, bending/twisting, lifting, and standing for long hours and pushing were associated with a higher risk of LBP. There is urgent need for appropriate assistive devices for manual handling of patients in similar resource constrained settings. Induction courses on lower back care, correct lifting techniques, individual physical exercises and building health public policies for new health worker recruits could mitigate this public health threat. Future research should be multi-center prospective randomized cohort studies to determine the cumulative impact of manual patients handling activities on LBP and the resulting economic implications.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Kampala International University Western Campus, School of Biomedical Sciences, Faculty of Clinical Medicine and Dentistry (Ref: BMS/0100/151). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

MA, AA, and ML conceived and designed the study, performed literature review, analyzed the data, prepared tables, authored and reviewed drafts of the manuscript, and approved the final manuscript. KN conceived and designed the study, analyzed the data, prepared tables, authored and reviewed drafts of the manuscript, and approved the final manuscript. HL conceived and designed the study, performed literature review, analyzed the data, prepared tables, authored and reviewed drafts of the manuscript, supervised, and approved the final manuscript. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2021.761765/full#supplementary-material

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Prevention Practice of COVID-19 Using Personal Protective Equipment and Hand Hygiene Among Healthcare Workers in Public Hospitals of South Wollo Zone, Ethiopia

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Objective: The use of personal protective equipment and hand hygiene are often the most recommended line of defense against coronavirus disease-19 (COVID-19). The purpose of this study is to determine the magnitude of compliance and associated factors of personal protective equipment (PPE) utilization and hand hygiene practice among healthcare workers in public hospitals of South Wollo Zone, Northeastern Ethiopia.

Methods: A hospital-based cross-sectional study was conducted among 489 healthcare workers in public hospitals of South Wollo Zone, Northeastern Ethiopia from June 15 to July 30, 2021. Proportional sample size allocation to each selected hospital followed by simple random sampling techniques were used to select the study participants using human resource records from each hospital. A pre-tested and structured self-administered questionnaire with WHO's standardized hand hygiene and PPE utilization observational checklist were used to collect data. Bivariate and multivariable analyses with 95% CI and p-value < 0.05 were employed to identify the associated factors of personal protective equipment utilization.

Results: About 32 and 22.3% of healthcare workers were compliant with personal protective equipment utilization and hand hygiene practice, respectively. Feedback for safety (AOR = 2.05; 95% CI: 1.26–3.35), training on COVID-19 prevention (AOR = 3.43; 95% CI: 2.01–5.86), and perception to infection risk (AOR = 1.98; 95% CI: 1.18–3.33) were significant factors of good compliance with personal protective equipment utilization.

Conclusion: The magnitude of good compliance with personal protective equipment utilization and hand hygiene was low. Interventions to promote personal protective equipment utilization and hand hygiene should focus on feedback for safety, training on COVID-19 prevention, and perception of infection risk.

Keywords: COVID-19, compliance, hand hygiene, health care, personal protective equipment

INTRODUCTION

The coronavirus (COVID-19) pandemic has overwhelmingly changed the world and, consequently, is changing the conditions of healthcare workers (HCWs) (1). This pandemic is creating profound challenges for healthcare workers and healthcare systems in the world, as the disease is spreading at an alarming rate, surpassing hospital capacities and exposing healthcare workers to a high risk of exposure (2). The outbreak of severe acute respiratory syndrome coronavirus (SARS-CoV-2) was first reported in Wuhan, Hubei province, China, in late December 2019 and has rapidly spread to other countries (1).

SARS-CoV-2 is especially transmitted through droplets and touch (3) especially during airway maneuvers in an infected patient, like during tracheal intubation (4, 5). The majority of people infected with the coronavirus are associated with occupational exposure. COVID-19 could also be the primary new industrial disease during this decade (6). It is believed that the primary occupational groups in danger are persons working in seafood and wet animal markets in Wuhan (3).

As of July 2021, over 206 million confirmed cases of COVID-19, the disease caused by SAR-CoV-2, and close to 4.4 million confirmed deaths were reported by the World Health Organization (WHO) (4). The cumulative number of cases within the African continent is over 6.5 million (6,587,734) confirmed COVID-19 cases which accounts for 3.4% of the total cases reported globally, and 167,183 deaths with a 2.5% fatality rate (4, 5). A global systematic review indicated that a total of 152,888 infections and 1,413 deaths were reported among healthcare workers worldwide. Infections were mainly in women and nurses but deaths were mainly in men and doctors (7).

The people most in danger of infection are those that are in close contact with a COVID-19 patient or who look after COVID-19 patients. Subsequently, healthcare workers are a subsequent high-risk group to accumulate this infection (8). According to OSHA, high-risk workers include those involved in healthcare, death care, laboratories, airline operations, solid waste, and wastewater management and visit areas where the virus is spreading (9).

Since, HCWs are putting themselves at high risk of COVID-19, measures to stop SARS-CoV-2 transmission in healthcare staff are an instantaneous priority (5, 10); therefore, HCWs are required to protect themselves and stop transmission within the healthcare setting (3) since the health and well-being of our healthcare workers determine our nation's health, security, and economic prosperity.

Of concern, doctors are significantly suffering from COVID-19 in Africa, with 14,148 HCWs being infected in many counties since the start of the outbreak. Overall, South Africa has been the foremost affected, with 4,842 (34%) infected, followed by Algeria (2,300), Ghana (2,065), Nigeria (987), Cameroon (593), Senegal (271), Guinea-Bissau (268), Malawi (264), Guinea (244), Côte d'Ivoire (187), Liberia (184), Niger (184), Sierra Leone (168), and Ethiopia (87) (2, 11).

WHO and other national and international public health authorities recommend proper personal protective equipment (PPE) utilization and hand hygiene compliance (3, 5). As a result, any potential transmission can be prevented, thereby HCWs are often protected. Although the foremost effective interventions to protect HCWs are to physically separate HCWs from infectious patients and body fluids, mortality rates of COVID-19-infected patients are often decreased with more aggressive care that needs close contact with these patients (12, 13).

During this setting, adhering to PPE utilization and hand hygiene practice are the last physical barrier between a healthcare provider and infectious body fluids (2, 6). However, there is a big discrepancy concerning access and utilization of PPE and hand hygiene protocols which are not always followed in many medical institutions during COVID-19 patient management.

The speed with which COVID-19 is spreading across the world involves an assessment of the reality of healthcare workers' PPE utilization and hand hygiene during the COVID-19 pandemic (1, 3, 14). Even though hand hygiene is the most critical intervention for protecting HCWs from infections including COVID-19, the compliance rate for hand hygiene has not drastically improved (15). This study aims to determine compliance of personal protective equipment utilization and hand hygiene practice and associated factors among healthcare workers toward the COVID-19 pandemic in hospital settings.

METHODS

Study Setting

South Wollo Zone is one among 10 zones within the Amhara Region of Ethiopia (**Figure 1**).

Based on the 2007 Census conducted by the Central Statistical Agency of Ethiopia (CSA), this zone features a complete population of 2,518,862, an increase of 18.60% over the 1994 census, of whom 1,248,698 are men and 1,270,164 are women in an area of 17,067.45 square kilometers. South Wollo has a population density of 147.58. While 301,638 (11.98%) are urban inhabitants, a further 2,217,224 (88.02%) inhabitants were reported to be rural. A total of 598,447 households were counted in this zone, which can be calculated in a mean of 4.21 persons to a household, and 574,378 housing units. There are seven public hospitals in the South Wollo Zone with a total of 1,051 healthcare workers to serve the catchment population of the South Wollo Zone and the nearby zones especially for the Afar region.

Study Design and Period

A hospital-based cross-sectional study was conducted to assess the magnitude of compliance with personal protective equipment utilization and hand hygiene and its associated factors among healthcare workers in public hospitals of South Wollo Zone, Northeastern Ethiopia from June 15 to July 30, 2021.

Abbreviations: 2019-ncov, 2019-novel coronavirus; AOR, adjusted odds ratio; CI, confidence interval; COR, crude odds ratio; COVID-19, coronavirus disease-2019; CSA, Central Statistical Agency; HCWs, healthcare workers; PPE, personal protective equipment; SARS-CoV-2, severe acute respiratory syndrome-coronavirus-2; SPSS, Statistical Package for Social Science; WHO, World Health Organization.

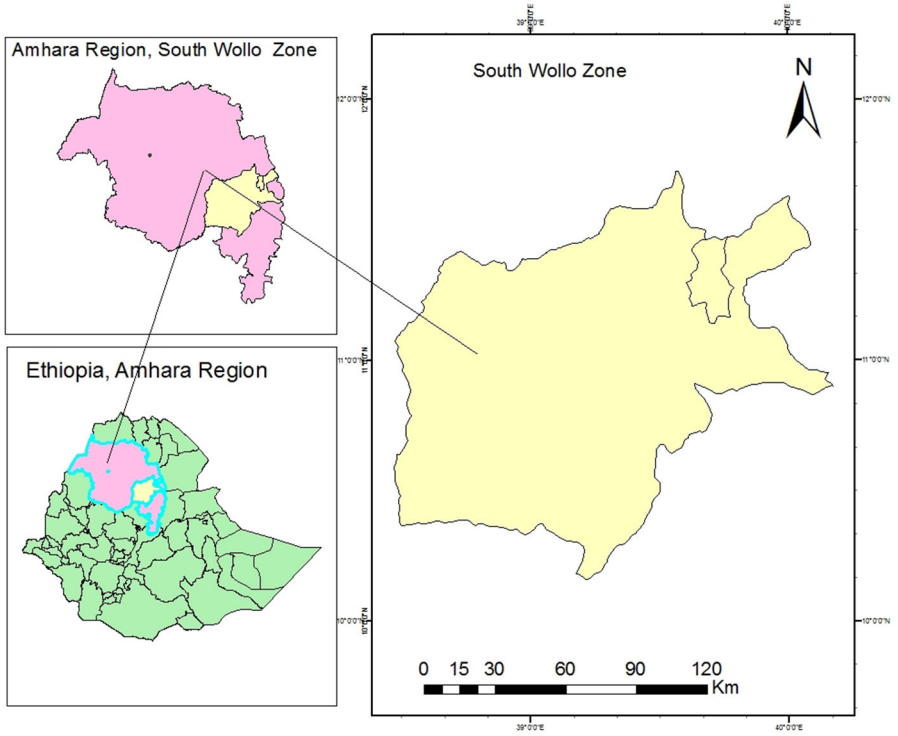

FIGURE 1 | Map of the study area.

Source Population and Inclusion Criteria

The source population of this study was all healthcare workers working in South Wollo Zone hospitals while the study population was all selected healthcare workers in South Wollo Zone hospitals. From the study population, all permanent healthcare workers employed in the hospitals were included in the study.

Sample Size Determination and Sampling Procedure

The sample size was determined using the single population proportion formula with the following assumptions: Magnitude of compliance with standard precaution practice (p = 12%) was taken from a study conducted in Gondar University Comprehensive Specialized Hospital, Northwest Ethiopia (16).

$n = \frac{(Z_{a/2})^2 * p(1-p)}{d^2}$ where **n** is the optimum sample size required**, P** is an estimate of the magnitude of compliance with standard precaution**, Z** is the standard normal variable at a (1-α) % confidence level, α is mostly 0.05, i.e., with 95% CI ($z = 1.96$), and **d** is the margin of error to be tolerated (%).

The determination of the margin of error is based on the optimum sample size and availability of resources considering one percent (1%) giving the largest sample size and 5% giving the smallest sample size. For this study, a margin of 3% was used which was based on the proportion of 12% taken from a similar study mentioned above, which gave an adequate sample size.

$$n = \frac{(1.96)^2 * 0.12(1-0.12)}{(0.03)^2} = 451 \quad (1)$$

After adding a 10% non-response rate the final sample size was $\boldsymbol{n = 496}$**.**

There are seven public hospitals in the South Wollo Zone from which three hospitals were selected randomly. All 496 estimated participants were proportionally allocated to each hospital based upon their respective numbers of healthcare workers. The sample size from each hospital was proportionally allocated based on the types of profession (strata) and numbers of their healthcare workers. The study participants were selected using a simple random sampling method within their strata using human resource records from each hospital.

Dependent and Independent Variables

Dependent Variables

- Personal protective equipment utilization (good compliance/poor compliance).
- Hand hygiene practice (good compliance/poor compliance).

Independent Variables

Socio-Demographic Factors

Age of respondent, sex, marital status, type of profession, educational status and work experience, and respondent working unit.

Institutional Factors
Availability of PPE, presence of COVID guidelines, and feedback for safety.

Behavioral Factors
Infection prevention training on COVID-19, perception of infection risk, drinking alcohol, chewing khat, and hand hygiene practice.

Operational Definition

PPE Utilization and Hand Hygiene Measurement
Compliance was measured using data from direct observations by trained BSc nurses.

Compliance of Personal Protective Equipment Utilization
Good compliance with PPE utilization was considered when the HCW scored more than or equal to the mean score, and a score less than the mean score was taken as "poor compliance" from the observational checklist (17–19).

Hand Hygiene Compliance
Good hand hygiene compliance was considered when the HCW scored more than or equal to the mean score from the observational checklist (20, 21).

Data Collection Tools and Quality Assurance

The data were collected using WHO's standardized hand hygiene and PPE utilization observational checklist (22–24). The observation was focused on six moments of PPE use: wearing a face mask, eye goggle, apron, glove, and gown, while observation for hand hygiene was focused on six domains: washing hands before touching a patient, before clean or aseptic procedures, after body fluid exposure, after touching a patient, immediately after removal of gloves, and between patient contact. Before actual data collection, six observers (BSc nurses) and three supervisors (public health experts) were trained for two days in accordance with WHO hand hygiene and PPE utilization techniques focused on each item on the observational checklist plus additional time for observing the practice and considering ethical issues. After training, a pre-test was conducted on 25 healthcare workers in nearby Woldeya Hospital, North Wollo Zone, Ethiopia.

During observation, the data collectors directly observed the study participants while the HCWs conducted clinical examinations on patients. The observation was made on nine units in the selected hospitals: emergency room, pediatrics ward, delivery/gynecology ward, medical ward, surgical ward, operation theater unit, laboratory, radiology unit, recovery, outpatient department (OPD), and a physiotherapy room. Along with standing concern with clinical observation is the Hawthorne effect, in which study subjects' awareness of being observed causes them to alter their behavior. To minimize such bias, data collectors were coached to observe discretely in which the HCWs were unaware of the research activities. Some days after the completion of observation, a self-administered pretested structure questionnaire was distributed to the same HCWs to collect other required information such as socio-demographic, institutional, and behavioral factors. Three public health experts supervised the data collection process including observation and completeness of questionnaires by giving daily feedback to data collectors before data entry.

Statistical Analysis

Data were entered using EpiData version 3.1 and exported to Statistical Package of Social Science (SPSS) version 25.0 for data cleaning and analysis. Once the data were entered, basic quality assurance measures including data cleaning using browsing of data tables after sorting, frequency distributions, and cross-tabulations and summary statistics using sorting were performed. Descriptive statistics were used for socio-demographic characteristics and mean ± SD (standard deviations) for continuous variables. Continuous variables were categorized using information from the literature, and categorical variables were re-categorized accordingly.

Bivariate (crude odds ratio [COR]) and multivariable (adjusted odds ratio [AOR]) values were calculated using logistic regression analysis with a 95% confidence interval [CI]. From the bivariate analysis, variables with $p < 0.25$ were considered as candidate variables for multivariable analysis and AOR was determined after adjusting for the availability of PPE, feedback for safety, training on COVID-19 prevention, perception to infection risk, drinking alcohol, and chewing khat using the backward stepwise method. From the multivariable logistic regression analysis, variables with a significance level of $p < 0.05$ were taken as statistically significant and independently associated with compliance with personal protective equipment utilization. The presence of multi-collinearity among independent variables was checked using standard error at the cutoff value of 2. Model fitness was checked using the Hosmer-Lemeshow test which had a p-value > 0.05.

RESULTS

Socio-Demographic Characteristics of the Respondents

A total of 489 healthcare workers were observed and completed the survey with a response rate of 98.6%. More than half of the participants were women which accounts for 276 (56.4%), nearly half 238 (48.7%) of the HCWs were married, and the majority of the participants 292 (59.7%) were nurses. About two-thirds 343 (70.2%) of the respondents had Bachelor degrees and 367 (75.1%) of the respondents had >10 years of work experience (**Table 1**).

Institutional and Behavioral Factors

More than three-quarters 381 (77.9%) of the healthcare workers had personal protective equipment in their working department and nearly three-quarters 361 (73.8%) reported having COVID-19 guidelines as a working protocol for COVID-19 management but less frequent feedback for safety 390 (79.8%) was given by the infection prevention officers. Even though, nearly two-thirds 300 (61.3%) of the HCWs had a perception of infection risk, only half 256 (52.4%) of healthcare workers had taken training on COVID-19 prevention and control (**Table 2**).

TABLE 1 | Socio-demographic characteristics of healthcare workers in public hospitals of South Wollo Zone, Northeastern Ethiopia, 2021.

Variables	Category	Frequency (n)	Percentage (%)
Sex	Male	213	43.6
	Female	276	56.4
Age of respondent	19–30	156	41.9
	31–40	172	46.2
	41 and above	44	11.8
Marital status	Currently unmarried	251	51.3
	Currently married	238	48.7
Respondent working unit	Emergency room	33	6.7
	Pediatrics ward	45	9.2
	Delivery or gyn ward	81	16.6
	Medical ward	68	13.9
	Surgical ward	22	4.5
	Operation theater unit	42	8.6
	Laboratory	63	12.9
	Radiology unit	32	6.5
	Recovery	33	6.7
	OPD	53	10.8
	Physiotherapy room	17	3.5
Educational status	Certificate	70	14.3
	Diploma	76	15.5
	BSc	199	40.7
	Medical doctor	107	21.9
	MSc/specialist	37	7.6
Work experience in years	>10 years	367	75.1
	5–10 years	95	19.4
	<5 years	27	5.5
Types of profession	Nurses	292	59.7
	Medical doctor	122	24.9
	Laboratory	39	8.0
	Other allied HCWs	36	7.4

TABLE 2 | Institutional and behavioral factors of healthcare workers in public hospitals of South Wollo Zone, Northeastern Ethiopia, 2021.

Variable	Category	Frequency (n)	Percentage (%)
Availability of PPE	No	108	22.1
	Yes	381	77.9
Presence of COVID guidelines	No	128	26.2
	Yes	361	73.8
Feedback for safety	Less frequent	390	79.8
	More frequent	99	20.2
Training on COVID-19	No	233	47.6
	Yes	256	52.4
Perception to infection risk	No	189	38.7
	Yes	300	61.3
Drinking alcohol	No	391	80.0
	Yes	98	20.0
Chewing khat	No	423	86.5
	Yes	66	13.5

TABLE 3 | Compliance of PPE utilization measurement indications among healthcare workers in public hospitals of South Wollo Zone, Northeastern Ethiopia, 2021.

PPE use indications	No	Yes
Wearing facemasks	244 (49.9%)	245 (50.1%)
Wearing eye goggles	333 (68.1%)	156 (31.9%)
Wearing aprons	331 (67.7%)	158 (32.3%)
Wearing gloves	170 (34.8%)	319 (65.2%)
Wearing gowns	184 (37.6%)	305 (62.4%)
Overall PPE utilization compliance	Poor compliance	333 (68.1%)
	Good compliance	156 (31.9%)

TABLE 4 | Proportion of HCW compliance with PPE utilization by professionals in public hospitals of South Wollo Zone, Northeastern Ethiopia, 2021.

Professions	PPE utilization			
	Good compliance		Poor compliance	
	Frequency	Percentage	Frequency	Percentage
Nurses	107	21.88%	185	37.83%
Doctors	28	5.73%	30	6.13%
Laboratory	9	1.84%	94	19.22%
Other allied HCWs	12	2.45%	24	4.92%
Total	156	31.9%	333	68.1%

Personal Protective Equipment Utilization

In the routine care of patients in the healthcare setting, most HCWs reported that they always wear FFP2/N95 facemasks (245, 50.1%), gowns and gloves were used for routine care among 305 (62.4%) and 319 (65.2%) HCWs, respectively while 156 (31.9%) HCWs used eye goggles and aprons independently. According to this study, the overall number of HCWs who were compliant with personal protective equipment utilization was found to be 156 (31.9%) (95% CI: 27.9–36.6) (**Table 3**). Furthermore, the least compliant healthcare workers were laboratory professionals followed by nurses and doctors (**Table 4**).

Hand Hygiene Measurement Domains

The potential range of cumulative hand hygiene domain score was 0–6, and we assessed a mean score of 3.56 ± 1.31. According to the observational result, only one-third 153 (31.3%), more than half 269 (55.0%), and much more than three-quarters 427 (87.3%) of them practiced hand washing before touching a patient, before clean or aseptic procedures, and after body fluid exposure, respectively. Moreover, 157 (32.1%), 429 (87.7%), and 176 (36.0%) HCWs practiced hand washing after touching a patient, immediately after removal of gloves, and between patient contact, respectively. The overall number of HCWs who had good compliance with hand hygiene was found to be 294 (22.3%) (95% CI: 18.8–26.0) (**Table 5**).

TABLE 5 | Hand hygiene domains among healthcare workers toward COVID-19 in public hospitals of South Wollo Zone, Northeastern Ethiopia, 2021.

Domains	No	Yes
Washing hands before touching a patient	336 (68.7%)	153 (31.3%)
Washing hands before clean or aseptic procedures	220 (45.0%)	269 (55.0%)
Washing hands after body fluid exposure	62 (10.2%)	427 (87.3%)
Washing hands after touching a patient	332 (67.8%)	157 (32.1%)
Washing hands immediately after removal of gloves	60 (12.3%)	429 (87.7%)
Washing hands between patient contact	313 (64.0%)	176 (36.0%)
Overall hand hygiene compliance	Poor compliance	380 (77.7%)
	Good compliance	294 (22.3%)

Factors Associated With Personal Protective Equipment Utilization

The adjusted logistic regression analysis result indicated that feedback for safety (AOR = 2.05; 95% CI: 1.26–3.35), training on COVID-19 prevention (AOR = 3.43; 95% CI: 2.01–5.86), and perception to infection risk (AOR = 1.98; 95% CI: 1.18–3.33) were significantly associated with compliance of personal protective equipment utilization (**Table 6**).

DISCUSSION

The present study assessed compliance of personal protective equipment (PPE) utilization and hand hygiene practice among 489 healthcare workers toward COVID-19 in public hospital settings in which findings of the present study are very essential to prevent the spread of COVID-19 (25, 26). Because HCWs are the frontline to prevent and control COVID-19, they are at high risk of contracting an infection and can transmit the virus to patients, families, and the community easily (5, 27).

This study result revealed that overall adherence to PPE utilization among healthcare workers was low. The observed utilization of PPE in this study was more frequent than the study findings from Nigeria (28), Gondar, Ethiopia (16), and India (29) in which HCWs who always complied with appropriate use of PPEs ranged from 4.3 to 18.1%. However, it was lower than systematic reviews studies conducted in industrialized countries on compliance with hand hygiene in hospital care: in intensive care units (30–40%), in other departments (50–60%), among physicians (32%), and nurses (48%) (30) and more than 50% in the emergency department (31).

The main reason for low adherence to PPE utilization in this study may due to lack of training about the use and function of PPE utilization for COVID-19 and other disease prevention methods (only half of HCWs reported that they received infection prevention training since the COVID-19 outbreak emerged). Training on infection prevention especially for COVID-19 can enhance compliance of PPE utilization and hand hygiene practice (32) and can reduce the perception of risk (33). Besides, insufficient time, carelessness, discomfort, forgetfulness, lack of habit, and perception of low risk of infection might be other factors for low compliance in PPE utilization.

Hand hygiene is the most essential protective measure to prevent infection, especially SARS-CoV-2. However, the overall compliance of hand hygiene practices among healthcare workers was low. A worldwide systematic review indicated that the overall compliance rate of hand hygiene in hospital care was 40% (30). In this study, lower compliance of hand hygiene practice was reported among doctors (18.9%) than nurses which may be influenced by lack of positive role models and perception of intensified dryness and soreness of hands. It might also be due to the inconvenient placement of the hand rub or sink, no hand rub in the dispenser, or no soap at the sink, being distracted by medical emergencies, low perception of hand hygiene importance to prevent infections, and low safety culture with no feedback for safety.

This study finding also indicated that lack of training on COVID-19 prevention can decrease compliance of PPE utilization among HCWs by more than three-fold (AOR = 3.43). This means that HCWs who had training on COVID-19 prevention were 3.43 times more likely to use the personal protective equipment compared to HCWs who had no previous training on COVID-19 prevention. It is similar to those earlier results found in studies done in Amhara regional state (34), Ethiopia (35), Egypt (36), Tanzania (20), and Italy (33).

Healthcare workers who received frequent feedback on safety practices by institutional management had more than two-fold (AOR = 2.05) higher compliance with PPE utilization. Compliance can be increased through personal or management supervision, instruction, and audit performance by providing feedback for safety (37). This finding is also supported by evidence that HCWs with a good perception of infection risk were nearly two times (AOR = 1.98) more likely to comply with PPE utilization in line with studies done in Addis Ababa, Ethiopia (38), and Italy (33). This indicated that increased perception of infection risk toward COVID-19 might empower HCWs to adhere to PPE utilization against the disease.

CONCLUSIONS

Healthcare workers' compliance on personal protective equipment utilization and hand hygiene practice was inadequate in the public hospitals of South Wollo Zone. The multivariable logistic regression analysis result indicated that feedback for safety, training on COVID-19 prevention, and perception to infection risk were the main predictor variables for compliance of personal protective equipment utilization.

These study results indicate the imperative need for decision-makers to address low compliance on personal protective equipment utilization and hand hygiene practice among HCWs in hospital settings. These findings should inform strategies designed to increase training on COVID-19 prevention and

TABLE 6 | Factors associated with personal protective equipment utilization among healthcare workers toward COVID-19 in public hospitals of South Wollo Zone, Northeastern Ethiopia ($n = 489$).

Variable	Category	PPE Utilization		COR (95%CI)	AOR (95%CI)
		Poor compliance	Good compliance		
Availability of PPE	No	70	38	1.22 (0.79–1.87)	1.63 (0.93–2.85)
	Yes	263	118	1	1
Feedback for safety	No	281	109	1.42 (0.84–2.43)	2.05 (1.26–3.35) *
	Yes	52	47	1	1
Training on COVID-19	No	120	113	4.66 (3.08–7.07)	3.43 (2.01–5.86)*
	Yes	213	43	1	1
Perception to infection risk	No	96	93	1.42 (0.95–2.13)	1.98 (1.18–3.33)*
	Yes	237	63	1	1
Drinking alcohol	No	275	116	1.64 (1.04–2.58)	0.99 (0.44–2.07)
	Yes	58	40	1	1
Chewing khat	No	297	126	1.96 (1.16–3.33)	1.07 (0.44–2.60)
	Yes	36	30	1	1

This analysis was adjusted for availability of PPE, feedback for safety, training on COVID-19 prevention, perception to infection risk, drinking alcohol, and chewing chat.
**Indicates variables significantly associated with PPE utilization at 95% CI.*

management support for safety to change the behavioral determinants of compliance with the relevant practices. We strongly urge national governments, the private sector, and the general public to pay concerted attention to healthcare worker safety.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The study was conducted in accordance with the Helsinki declaration. The ethical approval letter was obtained from the Institutional Ethical Review Committee of the College of Medicine and Health Sciences of Wollo University with the issue number CMHS/368/13/21. Furthermore, before data collection, written consent was obtained from each healthcare worker. Before data collection, the purpose of the study was explained to all participants and they were assured that their information would not be used for purposes other than scientific research. Participants were informed that participation would be voluntary and that they could withdraw at any time for whatever reason. Confidentiality was maintained by avoiding possible identifiers such as the names of the study participants. Only identification numbers were used as a reference.

AUTHOR CONTRIBUTIONS

AK, AA, and MA contributed to the conception and design of the study. AK and AA conducted the investigation. AK, AA, TS, ML, and MA performed data management and analysis. AK, AA, GB, and MA wrote and edited the manuscript. All authors contributed to the article and approved the submitted version.

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CASE REPORT
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Acute Respiratory Distress Syndrome Caused by Occupational Exposure to Waterproofing Spray: A Case Report and Literature Review

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Background: Acute respiratory distress syndrome (ARDS) is a serious respiratory disease, caused by severe infection, trauma, shock, inhalation of harmful gases and poisons and presented with acute-onset and high mortality. Timely and accurate identification will be helpful to the treatment and prognosis of ARDS cases. Herein, we report a case of ARDS caused by occupational exposure to waterproofing spray. To our knowledge, inhalation of waterproofing spray is an uncommon cause of ARDS, and what makes our case special is that we ruled out concurrent infections with some pathogens by using metagenomic next-generation sequencing (mNGS) as an auxiliary diagnosis, which presents the most comprehensive etiological examination of similar reports.

Case Presentation: A previously healthy 25 years old delivery man developed hyperpyrexia, chest tightness, cough and expectoration. The symptoms occurred and gradually exacerbated after exposure to a waterproofing spray. The chest computed tomography (CT) finding showed diffuse ground glass and infiltrative shadows in both lungs. The diagnosis of ARDS related to waterproofing spray was established on the basis of comprehensive differential diagnosis and etiological examination. The patient achieved good curative effect after proper systemic glucocorticoid therapy.

Conclusions: The diagnosis and differential diagnosis of acute respiratory failure for outdoor workers, such as delivery drivers or hikers, should be considered whether toxic aerosol exposure exists from daily contacts. The case can educate the public that more attention should be paid to avoid exposure to these chemicals by aerosols/ingestion mode and some preventive strategies should be taken in occupational environment. The treatment effect of glucocorticoids is significant in ARDS patients with general chemical damage caused by inhaling toxic gases and substances.

Keywords: ARDS, occupational exposure, waterproofing spray, mNGS, glucocorticoids, case report

INTRODUCTION

Acute respiratory distress syndrome (ARDS) is characterized by refractory hypoxemia and progressive respiratory failure, caused by severe infection, trauma, shock, inhalation of harmful gases and poisons (1–3). Timely identification and diagnosis, accurate assessment of disease severity, and early initiation of therapy will improve prognosis (4). Integrated therapeutic strategies of ARDS include treatment of primary disease, prone position ventilation, lung protective ventilation strategy, extracorporeal membrane oxygenation, short-term of neuromuscular blockers and glucocorticoid (3, 5–7). Prognosis of patients suffering with ARDS depends on the primary diseases, complications, effect of treatment and drug-related adverse reactions.

Inhalation injury is an acute respiratory tract damage, caused by direct thermal injury, carbon monoxide poisoning, or toxic chemical inhalants including mist, fumes, and gases (8). ARDS caused by inhalation injury of occupational exposure should paid more attention to, especially for outdoor workers, such as delivery man or cleaner. Most of the time they need to work outside, even in rainy days. Therefore, it is necessary to make waterproofing process on footwear during outdoor activities. Waterproofing products can be impervious to water or dirt by using coat textile fabric, leather or solid surfaces. These products consist of three key parts: a water repellent, a solvent and a propellant (9). The inescapable truth is that these products may lead to acute lung injury after frequent and continuous contact (10–12). Herein, we report a case of ARDS caused by occupational exposure to waterproofing spray. This is a rare case which excluded the possibility complicated with specific pathogens by metagenomic next-generation sequencing (mNGS) as an auxiliary diagnosis, which presents the most comprehensive etiological examination of similar reports.

CASE PRESENTATION

On November 7, 2020, a previously-healthy 25 years old delivery man was sent to the emergency room with hyperpyrexia and chest tightness for about 22 h, accompanied by cough and expectoration. Through case history inquiry, we known that he applied a homebred waterproofing spray (about 100 mL) to his shoes in a bathroom 6 h prior to symptom onset, being exposed to terrible smells and poor ventilation room. He smelt pungent odor when inhaled directly some of the spray. Additionally, he smoked 10 cigarettes a day for 5 years. He had no history of drinking and neurological or psychiatric disorders. Family members of the patient were in good health. There was no history of hereditary diseases, preexisting sensitivity or pulmonary disease, such as asthma, pneumonia, tuberculosis, cardiovascular diseases, infectious diseases, and surgical interventions. The patient with low flow oxygen presented stable vital signs by a bedside ECG monitor [heart rate (HR) 71/min, blood pressure 126/69 mmHg, SpO_2 97% (91% in room air), respiratory rate (RR) 22/min]. General physical examination and specific check-up for the rest body system revealed no abnormality. Listening to the chest with a stethoscope revealed diminished respiration of bilateral lung.

TABLE 1 | Laboratory data of the patient after admission.

Laboratory test	Results	Reference value
Complete bloodcount		
WBC	32.35	3.50–9.50
Neut	29.25	1.80–6.30
Lym	1.39	1.10–3.20
Mon	1.68	0.10–0.60
Eos	0.00	0.02–0.52
Bas	0.03	0.00–0.06
RBC	4.77	4.30–5.80
Hb	148	130–175
Hct	0.442	0.400–0.500
PLT	253	125–350
Serologic tests		
CRP	12.3	0.0–10.0
PCT	8.66	0.00–0.10
d-dimer	0.28	0.00–0.50
Blood gas analysis		
PH	7.40	7.35–7.45
pO_2	66	80–100
pCO_2	34	35–45
$HCO3^-$	20	22–28
BE	−1	−3 to +3
PaO_2/FIO_2	220	400–500

WBC ($\times 10^9$/L), whitebloodcells; Neut, neutrophils; Lym, lymphocytes; Mon, monocytes; Eos, eosinophils; Bas, basophils; RBC ($\times 10^9$/L), redblood cells; Hb (g/L), hemoglobin; Hct, hematocrit; PLT ($\times 10^9$/L), platelets; CRP (mg/L), C-reactive protein; PCT (μg/L), Procalcitonin; G test, Fungi 1-3β glucan test; pCO_2 (mmHg), partial pressure of carbondioxide; pO_2 (mmHg), partial pressure of oxygen; $HCO3^-$ (mmol/L), bicarbonate; BE (mmol/L), baseexcess.

On admission, the routine blood test revealed total leucocyte count of 32.35×10^9/L, of which neutrophile granulocyte count of 29.25×10^9/L (90.4%), and procalcitonin (PCT) level of 8.66 ng/ml. C-reaction protein (CRP) level of 12.3 mg/L. There is no obvious abnormality of his blood serum chemistries and fibrin d-dimmer test, shown in **Table 1**. Blood gas analysis revealed PH 7.4, pO_2 66 mmHg, pCO_2 34 mmHg, $HCO3^-$ 20 mmol/L, BE −1 mmol/L. $PaO_2/FIO_2 = 220$ (**Table 1**). His lung CT scan images revealed diffuse ground glass and infiltrative shadows (**Figure 1A**). But there were no evidences of immunosuppression and pathogens with sputum culture and blood serum test, such as bacteria, fungus, EB virus, CMV virus and so on. His antinuclear and vasculitis antibodies tests were normal. Electrocardiogram showed sinus rhythm. Admission chest x-ray of the patient demonstrated a decreased transparency in both lung field, and there were no signs of cardiomegaly and pleural effusion (**Figure 1C**). We also used fluorescence bronchoscope to obtain bronchoalveolar alveolar lavage fluid (BALF) for mNGS. The results of the mNGS were compared with four microbial genome reference sequence databases downloaded from the National Center for Biotechnology Information, which included the whole genome sequence of 1,798 DNA viruses, 6,350 bacteria,

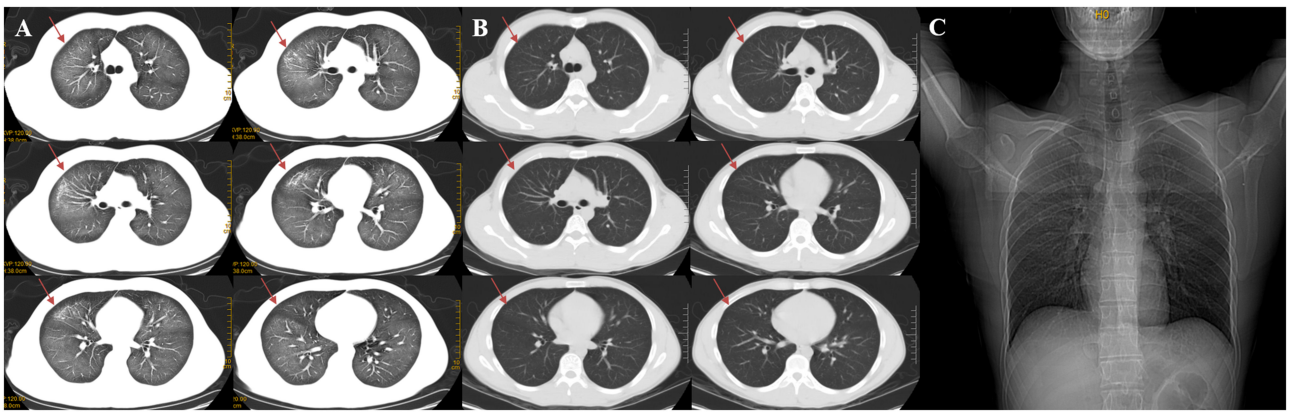

FIGURE 1 | Changes of chest CT before **(A)** and after treatment **(B)**, a CT contrast of marked absorption of the lesion after 3 days of treatment. Admission chest X-ray of the patient **(C)**. **(A)** The chest CT scan demonstrated diffuse ground-glass opacity and infiltrative shadows. **(B)** After 3 days of using prednisone acetate, the chest HRCT revealed marked absorption of the pulmonary lesions. Red arrows show that the lesions in both lungs were absorbed. **(C)** Admission Chest X-ray of the patient demonstrated a decreased transparency in both lung field, and there was no signs of cardiomegaly and pleural effusion.

and 1,604 fungi and 234 parasites genome sequences associated with human infection. The results of mNGS exhibited *Dialister pneumosintes* (sequence number 46) and *Dialister invisus* (sequence number 36) which can often isolate from the mouths of animals and even humans (13, 14). They are usually considered as conditional pathogens of immunocompromised individuals and rarely seen in immunocompetent patients, so these pathogens were considered to be contaminating or colonizing bacteria (**Table 2**).

Immediately on admission, based on the present and past history, age, clinical manifestations, physical examination and comprehensive auxiliary examinations, such as arterial blood gas analysis, a cardiogenic pulmonary edema was excluded and a preliminary diagnosis of mild ARDS was established. The patient was treated with moxifloxacin (400 mg given intravenously once a day), Cotrimoxazole (1,440 mg given orally every 8 h), oseltamivir (75 mg given orally twice a day), and terbutaline 1 mg (oxygen atomizing inhalation twice a day). We stopped anti-infective therapy after mNGS test, on account of lacking of etiological evidence. The recommendations from evidence-based medicine point out that a low dose of methylprednisolone 0.5–1 mg/kg body weight/d for mild ARDS (5). The total dosages of methylprednisolone were calculated based on the bodyweight of the patient (54 kg). And then the dosage of methylprednisolone (0.5 mg/kg body weight/d × 54 kg = 27 mg/d) was converted into the equivalent dosage of prednisone (27/4 × 5 = 33.75 mg/d). Subsequently, prednisone acetate (10 mg given orally three times a day) were started. The patient was afebrile and felt better after corticosteroid therapy. After 3 days of using prednisone acetate, the chest HRCT revealed a marked decrease of diffuse ground-glass opacity and infiltrative shadows (**Figure 1B**). The changes of neutrophil count, neutrophil proportion and white blood cell count had a continuously declining trend, which finally were close to normal. We decided to discharge the patient, and continued prednisone acetate for 10 days (10 mg given orally twice a day for 5 days and then 10 mg given orally once a day for 5 days). The patient treatment process is shown in **Figure 2**. During 12 weeks of follow-up, the patient was asymptomatic and was doing well. CT scans showed normal parenchyma of the lungs. Further follow-up observation is underway to research long term prognosis of ARDS patients involved in toxic inhalation.

TABLE 2 | Etiological examination results.

Etiological examination	Results	Reference value
COVID-19 DNA	–	–
CMV DNA	–	–
EBV antibody		
Ig A &Ig M	–	–
Ig G	+	–
Mpn IgM	–	–
Cpn IgM	–	–
Lpn IgM	–	–
Rickettsia IgM	–	–
INFA&INFB IgM	–	–
RSV IgM	–	–
PIV IgM	–	–
ADV IgM	–	–
Sputum culture	–	–
Sputum smear for AFB	–	–
BALF mNGS	*Dialister pneumosintes* (46*)	
	Dialister invisus (36*)	

*–, negative; +, positive; COVID-2019, Corona Virus Disease-2019; CMV, Cytomegalovirus; EBV, Epstein-Barr virus; Mpn, Mycoplasma pneumonia; Cpn, Chlamydia pneumonia; Lpn, Legionella pneumophila; INFA, Influenza A Virus; INFB, Influenza A Virus; RSV, Respiratory syncytial virus; PIV, Parainfluenza virus; ADV, Adenovirus; AFB, acid-fast bacillus; BALF, Bronchoalveolar lavage fluid; mNGS, Metagenomic next-generation sequencing. *The number of mNGS squences.*

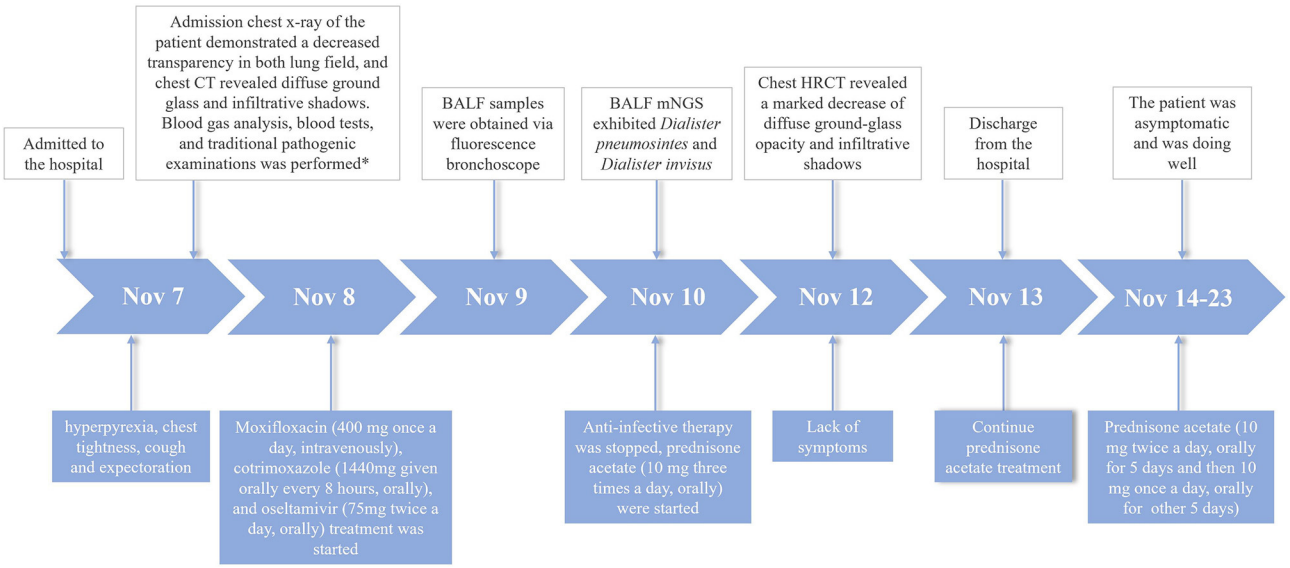

FIGURE 2 | Case history of the patient with ARDS caused by occupational exposure to waterproofing spray. *The blood tests included complete bloodcount, serologic tests (c-reactive protein, procalcitonin, d-dimer); Traditional pathogenic examinations included sputum culture, nucleic acids of respiratory pathogens, sputum smear for acid-fast bacillus, and laboratory investigations of respiratory pathogens serum antibody.

DISCUSSION

We reported the case of a 25-year-old man diagnosed as ARDS just due to inhale toxic aerosol and ruled out concurrent infections with some pathogens by using metagenomic next-generation sequencing (mNGS) as an auxiliary diagnosis. ARDS and acute lung injury (ALI) were confirmed according to Berlin criteria and the American-European Consensus Conference on ARDS, respectively (15). In this case, we given the diagnosis of mild ARDS according to ARDS Berlin's criteria. The diagnosis was based on following diagnostic criteria: ① Symptoms of the patient appeared in ∼6 h after using of the waterproofing spray, and exacerbated in the second day (<1 week). ② The CT scan revealed diffuse ground-glass opacity and infiltrative shadows, and there were no evidence of cardiogenic factors causing the symptoms and radiographic results. ③ The oxygenation index was from 200 to 300 ($PaO_2/FIO_2 = 220$). The inhalation of waterproofing spray was confirmed as the causative factor according to the evidence of comprehensive etiological examination while the evidence of microbial pathogenic background proved to be non-existent by mNGS. Rapid development of mNGS in recent years showed promising and satisfying application in medical microbiology. mNGS is a high-throughput sequencing technology that has broken the limit of traditional pathogen detection methods and allows for hypothesis-free, culture-independent pathogen detection directly from biological samples, including cerebral spinal fluid, blood, urine, and BALF samples (16). ALI/ARDS can result from various pathologies including sepsis, microbial infection, trauma or ischemia/reperfusion, with rapid progress and high mortality. Bacterial and viral respiratory infections (including secondary bacterial infections after an initial viral infection) are the most common etiological factors of respiratory failure including ALI and ARDS. It is crucial to figure out whether it is initiated by pathogenic bacteria based on the results of mNGS during the diagnosis and treatment processes of ARDS, which is linked to antibiotic administration, changes in therapy, or discontinuation of antibiotic therapy. In this case, the differential diagnoses just from the chest imaging manifestation should include viral pneumonia, hypersensitivity, drug-induced damage, acute eosinophilic types of pneumonia, and opportunistic infections (17). Thus, we performed mNGS to identify possible pathogens of the patient, and the results suggested that the lung lesions were uncorrelated with infectious factors.

The pathophysiologic hallmark of ARDS is alteration of increasing pulmonary vascular leakage, leading to pulmonary edema, in which protein-rich fluids flood the alveolar spaces, impair gas exchange, and culminate in respiratory failure (18). The pathogeny of ARDS in this case may be consistent with the typical pattern of chemical pneumonitis, in which infiltration of neutrophils into the alveoli and pulmonary interstitium leads to the acute inflammatory response that generally occurs 4–6 h after the insulting event. Chemical pneumonitis, as a common complication, often occurs after inhalation of toxic fumes or gases. The initial pathological events confined to the distal airway are results of cellular toxicity of the inhaled agent which disturb the impermeability of alveolar capillary interface. Severe pulmonary edema will inevitably occur and gas exchange will also be impaired due to absence of intact alveolar interface. The pulmonary edema presents a rapidly progressive development after a latent period and the severity tends to depend on inhaled dose. From mild alveolar infiltrates to diffuse alveolar damage

eventually leads to ARDS (19). According to previous study, even a single exposure can lead to long term sequelae like reactive airway dysfunction syndrome (RADS), bronchiolitis obliterans, or bronchiolitis obliterans with organizing pneumonia (BOOP) (20, 21).

The first similar case was reported in the US, and a consumer who contacted with 1,1,1-trichloroethane-based products suffered from acute respiratory failure (20, 22). Approximately 20 reports about various waterproofing agents resulting in different health effects have been described in the past 38 years (23). The complex composition of spray products and the toxicity of waterproofing aerosol spray are associated with fluorinated compounds (24, 25). A smaller particle size will allow the product to reach deep into the lungs, even to the alveoli and respiratory bronchioles that are covered by a thin liquid film of lung surfactant. The toxicity will be reduced if the particle size of fluoropolymer fumes increased (26). Aerosol particles with a diameter 10 μm aerosol have been confirmed to be risk factors for chemical pneumonitis (27). The waterproof sprays involved in this case are mainly composed of fluorocarbon resin, synergist, organic solvent, diluent, heptane solvent, which are consistent with previous researches. This finding can remind us that we should pay more attention to products which contain fluorinated compounds in daily life.

A systemic corticosteroid is usually administrated for the treatment of ARDS (28). Moreover, timely inhaled corticosteroids and beta-2 agonists may slow the progression by reducing lung inflammation and enhancing alveolar fluid clearance in ARDS patients (29). Only single-center study and small randomized trial demonstrated a certain effect of different dose of glucocorticoids in ARDS (5, 30). In our case, low-dose prednisone acetate played an important role in the treatment of waterproofing spray-related ARDS. However, more multicenter trials of high-dose glucocorticoids used in ARDS patients are restricted, because the increasing doses of glucocorticoids are associated with adverse reactions (28). Effective pharmacologic treatments need to be further explored directly targeting lung injury in ARDS patients (29).

CONCLUSION

We should consider whether toxic gases and substances are inhaled for outdoor workers who present with unexplained respiratory symptoms during the daily diagnosis and treatment process. Glucocorticoids have been shown to be effective to the inhaled chemical damage. For the public, especially for outdoor workers, precaution should be taken to avoid damage of occupational exposure. Therefore, the popularity of targeted occupational health care education still needs to be strengthened.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Medical Ethics Committee of Anhui Provincial Hospital. The patients/participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

MF, C-MF, L-JC, and J-QZ contributed to the conception and presentation of the case report. L-JC, J-QZ, and D-QX provided clinical expertise and interpretations. L-JC and J-QZ performed the fluorescence bronchoscope to collect BALF sample. MF and J-QZ analyzed the sequencing of mNGS. L-JC, J-QZ, D-QX, MF, and Z-MJ overall management and treat the patient. MF wrote the first draft of the report. C-MF contributed to manuscript revision. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.830429/full#supplementary-material

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The Role of Psychological Capital and Work Engagement in Enhancing Construction Workers' Safety Behavior

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Objectives: Construction is one of the unsafe industrial sectors, causing a considerable amount of harm to its workforce and organizations globally. Only a handful of research evidence has been found evaluating individuals' cognitive and engagement-related constructs to improve occupational safety. Psychological Capital (PsyCap) can have a promising impact on construction workers' psychological health, possibly leading to positive performance. Limited studies have tested PsyCap and work engagement regarding safety specifically in the context of the construction industry, with non-harmonious findings.

Methods: The proposed framework was assessed through the structural equation modeling (SEM) technique along with bootstrapping for mediation analysis. Responses were collected from different states of Malaysia from 345 construction workers. PsyCap dimensions (hope, efficacy, resilience, and optimism) were measured in connection with safety compliance and safety participation, with the mediating role of work engagement.

Results: According to findings, hope, optimism, and work engagement have a positive and significant impact on safety compliance. Also, hope, self-efficacy, resilience, optimism, and work engagement have a positive and significant impact on safety participation. Further, self-efficacy and optimism both have a positive impact on work engagement.

Conclusions: PsyCap can be a possible predictor for work engagement, which may enhance safety-related behavior. PsyCap should be treated as a multidimensional instrument to enhance occupational safety. In-depth deliberation is needed by the organization while applying PsyCap to enhance employees' work engagement as well as safety behavior. Practical interventions based on interactive training are proposed to enhance construction industry safety. Other industries can also adapt suitable dimension(s) of PsyCap to safety behavior improvements.

Keywords: psychological capital, work engagement, safety performance, safety compliance, safety participation, construction industry

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INTRODUCTION

Occupational health and safety issues are an utmost concern for every industry in today's complex and demanding work environments. Out of many industries, the construction industry is the one that has witnessed occupational accidents and injuries at large (1, 2). According to the US Bureau of Labor Statistics (3), around 1,102 fatalities were recorded in the construction industry, only in the year 2019 with an injury rate of 2.8 cases per 100 full-time workers, which is quite worrying. Specifically talking about the Malaysian construction industry, unfortunately, there were around 616 deaths reported from the year 2015 to 2020 only out of 2,000+ officially reported cases, which is a point of great concern for this sector (4). The occupational health condition in Malaysia's construction industry is not exceptional in contrast to worldwide occupational accident data, since this sector is reaching high heights even globally (5–7). The surge in occupational accidents in the construction industry stimulates researchers and academics to offer and evaluate new views, with a particular focus on employee safety behavior. According to the literature, human behavior is responsible for around 80% of occupational accidents, making it the most prevalent causal factor (8–10).

Certain physical, organizational, and psychological aspects may impact the cognitive mechanism behind an employee's safety behavior, although human behavior is unpredictable and may be influenced by both internal and external stimuli (11). Out of many organizational concepts, positive organizational behavior introduced the concept known as PsyCap which is widely utilized in the safety research discipline (12–16). The concept of PsyCap has been widely utilized in connection with employees' behavior, positive performance and satisfaction (17, 18), work systems & performance (19), wellbeing, and learning climate (20), job satisfaction, and organizational citizenship behavior (21) and employee attitude (22).

PsyCap is used as multidimensional a variable in some of the past studies (23, 24). Only a few of the researchers have empirically tested PsyCap through its sub-dimensions regarding safety behavior in the different cultural contexts for the construction industry (15). There prevails incongruities in prior researches and allowed us to explore PsyCap in the Malaysian construction industry. Further, the Malaysian construction workforce faces an environment that is riskier and contains performance pressure and psychological strain, which may negatively govern the psychological conditions of construction workers (25). Consequently, it would be useful to assess if the PsyCap of employees will modify their safety behavior and how the intervention of PsyCap can enhance safety performance overall. More empirical evidence will add value to the utility of PsyCap and its sub-dimensions to predict the behavioral phenomenon.

Referring to the possible outcomes of PsyCap (26), According to the literature, PsyCap, a person-oriented component, is necessary to enhance employee job engagement. Workers with higher levels of Psycap (hope, self-efficacy, resilience, and optimism) are more engaged and productive at work, leading to positive organizational behavior and job satisfaction. Luthans et al. (17), so engaged behavior is expected more often. Some of the studies in past have examined the predicting role of PsyCap for work engagement in different contexts alongside diverse variables i.e., leader and followers' Psycap (27), authentic leadership, fellowship (26), organizational socialization, and leader's PsyCap (28), self-leadership, mindfulness, and PsyCap (29).

Another individual aspect to look upon safety is the involvement and engagement of the workforce deployed. Boeldt (30) stated that an engaged workforce is a safe workforce, emphasizing the importance of an engaged workforce at the workplace. Prior literature also upholds that organizations that surpassed the performance standards are driven by their engaged workforce (31). Engagement at work is defined by having characteristics like vigor, dedication, and absorption (32) and continuous demonstration of them by employees. Before this, work engagement has been associated with variables like Training perceptions (33), engagement and performance (34), daily job demands and fatigue (35), proactive work behavior (31), and job demands, job resources, & burnout (32).

To specify the motivation behind this research, we would like to highlight the following. Using the meta-analytic approach for the construction industry, Xia et al. (36) highlighted the future theoretical avenues under the job strain domain, shifting the conventional wellbeing phenomenon toward the employee's flourishing state of work engagement and a work-related sense of wellbeing that needs to be explored further. The stem of the researchers also presented the conceptual model, representing work engagement as the possible predictor for safety behavior, which yet requires empirical testing in the construction industry (37). However, the quantitative evidence to predict the safety behavior through the work engagement as mediator is still non-existent and allowed us to explore this phenomenon in the Malaysian context. Further, the impact mechanism of work engagement and PsyCap in connection with safety behavior remains to be explored from the multidimensional perspective. To bridge this gap, our study is intended to assess the impact of sub-dimensions of PsyCap on the safety behavior of employees working in the construction industry. Moreover, the mediating role of work engagement will also be assessed, which in harmony with PsyCap may collectively enhance the safety performance of the construction industry. One of the first contributions of this study toward the body of knowledge would be to better understand the predicting role of PsyCap's sub-dimensions for work engagement and ultimately the safety behavior of employees, specifically in the construction industry. Secondly, this study will also shed some light on the multidimensional perspective between PsyCap and safety-related outcomes i.e., highlighting the importance of each dimension of PsyCap independently. Lastly, it will uncover the mediating mechanism of work engagement between PsyCap and safety performance. Our findings may lead to the better operationalization of psychological and behavioral mechanisms to strengthen safety performance for organizations.

LITERATURE REVIEW

Psychological Capital

Psychological capital is defined as an individualistic state or aptitude that an individual develops during his/her development and growth. According to some researchers, individuals' PsyCap can be measured, enhanced, and leveraged for better performance outcomes (17). PsyCap is comprised of three different perspectives. Posited by Letcher (38), for the first perspective, an individual's characteristics are the outcome of the interaction between the environment and the personality inheritance from his/her ancestors. This capacity is further elaborated through the five-factor model comprised of, neuroticism, extraversion, openness, agreeableness, and conscientiousness of an individual. The second perspective states that PsyCap is a state that can be utilized to foresee and enhance individual performance (17, 24, 39). The last perspective states that PsyCap is comprised of both individual psychological abilities and characteristics, and its augmentations are possible through interventions of other measures and are relatively stable (40). It is not surprising to have differences in the different dimensions of PsyCap ranging from two to five (23, 24, 41–43). Out of all sub-dimensions of PsyCap, Luthans et al. (44) emphasized four elements i.e., hope, efficacy, resilience, and optimism which are commonly referred to as HERO.

To elaborate on each dimension further; Hope, is an individual's motivation to attain the desired goal, and in the case of non-attainment of the desired goal, hopeful individuals tend to find new and different ways to achieve them (17, 45). Elements like clear goal setting, active participation, advanced preparation, practicing flexibility, cognitive exercises and realignment of goals can increase individual hope (46). The second dimension is Self-efficacy, a personal conviction that an individual possesses to achieve the desired outcomes. Efficacious individuals know their resources, where this self-belief comes from prior experiences, individual mastery, knowledge acquisition, constructive feedback, and psychological reinforcement. Self-efficacious individuals tend to know how to use their psychological and motivational resources for goal attainment which is the outcome of /her social beliefs, prior experiences, learning, and feedback from others (17, 47).

The third dimension is Resilience, referred to as the ability of an individual to stay strong and ambitious in adverse scenarios, and even after seeing any failure or unforeseen and abrupt situations (17). Persistent and tenacious individuals can easily catch up with swiftly changing environments, and they are not only able to recoup from failures, but they have the tendency to absorb criticism and excerpt key learnings (39, 47). Further, the literature states that the resilience of an individual can be augmented through prior evaluation of the associated risks, resources at hand, and a deep understanding of the processes.

The last dimension of PsyCap is Optimism, which is commonly known as an individual's ability to attribute positivity to the ongoing. Optimistic individuals do not indulge themselves with their past for a prolonged period, rather they work on making the present moment more productive, actively seek better alternatives, hold practical views, and maintain flexibility in their thoughts (47). According to Luthans et al. (39) optimistic individuals hold an explanatory style, as they tend to explain situations themselves internally. An optimistic individual is more inclined toward the assessment of causes and clues to ascertain positive emotions and due to the excessive emphasis on analysis and judgments, the optimistic individual is expected to make better choices (17).

Work Engagement

According to Schaufeli et al. (48), work engagement is an effective, motivational work-related state of an employee, which is made up of characteristics like vigor, dedication, and absorption. Engaged employees have higher degrees of energy, are passionate about their work, and are mostly found deeply submerged into work that their time flies by unnoticeably (49, 50). One of the qualities of engaging workers is that they enjoy challenges and show strong mental resilience, the ability to face challenges while enjoying as well as deep indulgence in their work. Prior literature from the healthcare sector highlighted that, the medical staff was able to take good care and patients were more satisfied when they encounter engaged employees, which not only boosted their performance but overall work effectiveness and quality of care was improved (31).

Work engagement also results in improved interpersonal relationships amongst employees, which in turn fosters a work environment. Together with improved interpersonal relations, work engagement is expected to foster a proactive attitude amongst employees which will ultimately lead to better organizational performance. Macey and Schneider (49) differentiated work engagement into three subcategories i.e., trait engagement (positive view of life and work), state engagement (feeling of energy absorption and effectiveness), and behavioral engagement (extra-role behavior). To relate work engagement with safety performance we will be opting for state and behavioral engagement perspective, as safety performance is comprised of safety compliance (in role behavior) and safety participation (extra-role behavior). The reason why work engagement is of such interest to our study is that it is not just a matter of simple satisfaction with work or at work, loyalty to company or employer, but it is way beyond, as the employees who are engaged are passionate and so committed that they almost invest themselves to help the organization succeed.

Another interesting fact about work engagement is that it fosters happiness and work enjoyableness, where it is not an external reward, but employees tend to work more toward their internal satisfaction by looking at the tasks positively even when they are expected to face strain (51). One of the most prominent reasons to link work engagement with safety behavior is the promising outcome of organizational citizenship behavior (52), which in turn will enhance organizational effectiveness.

Safety Behavior

Safety behavior is the outcome of actions initiated by employees when they encounter any safety-related situation in an organization. In other words, we can say that safety behavior is the actual safety performance through employees which

takes place in the occupational settings (53). Historically, safety performance was assessed via lagging indicators (past incidents/accidents), injury rate, mortality rate which had some shortcomings (54–59). Christian et al. (60) highlighted that relying too much on lagging indicators is expected to produce biased outcomes for the organization as it uses past data. More importantly, lagging indicators do not provide prompt or warnings for safety incidents. Griffin and Neal (61) described safety performance as the work-related behavior of an employee which is related to organizational safety. Griffin and Neal identified two sub-dimensions of safety behavior known as safety compliance and safety participation, which are quite similar to general job-related performance.

Safety Compliance is the in-role behavior, which is supposedly required by employers when they encounter and safety-related situations. It is comprised of those mandatory or required actions which are enforced through policy or part of standard operating procedure. Precise actions which come under safety compliance are, following safety policy, wearing personal protective equipment (PPEs), listening to what the organization says about safety at the workplace. In parallel to this concept, Safety Participation goes beyond safety compliance, where the involvement of employees to participate in safety is voluntary and self-initiated (61). It is not embedded in their roles and neither its part of their responsibility officially, yet they tend to participate in such efforts, which in turn overall facilitates the safety performance of and organizations. Specific actions related to safety participation are, giving suggestions and feedback to enhance safety, encouraging others to learn, act and perform safety, actively learning and participating in safety training, highlighting the possible safety-related issues to organizations, and stewardship behavior (62). Safety participation is an extra-role behavior that is voluntary (63).

We adopted the definition and dimension of safety behavior developed by Griffin and Neal (61). Prior literature in high-reliability organizations or high-risk industries affirmed that safety compliance and safety participation can be associated with occupational accidents (60, 63, 64). For example, the relation of safety compliance with safety procedure and near-miss was negatively related (65). Another researcher identified that prosocial safety behavior and proactive social behavior can also reduce the number of accidents (66). There is no doubt about the risk associated with the construction industry, safety compliance and safety compliance can perform a pivotal role in accidents and injury reduction (67, 68). All in all, research on these two dimensions of safety behavior in the construction industry may contribute meaningfully to the enhancement of occupation safety. Through this research, PsyCap as an antecedent to safety behavior will be assessed for the construction industry of Malaysia.

Psychological Capital and Safety Behavior

According to the literature, employees' performance at work, satisfaction, and organizational citizenship behavior can be predicted and positively influenced by PsyCap (23, 39, 69). For instance, Avey et al. (23) highlighted that job satisfaction and positive outcomes can be achieved through PsyCap. According to Luthans et al. (17), the effect of sub-dimensions of PsyCap may vary on performance outcomes, satisfaction with the job, happiness at work, and organizational commitment e.g., hope, as it may have a stronger impact than the rest of other dimensions. As it is widely accepted that PsyCap positively influences job performance, but its effect on safety performance may result in showing different patterns, because of the contextual difference in the task and their applicability (60). There are different views about the direct and indirect effects of PsyCap on safety performance. Some state that PsyCap has a direct effect on performance (18), whereas others suggest that PsyCap has an indirect on safety through the mediation of motivation (60). Contrary to aforesaid, some scholars believe that PsyCap may have both direct and mediated effects on performance (70).

It has been proven through research that the greater exhibition of PsyCap can result in stronger individuals who can handle difficulties (71). To elaborate on theoretical assumptions associated with PsyCap, we will be opting for Social Cognitive Theory, coined by Bandura's (72) propositions. Social Cognitive Theory states that behavior is not only modified or influenced by the environment but can be affected through an individual's psychological perception, which partially relies on an individual's characteristics (73). PsyCap is a unique resource that is based on an individual's positive psychological state. As a result, this unique ability of the individuals helps them generate positive behavior and attain acceptable performance. Being a prominent sign of an individual's psychological situation, PsyCap can be defined as one's "self-evaluation." Keeping aforesaid in view, it is defensible to say safety behavior, one of the components of work-related behavior will also be influenced by employees' PsyCap, and thus the following hypotheses are formed to be tested:

H1 Hope is positively associated with safety compliance and (H2), safety participation.
H3 Self-Efficacy is positively associated with safety compliance and (H4), safety participation.
H5 Resilience is positively associated with safety compliance (H6), safety participation.
H7 Optimism is positively associated with safety compliance (H8), safety participation.

Psychological Capital and Work Engagement

PsyCap is a multidimensional construct that can be linked with a variety of variables. Hope is one of the dimensions that is widely known to be goal pursuance which resembles the engagement dimension called vigor (74). According to literature, hope is not something that acts as a contributor toward work engagement, but it becomes essential to have some, where its absence may lead to confused employees. Posited by Maslach et al. (75), burnouts are the main outcome of employee low hope, where individuals with no hope will face a deficient amount of willpower to embrace a new challenge, resulting from difficulty in finding a way out in difficult situations. The second dimension is self-efficacy, where efficacy, can be described as an employees' conviction or belief in one's self about the capability to deploy their motivation and psychological resources to successfully execute tasks at hand (76).

Prior studies have examined and demonstrated the direct as well as the indirect influence of self-efficacy on job engagement, indicating the path that individuals' involvement takes, hence PsyCap is one of the determinants of work engagement (77, 78). Optimism, which reflects individuals' capacity to see the bright side of the current and future events and connect them to performance results. According to the literature, cynical people are less optimistic, but optimism can assist reduce the effect of cynicism and increase devotion, as well as reduce the negative impact of various stresses (51, 79). It is the presence of optimistic ideas about a positive conclusion in one's mind that allows him/her to be more psychologically open, allowing the individual to absorb its surroundings and, as a result, lead to a higher degree of engagement (80). In general, optimism relates more to engagement components like dedication and absorption (74).

Luthans (42), described resilience as the individual's capacity to react concerning abrupt or significant circumstances. Whereas, the job demand resource model attributed resilience with persistence. Psychological resources act as a repository that provides resources like resilience for motivation and works engagement, which depicts an individual's vigor or robustness (74). According to the literature, resilience can work as a backup or extra source which can mitigate the excessive negative impact of job demand and burnout. Resilience can be known as one's state which can not only influence the present moment but also help to neglect past stress. Relatedness of resilience with work engagement is proportional, where one's resilience is increased at one side, it would help tackle job demand, stress, and overall control. With this in mind, it is reasonable to assert that resilience is linked to the characteristics of job engagement. Based on the preceding reasoning, it is reasonable to conclude that persons who utilize their PsyCap will achieve good performance, resulting in better work engagement (74), thus the following hypotheses are formed to test the PsyCap effect on work engagement.

H09 Hope is positively associated with Work Engagement.
H10 Self-Efficacy is positively associated with Work Engagement.
H11 Resilience is positively associated with Work Engagement.
H12 Optimism is positively associated with Work Engagement.

Work Engagement and Safety Behavior

There is some empirical and qualitative evidence suggesting the relationship between engagement and work performance in general. For instance, engagement was associated with context and task performance (81). According to prior research, work engagement has proved to be positively influencing workplace outcomes e.g., organizational commitment, satisfaction in life, and organizational citizenship behavior (82–85). It has also been proved through research that employees who are more engaged, tend to see their job more positively and try to be productive, and are more interested in acquiring new knowledge (74). There is continuous arousal for engaged employees which keeps the spark alive for goal setting and attainment. Regarding safety performance, employees who show more engagement with work are more willing to exhibit safety behavior (86). Wachter and Yorio (87) highlighted that engaged employees perform role-specific activities and safety behavior as well. One of the important aspects highlighted by Sulea et al. (34) is that engagement at work results in the utmost dedication and pushes employees to go beyond their normal call of duty or routine work. This aspect of work engagement is quite similar to the safety participation role, which is voluntary and initiated by employees of their own free choice. Engaged employees are more eager to participate in safety because they have higher self-esteem and self-satisfaction. Evidence from previous literature also supports that work engagement is positively associated with safety outcomes (86, 88–90). Based on this discussion, we propose that work engagement will positively mediate the safety behavior of construction workers through the following hypotheses:

H13 Work Engagement is positively associated with safety compliance.
H14 Work Engagement is positively associated with safety participation.

Mediating Role of Work Engagement

There is much to explore about the fruitfulness of work engagement and its related outcomes. Where, the engagement itself is the outcome of resources (provided by the organization) (34), as well as resources held by employees in terms of their traits or characteristics. Prior literature identified PsyCap as a personal resource that has a significant impact on work engagement and it was supported that PsyCap contributes to increasing individual engagement at work (91). Leaving aside the personal resource component, it has been well-investigated and understood that if firms give adequate resources to employees, this, in turn, generates job engagement, which leads to organizational commitment and proactive behavior (34). Considering both ends of work engagement i.e., input (organizational and personal resources) output (organizational commitment, satisfaction in life and organizational citizenship behavior, positive emotions, vigor, dedication, and absorption), we hypothesize that work engagement will mediate the relation between all sub-dimensions of PsyCap and safety behaviors. **Figure 1** depicts the graphical representation of the overall hypothesis of this study:

METHODS AND MATERIALS

Research Design

The research design is the actual action plan that begins with the research questions and ends with the conclusion, as well as the debate and justification that follow, all of which operate simultaneously (92). Some of the study design includes quasi-experimental, longitudinal, and cross-sectional research designs; panel/cohort research designs; and comparative research designs (93). For this study, because all the data was collected at a certain time moment in time, thus this study utilized a cross-sectional research design. A study of the research phenomena and selected variables of our interest was possible using this method of data collection. Accordingly, basic features of an analysis unit (or unit of analysis), respondents (or individuals), sample strategy, data collection (or data gathering), and analysis will be discussed in later sections. Further, our study followed

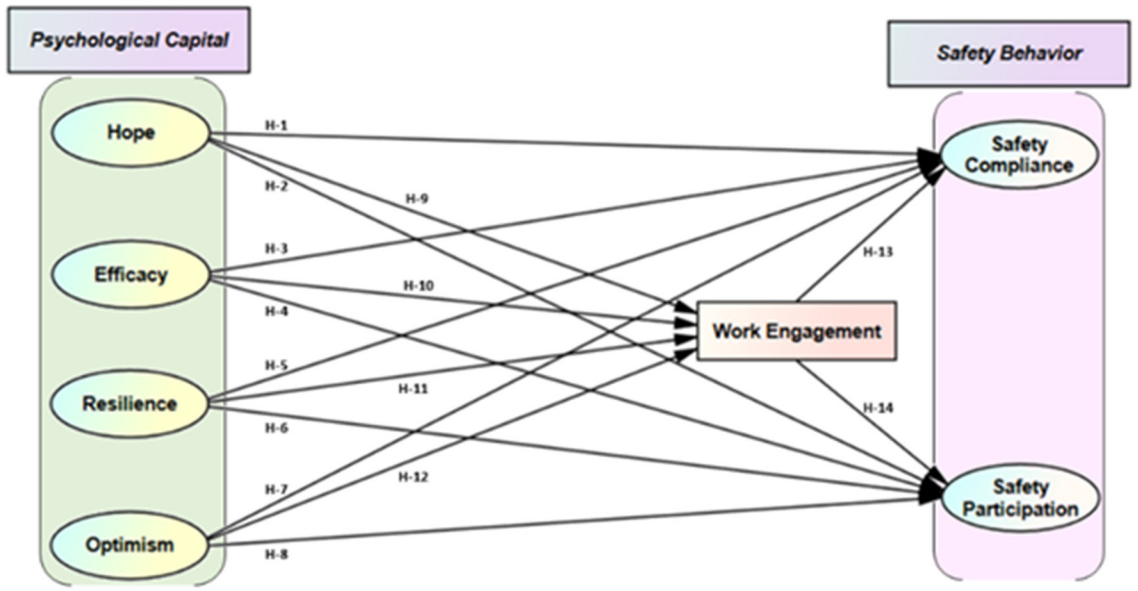

FIGURE 1 | Hypothesized model.

the quantitative paradigm that is in line with the cross-sectional research approach. The reason for opting for the positivist research paradigm is that this paradigm proposes the concepts that are established on facts and figures to better understand and appreciate current reality (94).

Data Collection

The target population for this research was Malaysian construction workers who are at the operative level i.e., working at the proximity of the hazards or they are being the immediate recipient of the possible accident. We opted for non-probability convenience and show-ball sampling technique for our research as we do not have the exhaustive list of our entire population being studied (95, 96). Questionnaires were printed and hard copies were given to workers involved in construction activities e.g., roofers, masons, plumbers, tiles and bricks installers, ironworkers, electricians, pipefitters, and concrete finishers. Questionnaires were usually filled during work intervals, meal brakes and whenever the workers were available during their working hours. Respondents were assisted when they were giving their responses by assisting them to use their thoroughness and answer questions on their own. After completion, they returned the questionnaire to the research team on the ground. It took 15–20 min to fill the survey. Anonymity is the most important aspect while doing any survey and respondents were assured about the privacy and anonymity of their given responses. Respondents were also ensured that the research was conducted for academic purposes only.

Data Analysis

For this study, data analysis was carried out in three different stages through IBM SPSS Version 21, IBM SPSS AMOS Version 21 software. Primarily, we analyzed descriptive and reliability statistics through SPSS 21. Thereafter, confirmatory factor analysis (CFA) was performed using AMOS 21 to test the validity of dimensions i.e., discriminant and convergent validity. For hypothesis testing, SPSS Amos 21 was used. Finally, a structural equation modeling (SEM) with 5,000 bootstrapping tests was conducted to assess the direct and indirect effect of PsyCap on safety behavior as well as the mediated effect of work engagement on safety behavior, an analysis technique commonly utilized (97–100). The measurement model, as well as the structural model, were measured and assessed through different goodness of fit (GOF) indexes e.g., *absolute fit indices* (how well the prior model fits or reproduces the data); RMSEA (root-mean-square error of approximation), GFI (goodness-of-fit index), and AGFI (adjusted goodness-of-fit index), *incremental fit indices* (deviation from the null model of representing factor); NFI (Normed fit index), TLI (Tacker-Lewis index), and CFI (Comparative fit index), and lastly the parsimonious fit indices (assessment of competing model); X^2 (i.e., X^2/degree of freedom) (101). Through aforesaid indices were utilized to assess the multifactor structure of PsyCap, safety performance, and unidimensional structure of work engagement.

Questionnaire Design

There were four different sections for the questionnaire of this research. Those sections were respondents' demographic information, PsyCap, Work engagement, and safety behaviors. Initially, all of the questions/items were discussed with four field research experts from academia. The questionnaire was also shown and discussed with construction industry experts. The purpose of this was to assess whether questions are easily comprehendible and the overall structure is easygoing for the respondents to address face validity. No major changes were made in the instrument structure, where necessary, wording

and text were reviewed and thoroughly studied following the conversational norms and habits of the construction site workers. Initially, four workers were met by the researcher along with an instrument to assess the content validity by discussing the questionnaire with them and observing if they were able to understand the written content.

The average time for questionnaire response was calculated through four respondents. To further enhance the reliability of the responses, overall four questions were reversed randomly, as it helped us in decreasing the socially desirable responding effect (102). For PsyCap, we used a 5-point Likert scale ranging from 01 "strongly disagree" to 05 "strongly agree." For safety behavior, we also used the Likert scale, and respondents were asked to rate their safety performance through preference like 1 "never" to 5 "quite often." For work engagement, a 7-point Likert scale ranging from a Likert scale, from 1 (strongly disagree) to a 7 (strongly agree) scale was used to measure employees' work engagement.

Measures Used

The measure developed by Luthans et al. (39) for PsyCap was used for this study. Utilization of this questionnaire can be observed in various studies (15, 23, 43, 46, 78, 91) especially in the context of the construction industry. PsyCap has four distinct sub-dimension i.e., hope (perseverance to achieve the goal and align when necessary), self-efficacy (confidence in one's self and exerting efforts to succeed), resilience (tendency to bounce back after advertises), and optimism (looking at the bright side through positive attributes). The questionnaire was comprised of a total of twenty-four statements, whereas six statements were assigned to each sub-dimension. example of the statement is "I feel confident analyzing a long-term problem to find a solution," "I usually manage difficulties one way or another at work," "When things are uncertain for me at work, I usually expect the best," "There are lots of ways around any problem."

For work engagement, a scale developed by Schaufeli et al. (48) was used. This scale is a short version of work engagement, which is comprised of nine items. Three dimensions of work engagement are represented through this unidimensional scale e.g., vigor (greater energy level with enough mental resilience), dedication (inspiration and enthusiasm about one's work), and absorption (well-connected and engrossed with work throughout). For the work engagement scale, we used a 7-point Likert scale. Some of the question statements were, "At my job, I feel strong and vigorous," "I am proud of the work that I do," and "Time flies when I am working."

Safety behavior was assessed using one of the renowned instruments developed by Neal and Griffin (64). This scale contains six items including three items for safety compliance (obligatory safety behaviors at the workplace, required formal compliance) and three statements for safety participation (extra-role behavior, not essential to perform, but self-generated behavior in the form of contextual performance). Statements for safety compliance are "I use all the necessary safety equipment to do my job," "I use the correct safety procedures for carrying out my job, "and "I ensure the highest levels of safety when I carry out my job," statements for safety participation are "I promote the safety program within the organization," "I put in extra effort to improve the safety of the workplace" and "I voluntarily carry out tasks or activities that help to improve workplace safety."

Scale for PsyCap and work engagement were adapted according to our research context i.e., construction industry, as the original scales items were generic and not-context specific to our research. We added the connecting statement before the original scale item as highlighted in previous literature as "item alteration" (103). An example of the adapted statements between PsyCap and work engagement is "I am able to positively engage in my work because; I feel confident in analyzing a long-term problem to find a solution" and "I am able to positively engage in my work because; I feel confident in representing my work area in meetings with management." An example of the adapted statement between PsyCap dimension and safety performance is "I am able to exhibit safe behavior at the construction site because; there are lots of ways to solve any problem." Lastly, the example statement between work engagement and safety performance is "I am able to generate positive safety behavior because; at my work, I feel bursting with energy" and "I am able to generate positive safety behavior because; I am enthusiastic about my job."

RESULTS

Demographic Results of the Research

Four hundred fifty questionnaires were filled through 25 ongoing construction projects in six provinces i.e., Kelantan, Johor Selangor, Perak, Penang, Negeri Sembilan of west Malaysia. Out of 450 questionnaires, 407 questionnaires were filled. After the assessment, 62 questionnaires were declared invalid because of inappropriate response marking, missing data, and obvious/odd patterns of responses. The final data was 345 valid questionnaires, which is 76.6% of the overall questionnaire disbursed. The details of the respondents are shown in **Table 1**.

Reliability and Validity Analyses

To test the internal consistency of each construct of the questionnaire, a reliability test was performed. To achieve acceptable reliability in responses, the acceptable value of Cronbach's alpha is 0.70 (104, 105). For all of the seven constructs, Cronbach values ranged from 0.86 to 0.97 (**Table 2**), which shows that our results are robust and reliable.

There are common indicators like construct reliability (CR), standardized factor loadings (SFL), and average variance extracted (AVE) to measure and assess the discriminate validity of the construct being studied. The critical value for aforesaid parameters are, SFL $>$ 0.6, CR $>$ 0.7, and AVE $>$ 0.5 (98, 106). Results of the convergent validity indicators are also shown in **Table 2**, which is reflecting the appropriate power of each item concerning its variables, whereas all variables met threshold criteria, thus demonstrating an acceptable convergent validity. For discriminant validity, the square root of the average variance extracted (AVE) value was compared with the correlation coefficient of other variables (107, 108). Further, if the outcome value is greater than its correlation coefficient then the

TABLE 1 | Demographic information of the respondents.

Main category	Sub-category	Frequency	% of total responses
Gender	Male	294	85
	Female	51	15
Respondent age	18–25	74	21
	26–35	124	36
	36–45	85	25
	45 & above	62	18
Work Experience	<5 year	81	23
	6–10 years	117	34
	11–15 years	86	25
	20 & above years	61	18
Education	Primary	37	11
	Lower secondary	63	18
	Upper secondary	82	24
	Post-secondary	97	28
	Diploma	66	19
States	Perak	64	19
	Johor	48	14
	Kelantan	65	19
	Negeri Sembilan	49	14
	Penang	58	17
	Selangor	61	18

discriminant validity is achieved (reflected in **Table 2**). All of the constructs met this criterion and are depicted in **Table 3**.

Measurement Model

To assess the validity of the measurement model for PsyCap and work engagement constructs, confirmatory factor analysis was performed. Our result indicated a good fit for measurement mode (109). A few of the indices like CMIN (chi-square X^2/degree of freedom), chi-square X^2, comparative fit index (CFI), root-mean-square error of approximate (RMSEA), normed fit index (NFI), goodness-of-fit index (GFI), adjusted goodness-of-fit index (AGFI), Tacker-Lewis index (TLI) (110, 111) were used to assess the measurement model fit for both one factor model of PsyCap, four factor model of PsyCap and one factor model of work engagement. The quality of the one factor model of two measurement models (PsyCap and work engagement) was confirmed, whereas, all of the values for each index were well under the criteria. Results for four fist order factors (primary factors) for PsyCap were; (Hope; $P = 0.012$, RMSEA = 0.062, GFI = 0.981, NFI = 0.985, AGFI = 0.955, CFI = 0.991, TLI = 0.985, and CMIN = 2.38), (Self-efficacy; $P = 0.935$, RMSEA = 0.00, GFI = 0.997, NFI = 0.997, AGFI = 0.992, CFI = 1, TLI = 1.00, and CMIN = 0.402), (Resilience; $P = 0.212$, RMSEA = 0.032, GFI = 0.990, NFI = 0.989, AGFI = 0.974, CFI = 0.997, TLI = 0.995, and CMIN = 1.352), and (Optimism; $P = 0.513$, RMSEA = 0.00, GFI = 0.992, NFI = 0.99, AGFI = 0.982, CFI = 1, TLI = 1.002, and CMIN = 0.912), which showed the best fit model fit for all the dimension of PsyCap.

TABLE 2 | Convergent validity and reliability results.

Constructs	Items	SFL	CR	AVE	α
Hope	H1	0.814	0.92	0.657	0.92
	H2	0.780			
	H3	0.857			
	H4	0.809			
	H5	0.809			
	H6	0.793			
Efficacy	EF1	0.742	0.894	0.585	0.89
	EF2	0.747			
	EF3	0.786			
	EF4	0.782			
	EF5	0.786			
	EF6	0.745			
Resilience	RE1	0.733	0.883	0.557	0.88
	RE2	0.797			
	RE3	0.774			
	RE4	0.716			
	RE5	0.713			
	RE6	0.744			
Optimism	OP1	0.755	0.867	0.521	0.87
	OP2	0.726			
	OP3	0.709			
	OP4	0.695			
	OP5	0.696			
	OP6	0.748			
Work engagement	WE1	0.716	0.907	0.521	0.91
	WE2	0.715			
	WE3	0.723			
	WE4	0.746			
	WE5	0.706			
	WE6	0.719			
	WE7	0.712			
	WE8	0.729			
	WE9	0.730			
Safety compliance	SC1	0.973	0.97	0.92	0.97
	SC2	0.957			
	SC3	0.949			
Safety participation	SP1	0.927	0.94	0.83	0.94
	SP2	0.902			
	SP3	0.907			

SFL, standardized factor loadings; CR, construct reliability; AVE, average variance extracted; α, Cronbach value.

Table 4 represents the overall one-factor model fit statistics against the confirmatory factor analysis (CFA), which shows that our results are acceptable and a good fit was achieved for the measurement model of PsyCap and work engagement. To summarize the scales' reliability, convergent validity, and discriminant validity, our study findings support that the internal factor structure of all scales being tested is well-validated and reliable by meeting the convergent validity as well as discriminant criterion with associated variables (112). These findings add

TABLE 3 | Discriminant validity results.

Constructs	AVE	Hope	Efficacy	Resilience	Optimism	Safety compliance	Safety participation	Work engagement
Hope	0.66	0.811						
Efficacy	0.59	0.133	0.765					
Resilience	0.56	0.215	0.284	0.747				
Optimism	0.52	0.255	0.075	0.047	0.722			
Safety Compliance	0.92	0.341	0.056	−0.141	0.21	0.96		
Safety Participation	0.83	0.395	0.468	0.471	0.633	0.261	0.912	
Work Engagement	0.52	−0.41	0.136	−0.104	0.028	0.204	0.114	0.722

TABLE 4 | Fit indexes for the measurement models.

Categories of statistics	Statistics	Fitness criteria	Psychological capital		Work Engagement	
			Value	Decision	Value	Decision
Absolute fit indices	RMSEA	<0.08	0.003	Accept	0.004	Accept
	GFI	>0.90	0.944	Accept	0.983	Accept
Incremental fix index	AGFI	>0.90	0.932	Accept	0.972	Accept
	NFI	>0.90	0.946	Accept	0.983	Accept
	TLI	>0.90	1	Accept	1	Accept
	CFI	>0.90	1	Accept	1	Accept
Parsimonious fit indices	χ^2/DOF	<2.00	1.003	Accept	0.959	Accept

RMSEA, root-mean-square error of approximation; GFI, goodness-of-fit index; AGFI, adjusted goodness-of-fit index; NFI, Normed fit index; TLI, Tacker-Lewis index; CFI, Comparative fit index; PNFI, Parsimony normed-fit index; X^2 (i.e., X^2/degree of freedom).

further value to the efficacy and predictability of the instruments being utilized in this study.

Structural Model

We formulated the hypothesized model (**Figure 1**) and with the SEM technique. To assess the Goodness-of-fit, we tested if the responses fitted the measurement as well as a structural model. Concerning the criteria for structural model fit (107), primarily model fit was seen to see if there are any abnormal variables, where all variance was significant with a value >zero, standard errors were well under the limit and all standardized factor loading were significant with the value ranging from 0.69 to 0.97. Our results exhibit strong empirical evidence for the good primary fit of the data. Again for the second phase of the overall model fit for all variable, we used indexes such as; absolute, incremental, and parsimonious (110), and values against criterion indexes for the overall model is in **Table 5**. All the indexes met the criteria, demonstrating an acceptable overall model fit.

TABLE 5 | Fit indexes for the structural model.

Categories of statistics	Statistics	Fitness criteria	Overall model	
			Value	Decision
Absolute fit indices	χ^2	–	857.582	Accept
	RMSEA	<0.08	0.028	Accept
	GFI	>0.90	0.887	Accept
	AGFI	>0.80	0.87	Accept
	NFI	>0.90	0.909	Accept
	TLI	>0.90	0.978	Accept
Incremental fix index	CFI	>0.90	0.979	Accept
Parsimonious fit indices	χ^2/DOF	<2.00	1.263	Accept

RMSEA, root-mean-square error of approximation; GFI, goodness-of-fit index; AGFI, adjusted goodness-of-fit index; NFI, Normed fit index; TLI, Tacker-Lewis index; CFI, Comparative fit index; PNFI, Parsimony normed-fit index; X^2 (i.e., X^2 /degree of freedom).

Hypothesis Testing

For hypothesis testing, we use a 95% confidence interval, whereas if the *P*-value of any variable is under 0.05 with the positive estimate, it would lead to acceptance. At first, the direct effect of PsyCap's sub-dimensions on safety behavior (safety compliance and safety participation) was tested. The outcome of the hypothesis testing depicted that both hypotheses (H1) ($\beta = 0.524, p < 0.001$), and (H2) ($\beta = 0.231, p < 0.001$) of Hope toward safety compliance and safety performance were accepted. For self-efficacy, (H3) ($\beta = -0.01, p > 0.05$) was rejected based on its non-significant and negative association with safety compliance, but for self-efficacy (H4) ($\beta = -0.277, p < 0.001$) toward safety participation was accepted. Out of two hypotheses for resilience, (H5) ($\beta = -0.205, p < 0.001$) was rejected based on negative association, whereas (H6) ($\beta = 0.335, p < 0.001$) of resilience with safety participation was accepted. Pertinent to the last sub-dimension i.e., optimism, both hypotheses (H7) ($\beta = 0.089, p < 0.001$) and (H8) ($\beta = 0.533, p < 0.001$) were accepted for safety compliance and safety participation.

Secondly, all sub-dimensions of PsyCap were tested with work engagement. Results indicated that Hope (H9) ($\beta = -0.45$, $p < 0.001$) had a significant but negative association with work engagement, whereas self-efficacy (H10) ($\beta = 0.207$, $p < 0.001$) had a significant and positive association with work engagement. Further, resilience (H11) ($\beta = 0.207$, $p > 0.05$) was found to have an insignificant effect on work engagement. Lastly, optimism (H12) ($\beta = 0.128$, $p < 0.001$) was found to have a significant and positive association with work engagement.

Finally, the direct effect of work engagement on safety behavior indicators i.e., safety compliance and safety participation to observe how work engagement impacts safety outcomes. As expected, both (H13) ($\beta = 0.395$, $p < 0.001$) and (H14) ($\beta = 0.194$, $p < 0.001$) were accepted as they showed a significant and positive association between work engagement and safety performance objective indicators (see **Figure 2**, **Table 6**). It was also found that PsyCap dimensions self-efficacy and optimism explained about 21.9% of the total variance in workplace engagement. Further, it was also found that 40% of the variance in safety compliance was explained by hope, optimism, and work engagement, while 73.8% of the variance in safety participation was explained by hope, efficacy, resilience, optimism, and work engagement. The amount of variance explained by the predictors of safety compliance i.e., hope, optimism, and work engagement in this study shows the importance of these variables to enhance the safety compliance behavior of the employees. Also, the amount of variance explained for safety participation through the predictor variables showed a strong association, indicating potential promising association.

To test the mediating role of work engagement between PsyCap dimensions and safety behavior (safety compliance and safety participation), the bootstrapping technique was used and, the results are depicted in **Table 7**. Mediation results highlighted that work engagement played a partially mediating role between hope and safety compliance ($\beta = -0.176$, $p < 0.001$), and a fully mediating role between efficacy ($\beta = 0.082$, $p < 0.001$), and safety compliance. Further, the evidence of the partially mediating role of work engagement was also found between hope ($\beta = -0.087$, $p < 0.001$), efficacy ($\beta = 0.04$, $p < 0.001$), optimism ($\beta = 0.05$, $p < 0.001$), and safety participation. Nonetheless, there was an insignificant mediating effect observed between resilience ($\beta = -0.015$, $p > 0.05$) and safety participation, and resilience ($\beta = -0.031$, $p > 0.05$) and safety compliance.

DISCUSSION

Our study was aimed to assess the impact of PsyCap on the safety behavior of construction industry workers while taking work engagement as a mediating variable. The empirical evidence was obtained between the discriminant facets of PsyCap i.e., hope, self-efficacy, resilience, and optimism against safety behavioral outcomes. Our results suggest that hope, optimism, and work engagement have a significant and positive impact on both safety compliance and safety participation. Further, efficacy and resilience were also found to have a significant and positive impact on safety participation. It was interesting and unexpected to find that resilience had a significant, but negative relation with safety compliance, hence showing that a more thorough and precise viewpoint to be given toward PsyCap adaption. Additionally, partial mediation of work engagement was found to reduce the negative effect of resilience on safety compliance. The direct effect of Psycap dimensions on workers' safety behavior and work engagement has been discussed separately in the following sections:

Psychological Capital Direct Effect on Workers' Safety Behavior

Association Between Hope and Safety Behavior

Established by Luthans et al. (39), that hope is related to the positive outcomes at the workplace for employees, and in our case, our findings were in harmony with that. Hope was found to have a significant and positive effect on both indicators of safety behavior which is in contrast with some literature (46). Our findings are also in consensus with some of the prior findings (15). Although our findings suggested that hope is positively associated with safety behavior, prior researches highlighted certain elements like excessive remote deployment, staying far away from home, having a non-permanent job, demanding and hazardous nature of the job (2, 36), can modify the hope of construction workers. Other characteristics elements like diverse and non-permanent team members, stringent project timelines, etc. can also modify construction employee behavior (36), possibly impacting the hope of the individual. Subsequently, construction firms need to work upon such elements to reduce their possible negative effect on employees' hope. Our findings suggest that high hope is associated with enhanced safety behavior, which contradicts the findings of He et al. (46). As described by Luthans et al. (39) hope works through two mechanisms; willpower to achieve goals and way power to choose pathways to attain goals. It is also worthwhile to mention here that hope does not always enhance safety behavior as it is based on individual willpower and excessive willpower to attain certain tasks and goals may undermine the safety behavior, thus a balance between willpower and task is necessary (113). In general, hope is one of the optimistic states of an individual, which is expected to motivate individuals for positive outcomes, thus our findings are consistent with this expectation.

Association Between Self-Efficacy and Safety Behavior

Bandura (114) posited that self-efficacy can affect one's feelings and motivation to engage in certain behavior. In our case, self-efficacy was found to be significantly impacting safety participation only, which is in harmony with prior literature (15, 46, 115), but self-efficacy was found to have an insignificant association with safety compliance which is unexpected and needs further validation. Keeping the intrinsic feelings of construction workers in mind, it is expected that self-efficacious workers tend to have more control over their working environment, thus resulting in better safety performance. In congruence with the propositions of the Theory of planned behavior (116), which stated that social and personal factors

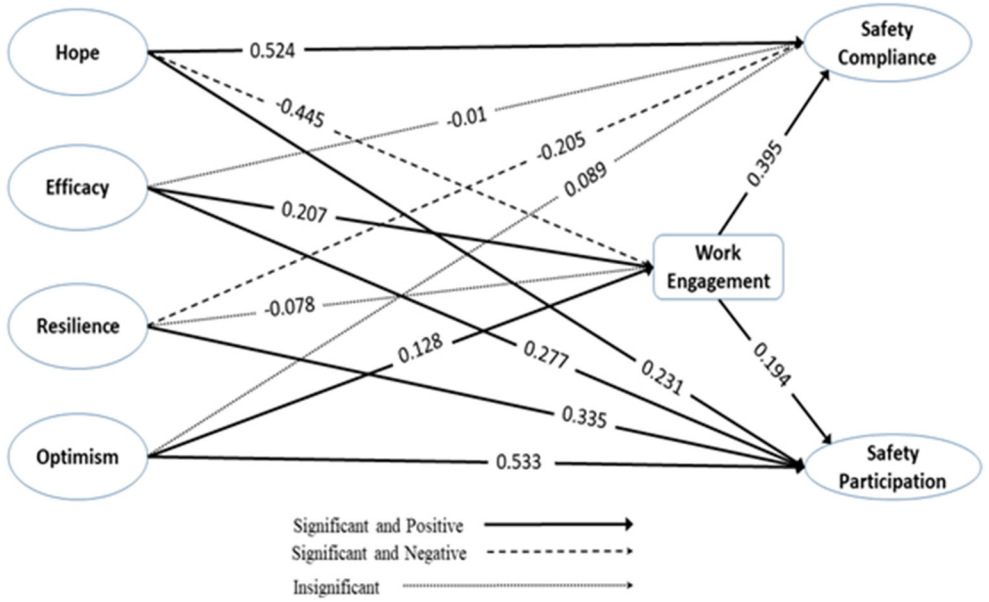

FIGURE 2 | The final structural model and impact paths.

TABLE 6 | Path coefficients of the final model.

Path	Estimate	S.E.	C.R.	*P*	Result		
Hope (H 01)	—>	Safety compliance	0.524	0.08	8.321	***	Accept
Hope (H 02)	—>	Safety participation	0.231	0.05	5.236	***	Accept
Efficacy (H 03)	—>	Safety compliance	−0.01	0.08	−0.184	0.85	Reject
Efficacy (H 04)	—>	Safety participation	0.277	0.06	6.6	***	Accept
Resilience (H 05)	—>	Safety compliance	−0.205	0.09	−3.735	***	Reject
Resilience (H 06)	—>	Safety participation	0.335	0.07	7.787	***	Accept
Optimism (H 07)	—>	Safety compliance	0.089	0.08	1.673	0.09	Accept
Optimism (H 08)	—>	Safety participation	0.533	0.07	11.2	***	Accept
Hope (H 09)	—>	Work engagement	−0.445	0.08	−6.935	***	Reject
Efficacy (H 10)	—>	Work engagement	0.207	0.09	3.486	***	Accept
Resilience (H 11)	—>	Work engagement	−0.078	0.1	−1.33	0.18	Reject
Optimism (H 12)	—>	Work engagement	0.128	0.09	2.196	0.03	Accept
Work engagement (H 13)	—>	Safety compliance	0.395	0.06	6.433	***	Accept
Work engagement (H 14)	—>	Safety participation	0.194	0.04	4.511	***	Accept

$^{***}p < 0.001$; Estimate, standardized regression coefficients; S.E., standardized error; C.R., critical ratio.

influence an individual's behavior and self-efficacy shows the potential to be applied as a predictor of an individual's safety behavior according to our findings. The utility of self-efficacy is not just limited to safety, but it also helps individuals to produce better outcomes at work in other contexts (117), thus continuous utilization of self-efficacy by construction workers may yield more stable safety results. Under the light of Bandura's assumption (72) that, it is the individual's judgment about his/her ability to manage the ongoing situation through the prepossessed skill, we can say that when a construction worker is faced with a safe situation, his/her role may conflict, thus leading to the non-compliance. This may have been caused by performance pressure (quantitative overload), e.g., a production supervisor is supposed to produce higher as well as to prioritize safety over productivity, which itself is a contradiction (118). Literature also states that highly efficacious individuals perceive demanding situations as more challenging, as they invest their energies and time against those situations, and in doing so they feel themselves less vulnerable to the outcomes (114). Consistent with aforesaid, one of the characteristics of construction workers' work behavior is having mastery in a certain task, leading to the possible excessive efficacious belief, because having prior experience in the same task may have undermined their safety compliance. Additionally, in our case, the employee may have

TABLE 7 | Standard direct and indirect effects for the mediation model.

Mediation effect	Direct effect *X*→ *Y*	Indirect effect	Result
Hope→ Work engagement→ Safety compliance	0.524**	−0.176**	Partial mediation
Hope→ Work engagement→ Safety participation	0.231**	−0.087**	Partial mediation
Efficacy→ Work engagement→ Safety compliance	−0.01(ns)	0.082*	Full mediation
Efficacy→ Work engagement→ Safety participation	0.277 **	0.04*	Partial mediation
Resilience→ Work engagement→ Safety compliance	−0.205**	−0.031 (ns)	No mediation
Resilience→ Work engagement→ Safety participation	0.335**	−0.015 (ns)	No mediation
Optimism→ Work engagement→ Safety compliance	0.089 (ns)	0.05 (ns)	No mediation
Optimism→ Work engagement→ Safety participation	0.533**	0.05*	Partial mediation

*ns, P > 0.05 (not significant); *P < 0.05 (Significant); **P < 0.01 (significant).*

found themselves efficacious to show participatory behavior, but their job/role demand might disrupt their compliance behavior, which yet requires more validation in future to testify this research outcome.

Association Between Resilience and Safety Behavior

Prior literature suggests that resilience is expected to have a positive effect on safety behavior (15, 39, 46), In our case, resilience was found to have a significant and positive effect only on safety participation, but a significant and negative effect on safety compliance, which is unexpected. Malaysian workers usually come from rural areas and they usually inherit the profession of agriculture, where agriculture accounts for a 7.1% contribution to national GDP, making it one of the significant sectors (119). One can expect that workers have to learn new skills, adapt to ever-changing living conditions, work pressure, and other personal factors (36), which might affect their compliance behavior. Posited by Olumide and Owoaje (120) in their study conducted on "Rural-urban disparity in knowledge and compliance with traffic sign" another form of "safety compliance," that individuals from rural areas tend to ignore safety compliance which can be the outcome of less knowledge about regulation and standard operating procedures. In connection with this, construction workers need to be more informed by their employers through training, discussion, and demonstrations which could enhance their knowledge and exposure toward safety compliance.

Another positive aspect of the positive relationship between resilience and safety participation is that workers who are coming from remote areas and backgrounds tend to be more resilient as they may have learned a lot from their prior experience and through their transitions to different locations, which have added value to their knowledge, thus encouraging them to show a positive attitude toward safety participation. It is obvious to see that individuals living on their own must be resilient as they have to face unpredicted situations and they expect to have less support from their surroundings, as these are also the occupational characteristics that the construction sector holds. This is high time for businesses to wholeheartedly focus on acts that can enhance the resilience of their employees, as this quality of individuals does not only help themselves, but it will also help organizations to recover from the worst scenarios. For instance, if an organization is facing financial hardship, fierce competition, and another constraint, it will ultimately put pressure on its employees in terms of overload, financial cut-downs, and so forth. In this scenario, a resilient workforce would be of prodigious help for organizations to sustain those hard times. Talking about the prime characteristics of the construction sector i.e., uncertainty and unannounced crisis often, not just physically but financially as well (121), this sector itself needs to be resilient as this sector is essential for the overall society. The organizational ability to be resilient toward unforeseen situations can be uplifted with the workforce that is more resilient and able to manage uncertainties. It is evident to observe positive outcomes of resilience especially for occupational safety, thus it allows researchers to explore this variable in other organizational settings.

Association Between Optimism and Safety Behavior

Optimism was significantly and positively associated with both safety compliance and safety participation, which is consistent with the findings of some studies (15, 122) and in contrast to the findings of certain literature (46). It is a worthy indication that optimism is positively influencing safety participation, and it shows that the construction workforce is optimistic about the outcome they expect from their actions. This exhibition of optimism can negate the negative effect of a pessimistic approach not only toward safety but also toward other work domains, as pessimism is contagious, negatively affecting the attitude and behavior of not only certain individuals but other employees also (123). There is also a tendency that workers might have an inflated or unrealistic optimism (124, 125), which possibly affects safety outcomes, in other words, too much optimism about the behavior related to safety can also cause accidents and derail the safety programs. Evidence from the Australian construction industry suggests that optimism bias was not related to deteriorated occupational performance and it could be due to the social desirability bias of their respondents (124). Certain factors of the construction sector i.e., safety climate, work condition, individual's safety perception, cognitive bias, and risk perception can influence his/her optimism (54). Posited by Perrow (126), accidents are normal and are formed through systematic failures, and keeping this assumption in mind, one should not be too much optimistic about the prevailing safety

instructions, scenarios, and actions at hand, but try to look far beyond. For the construction industry, the optimism construct needs to be utilized with more consideration and concentration.

In summary, the association of PsyCap was evaluated with safety behavior, where most of the sub-dimensions of PsyCap were positively and significantly associated with safety behavior, except efficacy and resilience with (safety compliance). The idea of PsyCap in connection with safety behavior may be communal, yet it still required more empirical evidence to achieve generalizability. While applying PsyCap in work and safety-related mechanisms, one should keep in mind the possible unexpected role of PsyCap.

Mediating Effects of Work Engagement

Work engagement partially mediated that relationship between; hope and safety compliance (Hope→ Work Engagement→ Safety Compliance), hope and safety participation (Hope→ Work Engagement→ Safety Participation), self-efficacy and safety participation (self-efficacy→ Work Engagement→ Safety Participation) as well as optimism and safety participation (Optimism→ Work Engagement→ Safety Participation). Work engagement fully mediated the relationship between self-efficacy and safety compliance (Efficacy→ Work Engagement→ Safety Compliance). There was no mediating effect of work engagement between; resilience and safety compliance, resilience safety participation as well as optimism and safety compliance. Although work engagement mediated the relationship between hope and safety behavior, it tends to have a negative indirect effect on safety behavior which is unexpected and against the literature (91, 127). A possible justification for this situation could be the excessive engagement shown by employees, as engagement at work goes beyond the normal call of duty (34). The excessive drive to be more productive via work engagement may force an employee to ignore personal and occupational safety to pursue their goals. Although prior literature supported the assumption that engaged employees are tended to be safe employees, this assumption needs more empirical evidence, as in our case the findings were contradictory. Organizations must design interventions that are directly related hope with the safety phenomenon, rather than going for the indirect interventions.

An efficacious attitude of individuals can result in engagement (128), where there was no mediation effect between efficacy and safety compliance that is in contrast with prior findings (127), and there found partial mediation between efficacy and safety participation. One of the possible reason could be the nature of the outcome as safety behavior are the subjective outcome, and not the objective, individuals tend to involve in such behavior of their own will and choice. As construction workers face tough and hazardous working conditions, thus they require strong self-confidence and motivation to perform. If workers tend to lack self-efficacy, they may not be more involved, thus leading to unsafe behavior. Future researchers should assess this relation in different contexts and organizations should design interventions that can foster the self-efficacy of an individual.

One of the interesting findings of this research was the full mediation effect between self-efficacy and safety compliance. This implies that safety compliance can only be influenced by the inclusion of engagement as a mediator between efficacy and safety compliance. The appropriate level of self-efficacy can influence individuals to observe safety compliance which ultimately will lead to enhanced safety performance. It was also noteworthy to find that there was no mediation of work engagement between resilience and safety behavior which is out of the ordinary as work engagement is expected to produce positive work outcomes (128). Out findings are contradicting with prior literature (129, 130), which requires further assessment. There may be cultural and contextual differences that might have affected the mechanism of efficacy and work engagement or the industrial characteristics. Lastly, work engagement partially mediated the relationship between optimism and safety participation. This implies that optimistic individuals tend to be more productive and engaged, as they foresee and expect positive outcomes. Intervention addressing the relationship between optimism and work engagement might further strengthen the safety outcomes for organizations. The further mediating role of work engagement between optimism and safety compliance was insignificant, although the linear effect of optimism on safety compliance was positive and significant. Overall our research findings are in congruence with few of the past studies that have tested PsyCap as the possible predictor of work engagement (26–28), and in our case, only two of the dimension of Psycap were found positively and significantly affecting workers' work engagement behavior. We expect to see different results in the future if the scale of Psycap can be utilized as unidimensional to predict the work engagement behavior of the construction industry workers.

Theoretical Implications

Our study contributed to safety literature by assessing the impact of PsyCap on employees' work engagement and their safety behavior (safety compliance and safety participation). First, our study reported the sound psychometric properties of all the measurement scales that we utilized for this study. By doing so, we have obtained further validity of these scales in the construction industry context. The concept of PsyCap (17) has not been introduced to many industrial sectors, consequently, the validation of this scale, as well as its predictors and outcomes, are not abundant in the literature. The role of PsyCap in the purview of occupational safety especially in the construction industry is very limitedly studied except for a few studies (30, 53). Our study went one step further by not just assessing the direct effect of PsyCap dimensions on safety behavior, but also proposing the four dimensions of PsyCap as a possible predictor of work engagement. Referring to the role of PsyCap for safety performance, it is expected to be a key construct in the coming years. Work engagement refers to the individual's vigor, dedication, and absorption while performing tasks, and in our study work engagement exhibited a positive association with safety compliance and safety participation. One of the possible reasons for this could be the assumption that workers who are highly engaged in their work are more aware of their surroundings and are more likely to engage in safe behavior (30). Our findings also exhibited that work engagement

possibly mitigates the negative effect of false employees' hope, which is of great importance to understanding individuals' hope. Further work engagement also depicted that it can further enhance the direct effect of self-efficacy for both safety compliance and safety participation as well as for optimism and safety participation.

Such findings of this study elaborated the notion of work engagement via empirical testing and exhibited its positive impact on both safety compliance and safety participation. Further, prior literature has identified many predictors of safety performance (53, 131, 132), whereas the combined empirical evidence of both PsyCap and work engagement on safety behavior was yet to be tested. In past, much of the research has been devoted to identifying and testing variables that are not intrapsychic rather social, hierarchical, and organizational, where our study is of great value, as it demonstrated the positive association between PsyCap certain dimensions, work engagement, and safety performance. Lastly, we tested the theoretical assumption of social cognitive theory, stating that an individual's behavior is not solely influenced by their environment, but one's psychological perception can also play its part as well as one's characteristics. This theoretical assumption was supported through this study as sub-dimension of PsyCap as well as individual's work engagement showed association in between. At last, our findings can enhance prevailing knowledge of the relationship between safety behavior and its antecedents, adding further breadth to the understanding.

Practical Implications

Our findings suggested that PsyCap should be treated with much care and attention in an organization. Although optimism predicted positive outcomes for both safety behaviors, organizations must keep in mind that the bias in terms of the over-optimistic behavior may prevail, which can influence employees' indulgence in safety behavior. Organizations should strategize their systems and policies keeping this bias in mind. It must be made clear through an organizational strategy that organizational health and safety standards are universally applicable regardless of experience, gender, role, and hierarchical position. Another important implication of the PsyCap sub-dimension is a false hope that can probably ruin the safe behavior by ignoring possible adversities, thus deteriorating organizational safety performance. These aspects make PsyCap advantageous as well as sensitive for organizations who would like to opt for it. Although it is not possible to measure the exact amount of hope and optimism of an employee for a specific outcome, a balance for this would be expected to be beneficial for both workers and organizations. It would also be beneficial for managers in terms of their safety-related objectives if they can opt for PsyCap interventions depending on the employees' PsyCap level. Talking in terms of effect size, hope and optimism both had a greater influence on safety compliance and safety participation of construction workers, therefore relevant interventions for enhancing safety can be designed to alleviate workers' PsyCap. One of the basic interventions is introducing employee training and activities that are tailored to boot psychological health.

Considering the positive effect of work engagement on both safety behaviors, managers should take certain measures to enhance work engagement. For instance, vigor can be increased through exercise as well as focusing on the life of an individual (133). To increase dedication amongst employees, the first step is to know them as the needs and expectations of every individual are different. There is a plethora of literature that can highlight certain ways to improve employee dedication and managers of the construction sector can choose them according to their teams and other factors. Lastly, to enhance absorption amongst employees to enhance safety performance, managers should make their activities interesting and easy so that they become engrossed while performing. Reference to the personal characteristics of study respondents, education of the construction worker is pivotal for one's self-confidence and efficacy, thus managers should give construction work awareness about their roles and responsibilities clear. This may help in boosting their confidence and enhancing their efficacy. Finally, the resilience of the construction workers can be enhanced through portraying specific scenarios, discussing worst-case scenarios of past and training, where they may be introduced to the certain scenario to see their reaction and learn out of it.

Since the data was gathered from local firms, hence the global generalization of the findings is not recommended, however, a few points are mentioned here as organizations, in general, have some common characteristics. Nonetheless, considering the generalizability of the findings, we used a sample that was drawn from different construction firms with a diversified set of respondents having different experiences, positions, and backgrounds. There is a bundle of variables that are generalizable across organizational-level, but specifically talking about PsyCap, it contains immense opportunities for organizations. Under the context of positive organizational behavior, efforts to introduce PsyCap may trigger the development of self-development, self-regulation, and self-awareness amongst employees (39). To generalize the study findings of hope and optimism results regarding safety compliance and participation behavior, organizations should work upon setting up clear goals and pathways for their workforce, as it may help employees to have genuine hope, and optimism and may protect them from having false hope or being over-optimistic. Since the designing of career goals and removing obstacles while performing jobs is universal to all organizations as one of their function, it can be implied that our findings may help design strategies related to hope and optimism for employees in other industrial settings. To generalize the outcome of efficacy and resilience regarding participation behavior, in general, organizations do have a mechanism through which they try to persuade and arouse their workforce toward success, as well as appreciate those who have achieved the desired outcomes. some high-reliability organizations (HROs) also work upon establishing a mechanism that mitigates or avoid possible risks, and also a design mechanism that may negatively affect their process (100). Keeping this in view our

findings can be generalized in other organizations to enhance participatory behavior since one's self-belief/confidence and being resilient would not help to perform an ordinary task, but it would also help him/her to go beyond the normal call of duty.

Study Limitations

One of the prime limitations would be the utilization of cross-sectional data, which is widely used in the research world, whereas the longitudinal approach might yield more robust and reliable results in future studies. Secondly, we used self-reported measures for all of the study variables, and that might cause social desirability bias for the respondents, as they may have overrated their PsyCap, work engagement, and safety performance behavior. Further, his study is limited to the Malaysian cultural context, which requires further validation in different contexts. Further, our respondents were mainly workers, who are usually not highly qualified in terms of academic education, thus limiting the view to some extent. Therefore, research on a much wider level with diversified respondents would reveal more insights. As we found mediation evidence impacting PsyCap relation with safety behavior, thus more exploration in terms of individual evaluation of PsyCap, groups, and team may also yield different results. As this research is based on the construction industry workers, where employment for is mainly temporary or project-based, thus it may not unveil the complete picture or understanding of their behavior, therefore assessment of this framework in other hazardous industries where workers are employed over a length of time may provide different results. Another limitation of this is research is the distribution of our respondents, as most of the workers in the construction industry are male, thus including industries that have justified/optimum population mix may also provide different results.

CONCLUSIONS

This research helps enrich the current body of knowledge on employees' safety behavior (safety compliance and safety participation) in connection with PsyCap (hope, self-efficacy, resilience, and optimism) and work engagement (vigor, dedication, and absorption. This research contributed to the body of knowledge through; (a) identifying the influencing role of PsyCap on construction workers' safety behavior and its possible mechanisms, (b) differentiating the individual effect of each sub-dimension of PsyCap on safety behavior indicators, (c) the partially and fully mediating role of work engagement between PsyCap and safety behaviors. The finding of our research would help better-operationalizing interventions of PsyCap and work engagement to enhance safety performance and reduce occupational injuries. It was highlighted that one should be careful while opting for PsyCap's different dimensions to enhance safety.

Our results suggest that hope and work engagement have a positive and significant influence on safety behavior. Moreover, efficacy, resilience, and optimism have a positive and significant impact on safety participation. Nonetheless, efficacy was found to have an insignificant impact on safety compliance, whereas resilience was found to be negatively affecting safety compliance behavior. Both of these findings are contradictory to prior knowledge and need further quantitative evidence. Results also suggested that efficacy and optimism are positive and significant predictors of work engagement leading toward safety compliance and safety participation. Contrary to this, resilience had non-significant and negative relations, as well as hope, had a significant but negative association with work engagement. The indirect effect of resilience and optimism being insignificant provides an opportunity for future researchers to test this phenomenon.

PsyCap is a sensitive tool, which requires an in-depth amount of care and attention when applied, where elements like efficacy and resilience can negatively affect safety behavior. On the other hand elements like hope and optimism can positively influence work engagement and safety behavior. Our study also resulted in the theoretical advancement for Social Cognitive Theory (134), which states that personal factor also influences individual choices. In our case, hope, efficacy, resilience, and optimism being individualistic personal cognitive capabilities showed their influence toward the behavioral outcomes of construction workers, hence verifying the theoretical propositions of Social Cognitive Theory. PsyCap and work engagement need to be applied with care. The good news for management science researchers is that work engagement intervention may be anticipated using self-efficacy and optimism, both of which are individualistic but can be molded and impacted by organizational policies to increase work engagement. In contrast, hope may have a big yet negative influence on job engagement, which must be carefully considered when deciding how to improve work engagement. Organizations should carefully examine the existing degree of individual PsyCap and work engagement behavior, and then plan interventions appropriately. Although it is tough for managers to assess their workers' PsyCap status and allocate responsibilities and assignments. Consideration must be given to individuals' PsyCap, i.e., what kinds of attributes are necessary to accomplish a specific activity.

DATA AVAILABILITY STATEMENT

Data of the research are only available through the corresponding author upon reasonable request.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

Idea inception and execution were done by MS and GN, led by content analysis and writing. AI and YY further refined the concept, revised, and reviewed the overall manuscript writing. All authors read and approved the final manuscript.

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Linking Safety-Specific Leader Reward and Punishment Omission to Safety Compliance Behavior: The Role of Distributive Justice and Role Ambiguity

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Background: Although positive safety leadership has attracted increasingly academic and practical attention due to its critical effects on followers' safety compliance behavior, far fewer steps have been taken to study the safety impact of laissez-faire leadership.

Objective: This study examines the relationships between safety-specific leader reward and punishment omission (laissez-faire leadership) and followers' safety compliance, and the mediations of safety-specific distributive justice and role ambiguity.

Methods: On a two-wave online survey of 307 workers from high-risk enterprises in China, these relationships were tested by structural equations modeling and bootstrapping procedures.

Results: Findings show that safety-specific leader reward omission was negatively associated with followers' safety compliance through the mediating effects of safety-specific distributive justice and role ambiguity. Safety-specific leader punishment omission was also negatively associated with followers' safety compliance through the mediating effect of safety-specific role ambiguity, while safety-specific distributive justice was an insignificant mediator.

Originality: The study addresses and closes more gaps by explaining how two contextualized laissez-faire leadership measures relate to followers' safety behaviors,

following the contextualization and matching principles between predictors, mediators and criteria, and by revealing two mechanisms behind the detrimental effects of laissez-faire leadership on safety outcomes.

Keywords: safety-specific leader reward omission, safety-specific leader punishment omission, distributive justice, role ambiguity, safety compliance, laissez-faire leadership

INTRODUCTION

Despite significant efforts over the past several decades, workplace injuries and accidents have shown to be frequent among national and global firms in high-risk industries, which indicates that occupational safety is still a highly relevant and serious issue worthy of academic attention (1, 2). Among the strongest antecedents of injuries and accidents, increased individual compliance with organizational safety procedures and standards has shown to decrease the probability and number of accidents, injuries, and near-misses (1, 3, 4). Accordingly, two meta-analytic reviews have shown the robust prediction of safety compliance on various safety outcomes (5, 6). Hence, to minimize the direct and consequential losses of accidents, the measures for motivating safety compliance have become focal points for scholars in this field (5–7).

Recently, safety-specific leadership has attracted increasingly academic and practical attention due to its critical effects on followers' safety compliance behavior (8–11) (**Appendix A** summaries some of safety leadership studies). Since Barling et al. (8) and Zohar (12), extensive studies have supported the positive relationship between safety-specific *transformational leadership* and followers' safety compliance through the mediation of safety climate, safety consciousness and safety attitude (8, 10, 13–16). Similar to transformational leadership, *active transactional leadership* (i.e., leader contingent reward and punishment) has been further substantiated to be an effective way to improve employees' occupational safety compliance (9, 15, 17).

However, compared to transformational and transactional leadership, far fewer steps have been taken to study the safety impact of *laissez-faire leadership*, proposed as a destructive type of leadership (18, 19). Given that most followers are more likely to experience laissez-faire leadership (20), it is relevant and important to examine the potential effect of laissez-faire leadership on followers' safety compliance. Although the negative effects of laissez-faire leadership have been demonstrated in few safety studies conducted in the USA and European countries (15, 17, 21), we believe that further studies, and not the least in China with a different national culture, are important and necessary for testing the generalizability of the link between laissez-faire leadership and followers' safety compliance. Moreover, we notice that previous studies have used a relative generalized and uncontextualized measure of laissez-faire leadership (22), which may prevent us from getting a nuanced understanding of the predictive power of safety-specific laissez-faire leadership behavior on corresponding follower safety-specific behavior in the form of safety compliance (23, 24). Further, and in line with the fact that laissez-faire leadership has been a stepchild in leadership research (25), very few studies have focused on the underlying mechanisms that may explain the detrimental effects of laissez-faire leadership on various attitudinal and behavioral outcomes.

Hence, the current study strives to narrow these gaps by examining the impact of safety-specific laissez-faire leadership on follower safety compliance behavior in Chinese high-risk firms. Based on the fact that no previous study explicitly have measured supervisor's lack of responsiveness to good or poor follower performance, Hinkin and Schriesheim (25) developed two measures of "reward omission" (leader non-reinforcement of follower's good performance) and "punishment omission" (leader non-reinforcement of follower's poor performance), respectively, to capture leader's lack of performance-contingent reinforcements. As predicted, they found that leader reward and punishment omissions were negatively associated with supervisor-rated follower performance. Following these findings, and other well-documented findings on the negative and detrimental impact of laissez-faire leadership (12, 15, 17–19, 21), the present study introduces safety-specific reward and punishment omissions to the occupational safety context, and examines the effects of these two domain-specific laissez-faire leadership styles on followers' safety compliance.

A second purpose of this study is to reveal the mechanisms through which safety-specific laissez-faire leadership influences followers' safety compliance behavior by examining two parallel mediations, i.e., safety-specific distributive justice and safety-specific role ambiguity, respectively. We propose these two mechanisms based on the study by Podsakoff et al. (26) which showed that two main mechanisms explained how leader reward and punishment behaviors influenced follower cognitive and behavioral responses, namely followers' perceptions of fairness (27, 28) and role ambiguity (29, 30), respectively. Hence, we propose that contextualized distributive justice as well as role ambiguity will mediate the effects of superiors' safety-specific reward and punishment omission on followers' safety compliance.

Hence, we aim to contribute significantly to the laissez-faire leadership research field and to the workplace safety literature in several ways. First, as a response to recent calls for more attention to laissez-faire leadership in occupational safety settings (15, 31, 32), we contextualize leader reward and punishment omission measures to, in a nuanced way, better predict the effects of laissez-faire leadership on safety outcomes (33, 34). Accordingly, we contribute to safety as well as laissez-faire leadership research by, for the first time, testing two contextualized leadership omission measures within a safety framework, and matching leader and follower behaviors on congruent levels. Second, the present study is, to our knowledge, the first study to link safety-specific leader

reward and punishment omission to follower safety compliance, which contributes substantially to a better understanding of how concrete leadership behaviors are related to followers' concrete safety behaviors. Finally, this study expands upon the literature on workplace safety and laissez-faire by revealing underlying mechanisms, in the present study operationalized as followers' safety-specific justice and safety-specific role ambiguity (35). This study is, to our knowledge, the first study to test the parallel effects of these two mediators in the passive-avoidant leadership—safety behavior relationship, thus contributing substantially to workplace safety research with direct consequences for workplace safety interventions.

THEORY DEVELOPMENT

Reward and Punishment Omission in a Leadership and Safety Context

Given that the omission of leadership may be just as important as its commission, Hinkin and Schriesheim (25) introduced the concepts of leader reward omission and punishment omission which represent two types of interrelated concretized laissez-faire leadership behaviors. Reward omission refers to leader non-reinforcement of what a follower perceives to be his or her good performance. Accordingly, punishment omission refers to leaders' non-reinforcement of what a follower perceives to be his or her poor performance. Given the fact that people may think, perceive and act differently in different contexts (36), several studies have suggested that specifying the context through a frame-of-reference changes responses to scale items and typically improves the prediction of performance outcomes (33, 34, 37), especially when the outcome scale items are on the same level of specificity [cf., the matching principle; see e.g., (38)]. Unlike prior research focusing on relationship between leadership behaviors and safety outcomes without contextualizing leadership measures (8, 14, 15, 21), the present study, thus, relates these two types of leadership omissions by the contextual operationalization of safety-specific leader reward omission (SLRO) and a corresponding safety-specific leadership punishment omission (SLPO), both scales reflecting leaders' lack of motivational efforts toward stimulating and facilitating followers' safety behaviors (16, 32). Our contextualization is consistent with recent studies (10, 39) which have specified the safety context for transformational leadership, stressors, trust, motivation and citizenship behavior. Hence, we argue that such leader reward and punishment omission measures, tailored for the safety-specific context, will yield both higher content and criterion validity, as well as reliability, than those general measures of leadership in predicting employee safety compliance behaviors (34, 37).

The Influences of SLRO and SLPO on Perceived Safety-Specific Distributive Justice and Safety-Specific Role Ambiguity

Previous studies have established that how leaders administer rewards and punishments, respectively, influences followers' cognitive processes (27, 40). A recent study has shown that leader reward and punishment behaviors (active-approaching leadership) predict follower attitudes, as well as in-role and extra-role behaviors, via two internal mechanisms, namely perceived justice and role ambiguity (26). Distributive justice refers to the degree to which followers perceive rewards and punishments to be proportionally related to performance inputs (41), while role ambiguity refers to a lack of clarity about which demands and expectations to fulfill (30), also including ambiguity regarding the process and the criteria for evaluating one's safety performance (42). In line with the referred findings by Podsakoff and colleagues above, it is reasonable to expect that SLRO and SLPO (two forms reflecting passive-avoidant leadership) will influence followers' safety compliance via two parallel mechanisms, i.e., perceived safety-specific distributive justice and safety-specific role ambiguity.

Logically, followers strongly believe and expect that the rewards and punishments they receive from their leaders should be fitted to their performances. If their leaders administer rewards and punishments on the basis of such an equity rule, they have shown to be perceived as fairer than those administered by leaders who do not allocate rewards/punishments according to followers' good/poor performances (26). Hence, when followers devote their time and energy to comply with organizational safety-related operations, procedures and rules but do not receive corresponding praise, commendations, social approval or monetary rewards, and link this to their perceived safety performance levels (26), they are more likely to perceive a low level of distributive justice or no such justice at all. Similarly, when followers perceive that other employees have been punished because of their poor safety performance, they are prone to perceive this punishment as more distributively just (26, 27). Thus, it is reasonable to expect that leaders who do not respond to followers who violate safety-related operating procedures and rules will be perceived to be unfairer than those leaders responding according to distributive justice. Hence, we hypothesize:

> **Hypotheses 1 and 2:** Safety-specific leader reward omission (H1) and punishment omission (H2) are negatively associated with followers' perceived distributive justice.

A second mechanism through which the two context-specific leadership styles may influences follower safety compliance is that of safety-specific role ambiguity. It is by now well-established that leaders who in a systematic way provide positive and negative feedback help to clarify followers' roles in the organization (26, 29). Specifically, leaders' contingent rewards are decisive in this regard, whereas contingent punishments can serve as a strong signal to judge that the performance levels of followers do not meet the leader's expectations (29). In contrast, laissez-faire leadership has found to be a root source of followers' role ambiguity (18, 43). Accordingly, follower perception of leader reward and punishment omissions have been found to reduce role clarity (alternatively, enhance role ambiguity) (25, 44). Therefore, a reasonable hypothesis is that when followers perceive that superiors do not respond to good or poor follower safety performance, they are prone to become confused

about what he or she can do to fulfill desired and expected safety outcomes. That is, supervisors' safety-specific reward and punishment omissions will probably lead to safety-specific role ambiguity regarding followers' fulfillment of duties and specific aspects of task completion. Therefore, we hypothesize that:

Hypotheses 3 and 4: Safety-specific leader reward omission (H3) and punishment omission (H4) are positively associated with followers' experienced safety-specific role ambiguity.

The Influences of Perceived Safety-Specific Distributive Justice and Safety-Specific Role Ambiguity on Followers' Safety Compliance

Distributive justice has been demonstrated to positively relate to job satisfaction (45), organizational commitment (45, 46), employee engagement (47), and perceived insider status (48). To our knowledge, it is unclear whether distributive justice relates to employee's safety compliance behaviors. However, previous studies have found that distributive justice is associated with employee behaviors beneficial to organizations such as presenteeism (49), positive gossip behavior (48), and willingness to cooperate (50). Together, these studies highlight the critical role of distributive justice in generating positive cognitive, affective, and behavioral responses within organizations. Hence, we expect that when leaders reward followers relative to their safety performance, as reflected in safety-specific distributive justice, followers will accordingly comply with organizational safety-related operation procedures and rules, leading to the following hypothesis:

Hypothesis 5: Followers' perceived safety-specific distributive justice is positively related to their safety compliance.

Safety-specific role ambiguity refers to cases where available information and resources concerning safety roles are unclear or inadequate (39, 44). Accordingly, role theory suggests that role ambiguity will lead to individuals' dissatisfaction with their roles, hesitation over decisions, anxiety and confusion, and decrease their organizational commitment as well as increase their propensity to leave; and, accordingly, result in ineffective performance (39, 44, 51). If employees are confused about their safety duties, this will probably be followed with vague role expectations and a unsureness about how to operate correctly, which probably will lead to a general lack of confidence in superiors and an inefficacy to enact adequate and sufficient safety behaviors (39, 51). Leung et al. (52) showed that safety-related work stressors (e.g., role ambiguity and role conflict) hindered employees' safety performance and triggered accidents, resulting in injuries. More recently, Wang et al. (39) investigated Chinese frontline workers and their safety supervisors and revealed a negative relationship between safety-specific role ambiguity and proactive safety behaviors, including safety compliance. To conclude, we have substantiated that if employees experience role ambiguity in their work execution, they are expected to violate rather than comply with organizational safety procedures and rules. Hence, we hypothesize that:

Hypothesis 6: Followers' experienced safety-specific role ambiguity is negatively associated with their safety compliance.

The Mediating Role of Perceived Safety-Specific Distributive Justice and Safety-Specific Role Ambiguity in the Leader Behavior—Follower Safety Compliance Relationship

Lack of safety leadership is probably an essential disruptive antecedent of safety performance in organizations. Accordingly, we propose that SLRO and SLPO impede followers' perceived safety-specific distributive justice and enhance their experienced of safety-specific role ambiguity. We, further, propose that this will subsequently lead to followers worsened or lacking safety compliance behaviors. Indeed, studies have shown that laissez-faire leadership influences employee outcomes through the mediation of internal cognitive processes (28, 40). Moreover, prior studies support the idea that laissez-faire, as well as other forms of passive-avoidant leadership, influence safety performance through safety-related cognitive processes (6, 9, 16, 21). Further, our two mediation propositions are in line with a meta-analysis which showed that transactional leadership influences employee behaviors via perceived justice and role ambiguity (26). Hence, we propose the following mediation hypotheses:

Hypothesis 7: Perceived safety-specific distributive justice mediates the effect of perceived safety-specific leader reward omission (H7a) on follower safety compliance; and, accordingly, the effect of perceived safety-specific leader punishment omission (H7b).

Hypothesis 8: Perceived safety-specific role ambiguity mediates the effect of perceived safety-specific leader reward omission (H8a) on follower safety compliance; and, accordingly, the effect of perceived safety-specific leader punishment omission (H8b).

Figure 1 shows our defined research model and demonstrates that both perceived safety-specific leader reward and punishment omission are expected to affect followers perceived safety-specific distributive justice and safety-specific role ambiguity, and in the following influence their safety compliance, accordingly that perceived safety-specific distributive justice and safety-specific role ambiguity mediate the relationship between leader behaviors and followers' safety compliance behaviors.

METHODS

Sample and Procedure

This study used a two-wave online questionnaire survey to collect self-reported data for testing the hypotheses. We targeted front-line workers in enterprises located in central China.

These enterprises are in four high-risk industries including metal melting, construction, hazardous chemicals and machinery manufacturing. Although we did not recruit the participants from the entire China, they are heterogeneous and representative as regards industry type and firm size. Moreover, our recruitment method (see below) ensured that participants match the research context of workplace safety of this study.

To avoid common method bias, we distributed our online surveys across two different time periods. At the baseline assessment (T1) of the two-wave data collection, participants reported sensitive information, i.e., the frequency with which their superiors engaged in safety-specific reward omission and punishment omission behaviors, and answered demographic questions, i.e., gender, age, education, income and seniority. In the second wave survey (T2), which was conducted 2 weeks later, the participants reported their own perceptions of safety-specific distributive justice, safety-specific role ambiguity, and actual safety compliance behaviors. Because of the social distancing of COVID-19 epidemic and the advantage of online survey in collecting sensitive information (53), our questionnaires were distributed to participants on an online survey platform (www.wjx.cn). With the help from the Emergency Management Bureau, we contacted managers of safety management department in the target enterprises, and described the purpose of our survey. After getting their support, research assistants distributed questionnaire to these managers with a quick response code or by hyperlink through WeChat, one of the most popular instant messaging and social interaction application in China and the rest of the world (54), asked them to randomly distribute questionnaires to their front-line workers during weekend time, which ensures that the production activities of front-line workers were not interfered. Participants could fill in the questionnaire from computers as well as from mobile devices. Before filling in the online questionnaire, we informed them that the data would be used for research purposes only and that their personal information would be kept confidential, and asked them to read and understand the purpose of the survey as well as the instructions. Following previous studies like that of Wu et al. (53) we set up one questionnaire for each IP address to prevent more than one completion of each questionnaire.

The data collection lasted for 4 weeks, which is from 20 April to 20 May 2020. In the first wave, the online survey platform distributed 500 questionnaires to front-line workers who are working in high-risk industries. 426 participants filled out and returned, including 32 invalid questionnaires because of missing items, and 394 were retained. In the second wave, 335 out of 394 returned questionnaires, including 28 invalid questionnaires because of missing items and too long or short reaction time, and finally 307 usable questionnaires responses were retained for hypothesis test, yielding a response rate of 61.4%. **Table 1** reports the sociodemographic information of the 307 responses.

TABLE 1 | Demographic statistics of the sample ($n = 307$).

Variables	Freq.	%	Variables	Freq.	%
Sectors			**Gender**		
Construction	111	36.1	Male	250	81.4
Metal-melting	107	34.9	Female	57	18.6
Hazardous chemicals	63	20.5	**Education**		
Machinery manufacturing	26	8.5	Junior high school or below	5	1.6
Age (year)			High school or technical secondary school	47	15.3
20–30	95	30.9	Bachelor or senior college	226	73.6
31–40	76	24.8	Master or above	29	9.4
41–50	119	38.8	**Seniority (year)**		
≥51	17	5.5	<1	16	5.2
Monthly income (RMB)			[1,2)	24	7.8
≤3,000	15	4.9	[2,4)	21	6.8
3,001–5,000	111	36.2	[4,6)	35	11.4
5,001–7,000	116	37.8	[6,10)	36	11.7
7,001–10,000	47	15.3	[10,15)	28	9.1
≥10,000	18	5.9	>15	147	47.9

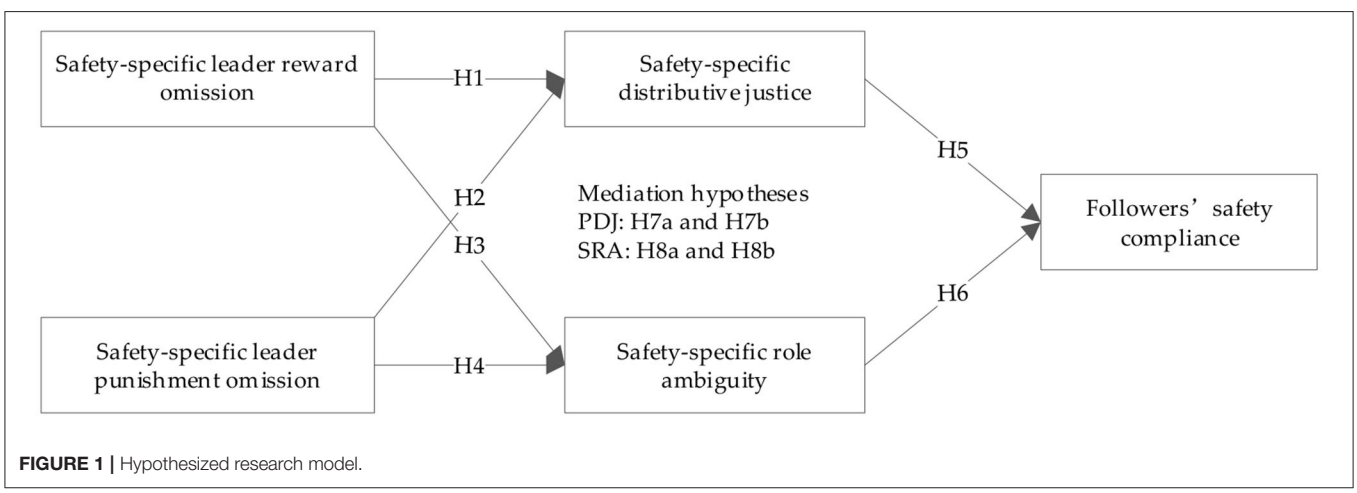

FIGURE 1 | Hypothesized research model.

Measures

In accordance with the recommendations of previous studies as regards measure contextualization (24, 33, 34), we employed frequently used multi-item scales within a safety context to measure safety-specific leader reward and punishment omission, safety-specific distributive justice, safety-specific role ambiguity, and safety compliance. Since all the scales are English version, we followed appropriate translation and back-translation procedures to ensure the reliability and validity. Specifically, two bilingual experts translated the original scales from English to Chinese in parallel, and two other bilingual scholars conducted a back translation. We then evaluated the semantic equivalence of each back translation, and made adjustments accordingly.

Safety-Specific Leader Reward and Punishment Omission

A twelve-item scale for leader reward and punishment omission was adapted from Hinkin and Schriesheim (25). Participants rated the frequency with which their superiors engaged in reward and punishment omission behaviors on a 7-point Likert-type scale (1 = "never" and 7 = "always"). Specifically, six items were developed to assess SLRO, where one sample item is "I often do my jobs safely and still receive no praise from my superior." The remaining six items were developed to measure SLPO, where one sample item is "When I perform unsafely my superior does nothing." In the analyses, we excluded one item (i.e., "My unsafety performance often goes unacknowledged by my superior.") of SLPO due to its low intercorrelations with the other items in the scale.

Safety-Specific Distributive Justice

We measured safety-specific distributive justice with a four-item scale derived from Colquitt (55) where the items were adapted to make specific reference to the context of workplace safety. One example item is "To what extent does your reward reflect the effort you have put into your workplace safety?" Participants were asked to report their perception of safety-specific distributive justice on a 7-point Likert-type scale (1 = "to a small extent" and 7 = "to a large extent").

Safety-Specific Role Ambiguity

A five-item scale was derived and adapted from a role ambiguity scale (56) to assess safety-specific role ambiguity by making specific reference to the context of workplace safety. A sample item is "I do not know what my responsibilities are in working safely." Participants rated their perception of safety role ambiguity on a 7-point Likert-type scale (1 = "strongly disagree" and 7 = "strongly agree").

Followers' Safety Compliance

We assessed followers' safety compliance as the criterion by using a three-item scale adopted from Neal and Griffin (57). One example item is "I use all the necessary safety equipment to do my job." All items were evaluated on a 7-point Likert-type scale (1 = "strongly disagree" and 7 = "strongly agree).

Control variables. In order to control for alternative explanations of our results, we followed previous research (58–61), and chose employee gender, age, education, income, and seniority as the control variables in this study.

Appendix B summaries all the questionnaires items used in this study.

RESULTS

Preliminary Analyses

The common method bias, reliability, and validity were tested before hypotheses testing. First, we used the Harman's single-factor test and confirmatory factor analysis to determine if the variance yielded a single latent factor. Harman's single-factor test indicated that the single factor accounted for 44.73% of the total variance for all measures, far less than the threshold of 70% (62). We further performed confirmatory factor analysis (CFA) to confirm if a single factor accounted for all variables. The results from Mplus 7.4 suggested that the fit of the five-factor model ($\chi 2/df = 2.097$, CFI = 0.965, TLI = 0.959, SRMR = 0.038, RMSEA = 0.060) was considerably better ($\Delta\chi 2 = 3360.88$, $\Delta df = 10$, $p < 0.001$) than the single-factor model ($\chi 2/ df = 16.617$, CFI = 0.473, TLI = 0.420, SRMR = 0.160, RMSEA = 0.226).

TABLE 2 | Results of reliability analysis and CFA ($n = 307$).

Items	CFA Loadings	Cronbach's α	AVE	CR
SLRO1	0.779	0.948	0.755	0.949
SLRO2	0.893			
SLRO3	0.922			
SLRO4	0.882			
SLRO5	0.868			
SLRO6	0.863			
SLPO1	0.752	0.936	0.770	0.943
SLPO2	0.888			
SLPO3	0.810			
SLPO4	0.967			
SLPO5	0.952			
SDJ1	0.792	0.925	0.761	0.927
SDJ2	0.899			
SDJ3	0.903			
SDJ4	0.890			
SRA1	0.922	0.931	0.746	0.936
SRA2	0.897			
SRA3	0.913			
SRA4	0.736			
SRA5	0.838			
SC1	0.815	0.896	0.749	0.899
SC2	0.883			
SC3	0.896			

SLRO, safety-specific leader reward omission; SLPO, safety-specific leader punishment omission; SDJ, safety-specific distributive justice; SRA, safety-specific role ambiguity; SC, safety compliance; AVE, average variance extracted; CR, composite reliability.

Taken together, it is reasonable to conclude that common method bias was not a serious concern in this study.

Second, as shown in **Table 2**, CFA of the scales indicated that the standardized loadings of each construct were higher than 0.70, the composite reliabilities of each construct were near to or larger than 0.90, and the average variance extracted (AVE) exceeded 0.70, showing good convergent validity (63, 64). We also evaluated the discriminant validity by testing whether the square roots of the AVE exceed the corresponding correlations between constructs (64). The results displayed in **Table 3** confirmed satisfactory discriminant validity.

Third, to assess the internal consistencies we used reliability analyses to determine scale Cronbach's alpha. As shown in **Table 2**, the respective Cronbach's α coefficients for the five scales ranged from 0.896 to 0.948, far greater than the threshold of 0.70 (63), exhibiting a satisfactory reliability of each scales.

Further, **Table 3** reports the means, standard deviation, and correlations of all study variables. Overall, respondents reported positive perceptions of safety-specific distributive justice (M = 4.61) and safety-specific compliance behavior (M = 5.73). Also, they showed positive (low) evaluations of safety-specific role ambiguity, SLRO, and SLPO (averaged scores ranged from 1.94 to 3.09). Analyses also showed that the five study variables correlated significantly in expected directions with each other.

Hypothesis Testing

We utilized Mplus 7.4 to test the hypotheses (the bias-corrected bootstrapping methodology, with 2,000 resamples at 95% confidence interval) and the results are presented in **Figure 2**. The hypothesized structural model fits the data well (χ^2/ df = 1.687, CFI = 0.958, TLI = 0.954, SRMR = 0.055, RMSEA = 0.047). Perceived SLRO shows a negative association with perceived safety-specific distributive justice ($r = -0.371$, $p < 0.001$) and positive association with perceived safety-specific role ambiguity ($r = 0.213$, $p < 0.001$), while SLPO are positively related to followers' perceived safety-specific role ambiguity ($r = 0.283$, $p < 0.01$), supporting H1, H3, and H4. However, the effect of perceived SLPO on perceived safety-specific distributive justice is not significant ($p > 0.10$), hence, not yielding support for H2. As expected, perceived safety-specific distributive justice ($r = 0.461$, $p < 0.001$) and safety-specific role ambiguity ($r =$

TABLE 3 | Mean, SD, and correlation matrix and square root of AVEs of the study variables.

Variables	Mean	SD	SEC	GED	AGE	EDU	INC	SEN	SDJ	SC	SLPO	SLRO	SRA
SEC													
GED			−0.13*										
AGE			0.42***	−0.01									
EDU			−0.33***	0.14*	−0.36***								
INC			−0.30***	−0.08	−0.12*	0.28***							
SEN			0.49***	−0.04	0.83***	−0.35***	−0.04						
SDJ	4.61	1.74	−0.06	0.06	−0.02	−0.04	0.13*	−0.06	0.87				
SC	5.73	1.36	0.00	−0.05	0.02	−0.11	0.12*	0.04	0.54***	0.87			
SLPO	2.47	1.61	0.01	−0.03	0.01	0.14*	−0.05	−0.01	−0.32***	−0.34***	0.88		
SLRO	3.09	1.62	−0.04	−0.03	0.04	0.12*	−0.07	0.03	−0.41***	−0.37***	0.64***	0.87	
SRA	1.94	1.09	−0.04	0.01	−0.10	0.10	−0.07	−0.13*	−0.33***	−0.46***	0.40***	0.40***	0.86

*SEC, sector; GED, gender; AGE, age; EDU, educational level; INC, monthly income; SEN, seniority; SLRO, safety-specific leader reward omission; SLPO, safety-specific leader punishment omission; SDJ, safety-specific distributive justice; SRA, safety role ambiguity; SC, safety compliance; SD, standard deviation. The square roots of AVE are reported in diagonal; ***p < 0.001; *p < 0.05.*

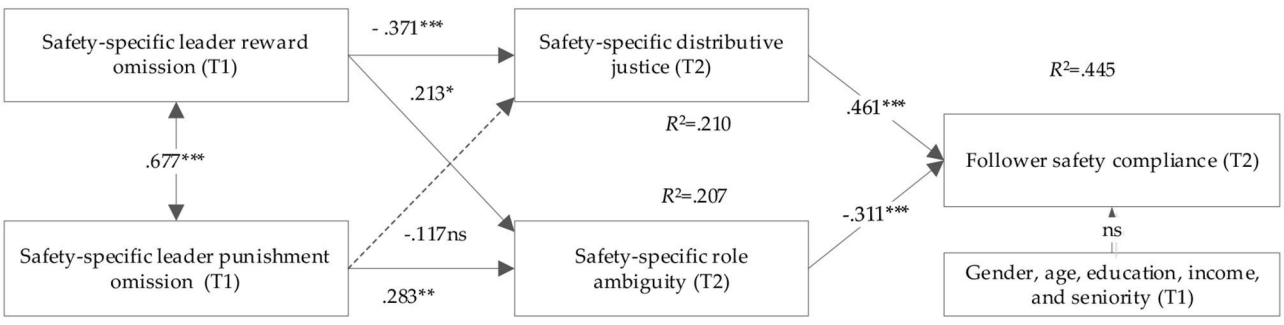

FIGURE 2 | Hypothesized model results. ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, Not significant, $p > 0.10$. T1 and T2 represent the first and second wave data collection, respectively.

−0.311, $p < 0.001$) are significantly related to followers' safety compliance, thus supporting H5 and H6.

Further, to test whether perceived safety-specific distributive justice and safety-specific role ambiguity mediated the relationships between SLRO/SLPO and followers' safety compliance, following Preacher and Hayes (65), we used the bias-corrected bootstrapping methodology, with 2,000 resamples at 95% confidence interval, to test the mediation effect with Mplus 7.4 statistic software, because the bias-corrected bootstrapping method can calculate more accurate confidence interval of coefficient product and has higher test power than traditional Sobel method (65, 66). When testing for these mediations, we included the direct relationships between safety-specific leader reward omission and punishment omission, and followers' safety compliance in the model. **Table 4** reports the results of the four mediating effects. As we predicted, the indirect effect of perceived safety-specific distributive justice on the relationship between SLRO and followers' perceived safety compliance was significant [−0.147; (−0.236, −0.089), excluding zero], thus supporting H7a. The indirect effects of perceived safety-specific role ambiguity on the relationships between SLRO/SLPO and perceived follower safety compliance were significant, because the 95% confidence intervals were [−0.059; (−0.125, −0.020); and 0.078; (−0.181, −0.050)], excluding zero, thus supporting H8a and H8b. However, the mediating effect of perceived safety-specific distributive justice on the relationship between SLPO and followers' perceived safety compliance (H7b) was not significant [−0.047; (−0.115, 0.006), including zero].

DISCUSSION

Findings

In this study, we partly replicated earlier studies on generalized leader reward and punishment omissions (25, 67) and extended our study by introducing new concepts and measures for safety-specific leader reward omission (SLRO) and a corresponding punishment omission (SLPO) within a laissez-faire leadership framework, as well as adapted context-specific measures of distributive justice and role ambiguity. Further, we retested two mechanisms to explain the relationship between these two domain-specific leadership styles and followers' safety compliance, by employing safety-specific distributive justice and safety-specific role ambiguity as mediators. The results substantiate that SLRO and SLPO are positively associated with followers' safety-specific role ambiguity, which in its turn negatively predicts their safety compliance. Further, SLRO, but not SLPO, is associated with followers' perception of safety-specific distributive justice, which in its turn predicts their safety compliance in a positive direction.

TABLE 4 | Mediating effects results.

	Estimate	S.E.	*p*-value	Lower 5%	Upper 5%
Mediation of SDJ: SLRO−> SDJ−>SC	−0.147	0.043	0.001	−0.236	−0.089
Mediation of SDJ: SLPO−> SDJ−>SC	−0.047	0.037	0.203	−0.115	0.006
Mediation of SRA: SLRO−> SRA−> SC	−0.059	0.029	0.048	−0.125	−0.020
Mediation of SRA: SLPO−> SRA−> SC	−0.078	0.035	0.026	−0.181	−0.050

The bias-corrected bootstrapping methodology, with 2,000 resamples at 95% confidence interval, was used to test the mediation effect with Mplus 7.4.

Hence, as regards our two mediation hypotheses, our findings substantiate that followers' safety-specific role ambiguity significantly mediates the relationships between SLRO and SLPO and followers' safety compliance, and that followers' perceived safety-specific distributive justice significantly mediates the relationship between SLRO and followers' safety compliance behaviors. These findings broadly support previous studies in this area linking laissez-faire leadership to followers' safety performance through underlying safety-related cognitive responses (i.e., safety-specific distributive justice and role ambiguity in this study) (6, 8, 9, 16, 21). They also accord with Podsakoff et al. (26) findings showing that followers' perceived distributive justice and role ambiguity mediated the relationship between active-approaching transactional leadership and followers' in-role and extra-role behaviors. However, counter to our hypothesis, and somewhat surprising, the relationship between SLPO and followers' safety compliance is not mediated by their perceived safety-specific distributive justice. However, with second thoughts the present finding can fruitfully be explained by attribution theory (68) which substantiates that followers are likely to attribute their own poor safety performance to external environmental factors beyond their own control (25). Ralph (69) further argued that punishment omission may be perceived more positively by followers because they do not want to be punished when things go wrong. Hence, leaders' non-responses to poor safety performance (i.e., safety-specific leader punishment omission) will probably not be perceived as unfair by followers which, accordingly, explains the insignificant relationship between SLPO and perceived safety-specific distributive justice.

Implications for Research

This study has important implications for occupational safety research as well as for laissez-faire leadership theory development, the last being an underdeveloped domain in leadership research. First, considering that today's employees, probably, relatively frequently experience detrimental laissez-faire leadership behaviors as compared to the dominating constructive ones (20), and the fact that more superiors are not proactively involved in safety promotion (21), we need more advanced and nuanced empirical studies focusing on plausible mediators in the context-specific laissez-faire leadership—follower safety behavior relationship (15, 17, 21). In this regard, alternative justice forms as well as alternative role stressors are also promising candidates to follow up.

Second, and paradoxically, although previous research shown in **Appendix A** has extensively examined the roles of safety-specific transformational and active transactional leadership in predicting safety compliance and occupational injuries (8–10, 13–15), to the best of our knowledge, only a few attempts

have been made to investigate the potential impact of the contrasting passive-avoidant forms, namely that of context-specific laissez-faire leadership on followers' safety outcomes (15, 17, 21, 32). Hence, this is a strong call to investigate the effects of domain-specific active-approaching forms (cf., safety-specific transactional and transformational forms) in parallel, and in tandem, with domain-specific passive-avoidant forms (cf. safety-specific reward and punishment omissions in this study) to test their unique and combined effects on all those relevant safety outcomes.

Third, beyond prior research examining safety climate as the mediator linking laissez-faire leadership and safety performance, this study introduced justice theory (55) and role theory (30) to the context of occupational safety to offer theoretically grounded explanations on why safety-specific leader reward and punishment omissions are related to followers' safety compliance behaviors through safety-specific distributive justice and safety-specific role ambiguity. Accordingly, and in line with justice theory and role theory, alternative forms of justice (interpersonal, informational and procedural) and role stressors (role conflict and role overload) may fruitfully be tested as mediators in the specified relationships; and in relationships with alternative mediators such as safety climate and with alternative safety outcomes such as safety accidents and injuries.

Fourth, the current study investigated two cognitive mechanisms, but did not consider potential affective mechanisms. In line with the affective event theory by Weiss and Cropanzano (70), followers' positive as well as negative affective responses evoked by leadership behaviors will influence individual compliance decision-making (70–72). Hence, future studies will profit from simultaneously examine both the cognitive and affective mechanisms through which safety-specific leader passive-avoidant and active-approaching leadership behaviors influence followers' safety behaviors.

Implications for Practices

The findings of the current study have more implications for managerial safety practices. The strongest implication is that leaders' reward and punishment omissions probably decrease followers' safety compliance behaviors, as well as other in-role and extra-role behaviors, through increased followers' perceived safety-specific role ambiguity and reduced safety-oriented distributive justice. This suggests that organizations will profit from inspiring and directing superiors to motivate and stimulate followers' safety compliance with safety-specific contingent reward and punishment, in tandem with safety-specific transformational forms; rather than non-responding to and/or avoiding followers' good or poor safety-related behaviors. Therefore, we believe that it is highly important both to stimulate and reward such leader behaviors for motivating leaders to provide rewards, recognition, and positive feedback contingent on followers efforts to maintain and improve their safety-related behaviors (26, 29). In contrast, punishment or negative feedback should be linked to low or declining levels of safety-related follower performance (29). These differentiated leadership styles, contingent on followers safety behaviors, will probably enable those employees to understand and enact those behaviors which are expected in their daily safety practice, and improve their behaviors thereafter (25, 26, 67). Likewise important, leaders are recommended to administer safety-specific rewards or punishments focusing on the specific safety behaviors that are desirable and undesirable; and not on the individual follower who exhibited those behaviors (29). Furthermore, superiors are suggested to provide timely and personalized rewards and punishments, and match the magnitude of the rewards and punishments to the specific follower behaviors (29); and, in this regard, communicate to followers which safety-specific behaviors will be rewarded and socially approved and which will be non-rewarded and punished (26).

Given the documented direct effects of followers' perceived safety-specific distributive justice and safety-specific role ambiguity on their safety compliance, leaders should remember well and pay even more attention to promote distributive justice and followers' role clarity. For example, in addition to transparent, personalized, and consistent rewards and punishments regimes, systematic and continued feedback seeking may help superiors to collect nuanced information about followers' needs, perceptions, and experienced performances, which can lead to followers' positive cognitive, emotional and behavioral responses via the avoidance of followers' perceptions of unfair safety-specific rewards and punishments (73). Our findings position safety-specific leader reward and punishment omission as a probable ambiguity-increasing leadership style (18, 43, 74), where the withholding and/or avoidance of legitimate and expected leader behaviors, followed by followers ambiguity, have been described to have detrimental consequences (19); further substantiating the necessity to restrain from such leader behaviors.

Furthermore, safety-specific role ambiguity, which is a very stressful demand, will decrease their motivation (75) and, further, trigger anxiety and confusion (76). Thus, we also propose that top managers should focus on reducing followers' safety-specific role ambiguity by elaborating sound policy statements, stimulating "good' safety climate, and clarifying and communicating their expectations to superiors and followers regarding safety performance goals and safe means by which to carry out their tasks safely (18, 26, 74), thus increasing desirable behaviors and outcomes (40).

Limitations and Future Directions

Although the present study has many strong characteristics, not the least the matched safety-specific measures of all study variables and significant findings, this study has some limitations. First, we used cross-sectional employees' self-reported data to test the hypothesized model, which may lead to common method bias and, further, implies the inability to draw causal conclusions (77, 78). Although the research design and results indicate that the potential common method bias is not a serious threat in the present study, future studies can benefit from collecting evaluations from superiors as well as subordinates, and even the evaluations of superiors' leaders (77, 78).

Another important path to follow in future research is that of reexamining the causal connections examined in the present study by incorporating a timely temporal design (e.g., experimental, longitudinal, and prospective designs) (78). Another limitation concerns the representativeness of the present

samples. The present survey study was completed by participants from enterprises from four typical high-risk industries in central China with a satisfactory response rate of 61.4%, higher than the average response rate of 52.7% in organizational research at the individual level (79). Therefore, potential selection biases might have influenced the generalization of our findings. Our recruitment method, however, focusing on industries and employees facing potentially relative high-frequent safety hazards and injuries in their daily work, probably strengthen the generalization of the present study to other comparable industries in China, and even other countries and cultures. As such, more studies are required to replicate the present findings across countries and cultures (80), also taking cultural difference variables into account, which may bolster the relevance and impact of such findings to a broader audience.

CONCLUSIONS

A growing body of studies on occupational safety behaviors has established positive relationships between constructive active-approaching forms of leadership (e.g., safety-specific transformational and active forms of transactional leadership) and followers' safety performance. However, very few studies have examined the degree to which, and how, passive-avoidant forms of leadership influence followers' levels of safety compliance, and no study is found to be focused on safety-specific leader reward and punishment omission (a specific passive-avoidant leadership) and its effect on follower safety compliance. The present study is the first study to investigate the effects of safety-specific leader reward and punishment omission on followers' reported safety compliance, also testing the mediations of followers' safety-specific distributive justice and role ambiguity in a sample of 307 workers from high-risk enterprises in China. We substantiate that safety-specific leader reward and punishment omission will decrease followers' safety compliance behaviors by the attenuation of safety-specific distributive justice and the enhancement of safety-specific role ambiguity, where safety-specific role ambiguity was the stronger mediator by mediating both relationships. Our results suggest that organizations and managers will benefit from recognizing and embracing that supervisors' omissions and avoidances of good and poor safety performance probably have strong negative effects on followers' cognitive responses (e.g., distributive justice and role ambiguity) and their following compliance behaviors. Hence, organizations should take adequate actions, both by firmly disapproving the "dark side" of leaders' safety-related omissions, and by firmly approving and continuously supporting the "bright side" of leaders' safety-related commissions.

DATA AVAILABILITY STATEMENT

The SHEDS data is available to academic researchers after one year of the launch of the respective wave. Researchers have to sign a confidentiality agreement and submit a short research proposal to indicate the intended use of the data. Data use for commercial purposes is not allowed. For more information on the SHEDS survey see https://www.sccer-crest.ch/research/swiss-household-energy-demand-survey-sheds/.

ETHICS STATEMENT

Ethical review and approval was not required for this type of study with human participants in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

LL contributed to the conceptualization, formal analysis, funding acquisition, investigation, and wrote the first draft. QM contributed to the conceptualization, funding acquisition, and investigation. AS contributed to the conceptualization, formal analysis, and writing—editing. JW contributed to the conceptualization, investigation, and writing—editing. SL contributed to interpretation of the findings and revision of the manuscript. MW made critical revisions of the manuscript. All authors confirmed the final version of the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.841345/full#supplementary-material

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Lessons Learned From Presumptive Condition Lists in Veteran Compensation Systems

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Presumptive condition lists formally accept connections between military factors and veteran health conditions. An environmental scan of such lists and their evidentiary basis was conducted across four veterans' administrations to inform other administrations considering the development of such lists. Information on included conditions, qualifying military factors, and scientific processes was obtained through targeted internet searches and correspondence with veterans' administrations. The content of presumptive condition lists across jurisdictions varied by conditions included, as well as military eligibility requirements (e.g., service in particular conflict, context, or time period). Scientific review processes to develop lists also varied across jurisdictions. Findings indicate that evidence and experience may be leveraged across compensation systems (veteran and civilian). Ongoing research to understand links between military exposures and veteran health is recommended.

Keywords: veteran health, veteran affairs, veteran benefits, scientific review, occupational compensation, veteran health administration

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INTRODUCTION

As our understanding of occupational hazards and their health impacts evolves, so does recognition of the need to compensate individuals affected. However, determinations of which conditions are compensable, and under what circumstances, are often not straightforward.

The complexities of establishing work-related causality are well demonstrated in military veteran compensation systems. When adjudicating a veteran's benefit application, the decision-maker must review and weigh different types of evidence to determine the relatedness of a claimed condition to military service. This process requires the gathering, analysis and weighing of past military service, exposure, and medical records, current scientific and medical evidence on occupational exposures and diseases, and relevant personal information.

Determinations of entitlement in this context can be challenging, since an individual's military service may include a range of occupational circumstances and hazards with subsequent impacts on various health conditions (e.g., mental, musculoskeletal, and other chronic outcomes) (1–4). While some hazards are similar to those found in civilian workplaces (e.g., diesel engine exhaust, temperature, and noise extremes), others are unique to military service. Examples of the latter include exposures during overseas deployments (e.g., burn pit smoke and infectious agents),

combat (e.g., chemical warfare agents and depleted uranium), and basic training (e.g., extreme physical loads) (1, 2). The challenge of isolating the occurrence and effects of military exposures is further complicated by time lags between release from active service and application for veteran benefits, variable quality and accessibility of military records, and long latency periods for many chronic health conditions (2).

To streamline the benefits application process, veteran compensation systems in some countries, such as the United States of America (5), the United Kingdom (6, 7), Australia (8), and New Zealand (9), have developed presumptive condition (sometimes referred to as "automated" or "streamlined") lists appearing either in schedules to legislation or supporting regulations. If a veteran diagnosed with a listed condition has been exposed to the corresponding military activity, the condition is presumed to be related to military service.

By reducing burden of proof requirements, presumptive condition schedules offer potential advantages of streamlined disability benefit processing and expedited decision making. However, determinations of which health conditions are presumptively compensated through veteran benefit systems, and under what circumstances, is a complex process informed by legal principles and, ideally, by scientific principles of causality.

This article intends to provide an overview of presumptive condition lists and scientific procedures underpinning their development, across four veteran compensation systems. Key scientific procedures and principles that support the development of veteran-focused presumptive condition lists are discussed, as well as opportunities for knowledge exchange across veteran and civilian systems. This information on scientific practices and principles underlying presumptive condition lists is meant to serve as a starting point for administrations tasked with establishing or expanding such lists within their own systems.

METHODS

Environmental scans are used in governmental and business contexts to gather and interpret information to inform strategic decision making and to direct organizational action (10). The current environmental scan was conducted by Veterans Affairs Canada in the summer of 2020 to collect information on presumptive condition lists (conditions included and military exposure criteria for presumption to apply) and the scientific procedures used to inform them. Four veterans' administrations, representing English speaking countries with a range of population sizes and geographic locations, were included: The United States of America (US), The United Kingdom (UK), Australia (AU), and New Zealand (NZ).

The scope of the scan was delineated by the following terms: "veteran presumptive conditions," "veteran compensation," "veteran health," and "occupational conditions veterans." The scan sought to identify health conditions included, prerequisites or criteria for entitlement, and scientific processes used for their selection. The scan did not include a comparison of the type of compensation paid (e.g., functional impairment), the types of benefits payable (e.g., disability award), or other procedural issues (e.g., treatment approaches, acceptance rates).

Enabling statutes and downstream policy instruments were searched and retrieved through official websites of the organization with responsibility for (or oversight of) veterans' benefits (The United States Department of Veterans Affairs, The United Kingdom's Ministry of Defense, Australia's Department of Veterans' Affairs, and Veterans' Affairs New Zealand), and other websites and online portals with details on relevant legislation and policy. Correspondence with research-affiliated individuals working within the relevant administration was also sought, for supplemental information.

All presumptive compensation statutes in the US, UK, AU, and NZ (as well as the regulations and policies made pursuant to the legislation) were examined to identify any relevant information regarding coverage (presumptive or otherwise) for health-related injuries, conditions and/or impairment. Where a piece of legislation, regulation or policy appeared to be relevant to the scan, information on conditions included, eligibility criteria, and scientific review (undertaken for the determination of conditions and eligibility criteria) was extracted and recorded.

This work was performed within the Research Directorate of Veterans Affairs Canada, Charlottetown, Prince Edward Island, Canada. Ethics approval was not required for this environmental scan of public data sources.

RESULTS

Conditions included within presumptive condition lists (or their equivalent), and their associated exposure criteria, across the US, UK, AU, and NZ are summarized in **Tables 1**–**4**, respectively. Cancers are the most widely presumptively covered types of conditions across countries, particularly in relation to Vietnam War service. Mental health conditions are also included in most presumptive lists, with the exception of the UK. Skin conditions are widely covered, with AU addressing a wider range of such conditions. The US and AU outline the greatest number of conditions/condition groupings, with differing exposure criteria and limits (8, 11).

In terms of exposure criteria for presumptions to apply (also summarized in **Tables 1**–**4**), the US outlines circumstances based on factors such as time since release from service, locations, conflicts, and time periods served. NZ identifies conflicts, while The UK's presumptions relate to service contexts (i.e., nuclear testing and sea-faring service). In addition to some specified military conflicts/situations (i.e., being a former prisoner of war), AU outlines other types of exposure criteria by condition, including both service-related and non-service related exposures. Service- related exposures (summarized in this article) are associated with exposures that may be encountered during service, while non-service-related exposures are those that may be encountered during civilian life outside of service.

Scientific procedures used to develop presumptive condition lists are described in the following sections.

TABLE 1 | Included conditions and exposure criteria for veterans, The United States of America (5, 11)[a].

Condition	Exposure criteria
Anemia, primary; Arteriosclerosis; Arthritis; Atrophy, Progressive muscular; Brain hemorrhage; Brain thrombosis; Bronchiectasis; Calculi of the kidney, bladder, or gallbladder. Cardiovascular-renal disease including hypertension; Cirrhosis of the liver; Coccidioidomycosis; Diabetes mellitus; Encephalitis lethargica residuals; Endocarditis; Endocrinopathies; Epilepsies; Hansen's disease; Hodgkin's disease; Leukemia; Lupus erythematosus, systemic; Myasthenia gravis; Myelitis; Myocarditis; Nephritis; Other organic nervous system diseases; Paget's disease; Osteomalacia; Palsy, bulbar; Paralysis agitans; Psychoses; Purpura idiopathic, hemorrhagic; Raynaud's disease; Sarcoidosis; Scleroderma; Sclerosis, amyotrophic lateral or multiple; Syringomyelia; Thromboangiitis obliterans; Tuberculosis, active; Tumors, malignant, or of brain, spinal cord or peripheral nerves; Ulcers, peptic (gastric or duodenal).	Condition becomes manifest within 1 year (within 3 years for Hansen's disease and tuberculosis; within 7 years for multiple sclerosis) from the date of separation from service.
Amebiasis; Blackwater fever; Cholera; Dracontiasis; Dysentery; Filariasis; Leishmaniasis; Loiasis; Malaria; Onchocerciasis; Oroya fever; Pinta; Plague; Schistosomiasis; Yaws; Yellow fever; Resultant disorders or diseases originating from therapy administered in connection with such diseases or as a preventative.	Tropical service.
Avitaminosis; Beriberi (including beriberi heart disease); Chronic dysentery; Helminthiasis; Malnutrition (including associated optic atrophy); Pellagra; Other nutritional deficiencies; Irritable bowel syndrome[a]; Peptic ulcer disease; Peripheral neuropathy except where directly related to infectious cause; Cirrhosis of the liver (September 28, 2009 or after); Osteoporosis.	Former prisoner of war, imprisoned for at least 30 days.
Any of the anxiety states; Psychosis; Dysthymic disorder; Stroke and its complications; Cirrhosis of the liver; Atherosclerotic heart disease or hypertensive vascular disease and their complications; Organic residual of frostbite or trench foot; Post-traumatic osteoarthritis; Osteoporosis (specified circumstances).	Former prisoner of war, imprisoned for any length of time.
AL amyloidosis; Chloracne or other acneform; Type 2 diabetes; Hodgkin's disease; Ischemic heart disease; All chronic B-cell leukemias; Multiple myeloma; Non-Hodgkin's lymphoma; Parkinson's disease; Early-onset peripheral neuropathy; Porphyria cutanea tarda; Prostate cancer; Respiratory cancers (cancer of the lung, bronchus, larynx, or trachea); Soft-tissue sarcoma (other than osteosarcoma, chondrosarcoma, Kaposi's sarcoma, or mesothelioma).	Exposure to an herbicide agent during active military, naval, or air service; including service in the Vietnam War in the Republic of Vietnam between January 9, 1962, and May 7, 1975.
Multiple Myeloma, All forms of leukemia (other than chronic lymphocytic leukemia); lymphomas (except Hodgkin's disease); Primary liver cancer (except if cirrhosis or hepatitis B is indicated); Bronchiolo-alveolar carcinoma; Cancer of the bile ducts, brain, breast, bone, colon, lung, gall bladder, esophagus, ovaries, pancreas, pharynx, salivary gland, small intestine, stomach, thyroid, or urinary tract (including kidneys, renal pelves, ureters, urinary bladder, and urethra).	Veterans who participated in a "radiation-risk" activity: Onsite participation in a test involving atmospheric detonation of a nuclear device; Occupation of Hiroshima or Nagasaki, Japan, between August 6, 1945, and July 1, 1946; Internment as prisoner of war in Japan (or service in Japan following internment) in WW2; Service before Feb 1, 1992 at specified US gaseous diffusion plants; Service before January 1, 1974 on Amchitka Island, Alaska; Qualification as "Special Exposure Cohort" member.
Cancer of the kidney, liver, or bladder; Non-Hodgkin's lymphoma; Adult leukemia; Multiple Myeloma; Parkinson's Disease; Aplastic anemia and other myelodysplastic syndromes.	Exposure to contaminants in the water supply at Camp Lejeune during service.
	Gulf War Veterans who:
Medically unexplained chronic multi-symptom illnesses that exist for 6 months or more, such as Chronic fatigue syndrome, Fibromyalgia, Irritable bowel syndrome; Any diagnosed or undiagnosed illness that warrants a presumption of service connection, as determined by the Secretary of Veterans Affairs	Served in the Southwest Asia Theater of Operations and have a condition that is at least 10% disabling by December 31, 2026
Brucellosis; Campylobacter jejuni; Coxiella burnetii (Q fever); Non-typhoid Salmonella; Shigella; West Nile virus; Malaria (or when accepted treatises indicate the incubation period began during a qualifying period of service); mycobacterium tuberculosis; visceral leishmaniasis	Served in the Southwest Asia Theater of Operations or in Afghanistan on or after September 19, 2001 and manifest one of the following infectious diseases to a degree of 10% or more within 1 year of separation (note: mycobacterium tuberculosis and visceral leishmaniasis covered at any time after separation)
Asthma; rhinitis; sinusitis, to include rhinosinusitis	Served any length of time in the Southwest Theater of Operations during the Persian Gulf War, or any length of time in Afghanistan, Syria, Djibouti or Uzbekistan on or after September 19, 2001, and manifests condition to any degree within 10 years of separation from military service

[a]*Abbreviated list and criteria; see references for full details on conditions and exposure criteria.*

TABLE 2 | Included conditions and exposure criteria for veterans, The United Kingdom (6, 7).

Condition	Exposure criteria
Mesothelioma	Royal Navy service of any duration on seagoing ships between 1939 and 1973
Leukaemias (other than chronic lymphatic leukemia)	Participation at the tests or experimental programmes without case-specific dose determination, when presenting clinically within 25 years of presence at the tests or weapons experiments

TABLE 3 | Included conditions and exposure criteria for Veterans, Australia (8).

	Exposure criteria[a]
Condition—Streamlined	
Non-melanotic malignant neoplasm of the skin; Malignant melanoma of the skin or eye; Acquired cataract; Benign neoplasm of the eye and adnexa; Malignant neoplasm of the eye; Non-melanotic malignant neoplasm of the skin; Pinguecula; Pterygium; Seborrheic keratosis; Solar keratosis	Sunlight or ultraviolet light exposure, various cumulative hours and geographic areas
Achilles tendonitis or bursitis; Chondromalacia patella; Femoroacetabular impingement syndrome; Iliotibial band syndrome; Patellar tendinopathy; Plantar fasciitis; Shin splints; Trochanteric bursitis and gluteal tendinopathy; Patellar tendinopathy	Weight bearing exercise involving repeated activity, various intensities
Acute articular cartilage tear; Acute meniscal tear of the knee; Labral tear; Sprain and strain; Dislocation of a joint; Cut, stab, abrasion and laceration; Fracture; Joint instability; External bruise; Internal derangement of the knee	Significant physical force or physical trauma applied to or through affected area
Physical injury due to munitions discharge	Munitions discharge
Sensory neural hearing loss; Tinnitus	Sound exposure of at least 140 dB(C)
External burn	Heat source, extreme cold, corrosive chemicals, radiation
Tinea	Exposed to the tinea dermatophyte; skin maceration; other
Condition—straight-through	
Intervertebral disc prolapse; Lumbar spondylosis; Osteoarthritis (lower limb); Thoracic spondylosis	Lifting loads, various cumulative load-factors
Rotator cuff syndrome	Repetitive or sustained activities of the affected shoulder
Post-Traumatic Stress Disorder (PTSD); Anxiety disorder; Adjustment disorder	Hostile or life threatening environment for at least 4 weeks, various onset timeframes

[a]*Abbreviated; see full summary of factors required to connect conditions with military service via (8).*

The United States of America

The US Department of Veterans Affairs ensures that a review of scientific and medical evidence is completed prior to the inclusion of any condition on their list of presumptions. This review includes reports from the National Academies of Sciences, Engineering, and Medicine (12), as well as analyses/reviews conducted by scientific bodies within the Department.

The process to develop a presumption begins with a request by Post Deployment Health Services for a report from the National Academies of Sciences, Engineering, and Medicine. The National Academy secretariat convenes nationally recognized experts who perform a consensus review of the literature on links between exposures to potentially hazardous agents and health outcomes. This format has been used for a range of exposures and conditions, for example when reviewing human health evidence on the effects of exposure to Agent Orange (13) and antimalarial drugs (14). National Academies reports are subsequently reviewed by technical working groups within the US Department of Veterans Affairs. Thus, scientific evidence is reviewed externally and then internally to develop recommendations for Veterans Affairs.

The United Kingdom

The UK War Pension Scheme (15) makes awards for disorders causally linked to service prior to April 6, 2005, when the Armed Forces Compensation Scheme (16) was introduced. There is no concept of prescription or presumption under the Armed Forces Compensation Scheme. However, under the War Pension Scheme there are two situations where presumption rather than case-by-case assessment may occur:

1) Entitlement for leukaemias (other than chronic lymphatic leukemia) is accepted without case-specific dose determination, when the affected person presents clinically within 25 years of presence at specified UK Atmospheric nuclear test and weapons experiments (7).
2) Entitlement for mesothelioma is based on a presumption of a service link where there is Royal Navy service of any duration on seagoing ships between 1939 and 1973 (6).

These presumptions are outlined in reports by the "Independent Medical Expert Group" (IMEG), tasked by the Minister for Defense Personnel and Veterans to investigate medical and scientific topics related to the Armed Forces Compensation

TABLE 4 | Included conditions and exposure criteria for veterans, New Zealand (9).

Condition	Exposure criteria
AL-type primary amyloidosis; Chloracne; Type 2 diabetes; Ischaemic heart disease; Hodgkin's disease; Hypertension; Non-Hodgkin's lymphoma; Chronic lymphocytic leukemia (including hairy-cell leukemia and other chronic B-cell leukaemias); Multiple Myeloma; Acute and subacute peripheral neuropathy; Parkinson's disease; Porphyria cutanea tarda; Prostate cancer; Respiratory cancers of the lung, bronchus, larynx, trachea; Soft-tissue sarcoma; Stroke	Served in Vietnam between May 29 1964 and March 1975
All forms of leukemia (except chronic lymphocytic leukemia); Lymphomas (other than Hodgkin's lymphomas); Multiple Myeloma; Primary liver cancer (except if cirrhosis or hepatitis B is indicated); Bronchioloalveolar carcinoma; Cancer of the bile ducts, brain, breast, bone, colon, lung, gall bladder, esophagus, ovary, pancreas, pharynx, salivary gland, small intestine, stomach, thyroid, or urinary tract (renal, ureter, urinary bladder, or urethra)	Exposed to nuclear radiation[a]
Chronic fatigue syndrome; Fibromyalgia; Irritable bowel syndrome	Served in the Gulf Conflict between December 20 1990 and April 13 1991
Any of the anxiety states; Beriberi; Chronic dysentery; Cirrhosis of the liver; Dysthymia; Heart disease or hypertensive vascular disease and their complications; Helminthiasis (intestinal vermiform parasites); Hypovitaminosis; Irritable bowel syndrome; Malnutrition (including optic atrophy); Organic residual of frostbite or trench foot; Pellagra and/or other nutritional deficiencies; Peptic ulcer disease; Peripheral neuropathy; Post-traumatic osteoarthritis; Psychosis; Stroke and residuals of stroke.	Prisoner of war, for any length of time, during the Second World War

[a]*Service as part of the British Occupation Force of Japan between 1946 and 1952 (J Force), or on HMNZS Pukaki from May 15, 1957 to November 8, 1957, HMNZS Pukaki from April 28, 1958 to September 23, 1958, HMNZS Otago on July 22, 1973, HMNZS Canterbury on July 28, 1973, HMNZS Rotoiti as part of Operation Grapple from May 15, 1957 to November 8, 1957.*

Scheme. The IMEG is a non-departmental public body comprising independent consultants drawn from a number of medical specialties, which investigates the issues on which advice is requested, provides evidence-based conclusions and recommendations based on peer-reviewed scientific and medical literature (17). It consults other experts and invites interested parties to submit relevant research on an as-needed basis (18).

Australia

Since 2007, Australia's Department of Veterans' Affairs has been developing systems to streamline and automate disability benefit processing, with 43 "decision ready" conditions processed through multiple streams to date. An important basis for these conditions are Statement of Principles (SOPs), legislative instruments with statements concerning which exposure factors must exist to establish a causal connection between military service and a particular health condition (19). Burdens of proof vary, for example combat service is associated with a lower burden of proof compared to non-combat service.

SOPs are developed by the AU Repatriation Medical Authority [an independent statutory authority responsible to the Minister for Veterans' Affairs (20)] through a global review of military and civilian evidence. If sufficient evidence is found to support a link between an exposure factor and condition, then this factor will be included in the SOP. While not presumptive, SOPs inform the development of decision-ready condition lists, with their listed exposure criteria used in application of the presumption in some instances. Lumbar spondylosis provides one example of a quantifiable SOP where a lifting factor is applied, with required periods of service ranging from 28 days for Special Forces members up to 1,360 days for Officers in the Royal Australian Air Force.

New Zealand

Lists of conclusively presumed conditions linked to operational service in NZ were introduced as policy to direct decision-making in 2007, adapted from the US list of presumptive conditions. When the NZ Law Commission conducted an independent review of the War Pensions Act 1954 in 2010, it recommended the adoption of AU's Statements of Principles but did not recommend removing the lists of conclusively presumed conditions that had been adopted from the US. The current list of presumptive conditions (9) was accepted in 2014.

Veterans' Affairs NZ adopted AU's SOPs in December 2014 and established a Veterans' Health Advisory Panel to adopt or amend presumptive decision-making. As a result, NZ relies heavily on AU's scientific review process, though it can determine which conditions to include, thus ensuring that any decisions adopted from AU fits the NZ context and veteran population. A Clinical Advisor from NZ is invited to AU's deliberations and provides advice on the scientific-medical evidence for the Statements of Principles as to whether the evidence is relevant to the NZ Defense Force. The Clinical Advisor is also a member of the NZ Veterans' Health Advisory Panel, which advises whether the Statements of Principles should be adopted by NZ. For example, the NZ Defense Force has many Maori and Pacific peoples as members and it is expected that any differences that may impact on medical conditions be taken into consideration. The presence of experts from numerous fields on the panel (e.g., epidemiology, psychology, socioeconomics, and medical

practice) also promotes a comprehensive evidentiary review prior to decision making.

DISCUSSION

Across the four countries summarized, presumptive condition lists vary by the conditions included, the military requirements for eligibility, and the evidentiary review processes used to develop these lists and exposure criteria. This is not unexpected, given national differences in domestic environments and international deployments that can impact risk arising from hazardous exposures (21).

The Role of Scientific Review

A notable consistency across countries is the presence of scientific review in the development of presumptive condition lists. A comprehensive review of available scientific evidence is an essential step to evidence-based decision making and, when communicated effectively, can positively impact public trust (22). Scientific advisory panels or other external scientific advice mechanisms that assess the current state of evidence on a given condition and its relationship to military service play an important role in processes to develop or update presumptive lists, as well as other decisions concerning causation and military-relatedness. Internal/external membership representing a range of fields of expertise may independently conduct an evidentiary review (e.g., AU), assess the applicability of decisions in other jurisdictions to their own contexts (e.g., NZ) or commission external agencies to conduct reviews on their behalf (e.g., US). Criteria guiding the composition of such scientific committees typically include medical and scientific expertise in various health fields. For example, Australian legislation detailing the composition of the Australian Repatriation Medical Authority states "one of the (5) members must be a person having at least 5 years of experience in the field of epidemiology" with the committee's Chairperson being "a registered medical practitioner, or medical scientist, with at least 10 years of experience" (23). Similar requirements have been noted in civilian worker compensation contexts, where the majority of scientific/advisory committee members require "medical and scientific expertise" in backgrounds including occupational medicine, environmental health, occupational hygiene, epidemiology, and toxicology (24).

Scientific Principles

Scientific principles to consider during the development and expansion of presumptive condition lists have been discussed in detail elsewhere (25). One important consideration is the existence of strong scientific evidence to establish a causal connection between one or more relevant exposures during military service and the health condition. Findings from national and international agencies and organizations tasked with assessing links between chemicals, forms of radiation, or other factors with long-term disease (such as the US National Academy of Sciences and the International Agency for Research on Cancer) are often referred to. Systematic reviews, or multiple high-quality studies showing a causal relationship between the disease and the military-related exposure, may also be used to guide decision making.

Clear diagnostic criteria are also important, to minimize doubt that the claimant has the condition in question (straightforward for some conditions, such as cancers, but less so for others, such as syndromes). It is also preferable for a presumptive schedule to be structured around conditions of interest with qualifications as to which exposures should be considered as causal, rather than around a particular exposure. For example, exposure to chromium has been linked to a number of chronic diseases and respiratory and skin disorders that may also be caused by agents other than chromium. "Lung cancer caused by exposure to chrome or its toxic compounds" provides clearer guidance as compared to "Diseases arising due to exposure to chrome or its toxic compounds". Finally, it is relevant to consider the contribution of military factors to the burden of the condition in question, which can be examined by, for example, comparing age-adjusted rates in veterans to their civilian counterparts (26).

Knowledge Transfer Across Veteran Compensation Systems

As stated previously, knowledge sharing across veterans' administrations with similar priorities may support program efficiencies *via* leveraging of external experience and resources. Therefore, presumptive condition lists and procedures developed by other jurisdictions may provide a useful starting point for other countries with similar priorities. However, it is important to examine the applicability and validity of other lists to the military population of interest, with consideration of cross-country differences in environmental and operational contexts (e.g., recruitment, training and operational policies, domestic environments, and deployments). It has been observed, for example, that even within a specific conflict the risk of hazardous exposures can differ according to the extent of a country's contribution of navy, army, and air force personnel (21). Domestic environments also vary; for example, the high prevalence of skin condition benefits administered to Australian Veterans may not be relevant to northern countries, where solar UV exposure is less of a domestic concern for military personnel.

Knowledge Transfer Across Veteran and Civilian Systems

In addition to exchange across veterans' administrations, it is relevant to examine the evidentiary basis of deemed disease lists in civilian worker compensation systems, since many workplace hazards are common to both civilian and military environments. There has been a historic separation of compensation for civilian and veteran populations in need of assistance, often through parallel systems governed by different principles and rules (27). However, there are also many similarities, since both systems must review and weigh various types of evidence to determine the relatedness of a claimed condition to military service or civilian work. Instances of cross-system benefits have also been demonstrated, such as the Canadian example of federal subsidies to rehabilitate spinal-cord-injured veterans from the Second

World War period leading to expanded disability policies and programs for civilians (28).

Scientific concepts that underpin deemed disease lists in civilian systems may also be informative to veteran systems. In Australia for example, Section 7 of the Safety, Rehabilitation and Compensation (Defense-related claims) Act 1988 (29) states provisions to accept certain condition claims on the basis of defined occupational exposures. These conditions are specified in a legislative act primarily related to a civilian context (30). The updated deemed diseases list as of 2017 is based on Safe Work Australia's Deemed Diseases in Australia (31), a recommended list of deemed diseases based on a detailed external review of published scientific information and the application of three required criteria: strong causal link between the disease and occupational exposure; clear diagnostic criteria for the disorder; and the diseases needing to comprise a considerable proportion of cases in the overall population (or identifiable subset of).

In the UK, civilian occupational conditions are compensated under the Industrial Injuries Scheme. Benefits are payable to workers with a prescribed condition that is listed in the Prescribed Diseases Regulations (32). The Prescribed Diseases List is updated on the advice of the Industrial Injuries Advisory Council, an independent scientific advisory body created in 1948 to advise the government on matters related to the administration of the Industrial Injuries Scheme [e.g., (33)].

Future Directions

This article provides insight into presumptive condition lists (or their equivalent) in veteran benefits systems of four primarily English-speaking countries. Extending this scan to systems in other countries would provide more information, and perhaps greater variability, in presumptive condition lists and processes used to develop them. A number of related issues also merit further investigation, including procedures undertaken to review scientific evidence and make determinations of causality, and as well as broader legal, political, and administrative considerations that impact decision making.

Prior studies of exposure and health surveillance and record keeping in the military context, particularly in deployed combat settings, illustrate both opportunities and limits of "big data" systems to inform research, prevention, and compensation of service-related injury and disease (34, 35). Support for ongoing research, including administrative linkages, is needed to strengthen this evidence base (2). While the establishment of clear criteria for exposure dose/duration is a challenge for many conditions, it is interesting to note that AU's approach to streamlining conditions for veteran compensation has undergone regular enhancements as additional data collection and research strategies have been undertaken. For example, significant work was carried out to collect and analyze physical training program data from each of the entry schools to the Australian Defense Force to develop streamlined condition processes (36).

Research focused on specific subgroups (e.g., females and other minorities) is also important to understand potential differences in exposures and susceptibilities, and implications for compensation rules and decisions. Such information can be directly applied in decision-making, for instance NZ's review and adaptation of AU's streamlined conditions considers unique characteristics of Maori and other Pacific populations and potential impacts on medical conditions in veterans.

CONCLUSIONS

Compensation policies carry broad impacts on claimants and government agencies responsible for veteran wellbeing. The establishment of presumptive condition lists is complex, particularly when attempting to assess condition causation and military-relatedness. This environmental scan of four countries identified a range of health conditions covered, military requirements for eligibility, and scientific review processes used to develop presumptive condition lists. Opportunities to leverage evidence and experience across veteran, as well as civilian, systems should be considered. Ongoing research to understand links between exposures and health outcomes in military populations is also recommended.

AUTHOR CONTRIBUTIONS

AH designed the study and drafted the manuscript. MD and AH performed data collection. All authors interpreted the study results, contributed to manuscript revisions, approved the final version for submission, and agree to be accountable for all aspects of the work.

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Developing an Integrated Evaluation Model for Physician Comprehensive Workload Tethered to Outpatient Practice: An Empirical Study From China

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Background: Previous studies, often simply using either objective workload or mental workload as a measure of physician workload in various healthcare settings might have failed to comprehensively reflect the real workload among physicians. Despite this, there is little research that further explores a comprehensive workload evaluation framework with the integration of objective workload and mental workload to describe their comprehensive workload.

Methods: A comprehensive evaluation framework for physician workload was proposed based on the combination of objective workload and task-level mental workload also with the consideration of quality of provided medical services and served patient complexity; and accordingly, an integrated evaluation model for physician comprehensive workload (PCW) tethered to outpatient practice was developed and further applied to perform a PCW analysis using cross-sectional data on outpatient workload of 1,934 physicians mainly from 24 hospitals in 6 provinces in Eastern, Central, and Western China. Multiple linear regression and multinomial logistic regression analyses were established to identify significant factors influencing the PCW.

Results: Overall, the average score of PCW tethered to outpatient practice Chinese physicians experienced was 811.30 (SD=494.98) with concentrating on between 200 and 1,200. Physicians who were female, from Eastern or Western China, and those who worked >60 h per week and longer outpatient hours per week were more likely to experience a higher PCW. 11.2% of participating physicians were identified as very high PCW physicians, compared with 11.6% as low PCW physicians, 45.5% as medium PCW physicians and 30.7% as high PCW physicians. Those who were female, older, from Western China, those who had lower educational levels, lower professional titles and longer working years in the current institution, and those who worked in tertiary A hospitals and Internal or Surgical, and worked >60 h per week and longer outpatient hours per week were more likely to be very high PCW physicians.

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Conclusions: Our work has a potential application for comprehensively assessing physician workload tethered to outpatient practice and could provide a solid foundation for hospital managers to further accurately determine and identify physicians with high workload, who would otherwise be missed in either objective workload or mental workload.

Keywords: physician comprehensive workload, outpatient practice, evaluation framework, integrated model, China

INTRODUCTION

Currently, heavy physician workload is a common challenge internationally. With a growing aging population with chronic and age-related diseases, along with subsequently ever increasing health care demands worldwide (1), especially in China (2), alarming increasing trends in physician workload have attracted much attention from health care providers, researchers and decision makers in recent years, owing to lack of a proportional growth in the number of physicians (3–5). Increased physician workload is associated with their worse occupational health (6, 7), inferior quality of medical care and even patient harm (5, 7–9). Healthcare organizations may also experience adverse effects such as low productivity, increased cost (10), and increased use of sick leave and turnover rates among physicians (9). Hence, there is an increasingly urgent need for assessing and managing physician workload to mitigate the potential negative effects caused by increased physician workload.

In China, overwhelming workload in physicians has become one of the major concerns for current health care system (11), which has become one of the main sources of their high work pressure; and the prominent physician shortage issue in China [2.04 practicing physicians per 1,000 people in 2017 (12), compared to the international average of 3.5 (13)] along with extremely unbalanced distribution of high-quality physicians between urban and rural areas and between regions may further lead to a much heavier workload for Chinese physicians, especially in tertiary A hospitals in big cities. As the hierarchical diagnosis and treatment system of China has not yet achieved effective triage of patients (4), also with ever-increasing patient demands for high-quality medical services, physicians especially in large general hospitals tend to have an increasingly heavy outpatient workload, with a greater number of outpatients seen daily (4) (even up to 100 patients a day), resulting in a more limited time available for interaction with their patients on average and patient dissatisfaction with the medical services they provided. Not surprisingly, data from a recent national survey from 136 public tertiary hospitals across 31 provinces in China showed that most physicians worked >10 h per day (an average of 10 h) to manage outpatients and inpatients, and almost two-thirds reported a heavy workload (14); and the latest data from Chinese Physician Practice Situation White Paper in 2018 also reported 85.41% of Chinese physicians worked $>$ 40 h per week, and even 32.69% worked $>$ 60 h per week (4). High levels of workload have also been recognized as a contributor to high error rates, and even patient and visitor violence. In addition to this, excess loads of the entire health care delivery system can be passed directly to or through the outpatient clinics, adding to the complexity and strain already being experienced, thereby becoming a location with high risks of suffering from medical disputes, and even violence against healthcare professionals. Under such circumstances, hospitals seek to determine individuals among physicians, who need interventions in priority, so as to expand effective supply of their outpatient services and continuously improve the quality and efficiency of medical services and patient safety while lightening their workload.

Chinese researchers have paid increasing attention to the measurement and evaluation of Chinese physicians' workload in recent years. Currently, the National Health Commission of the People's Republic of China and National Administration of Traditional Chinese Medicine jointly issued a document in 2020, clearly pointing out that it's necessary to scientifically calculate medical workers' workload and further allocate the human resources rationally, so as to avoid long-term overload and reduce their physical and mental pressure (15). Hence, it's of great importance to establish a comprehensive evaluation model for physician workload to further strengthen the assessment and management of Chinese physicians' workload. However, existing research on physician workload in China with slow progress, reflects the work burden of outpatient physicians mainly using several objective workload indicators (for example, the number of outpatients seen, and working hours per week), with less consideration of their subjective psychological experiences (that is, mental workload) (7). Such metrics for evaluating physician workload are inadequate. Physicians are generally simultaneously exposed to both physical and mental workload stress in outpatient practice, necessitating simultaneously monitoring of physical and mental workload for more comprehensive workload evaluation. There is therefore an urgent need for a comprehensive workload evaluation framework to describe their comprehensive workload that integrates both their objective workload and mental workload.

Given that the impending issues that outpatient clinics are facing underscore the need for an approach of comprehensively assessing physician workload, the main objective of this study is to explore to develop an integrated evaluation model for comprehensive assessments of physician workload tethered to outpatient practice. The specific objective is to perform a physician comprehensive workload analysis according to our developed integrated evaluation model for physician workload using cross-sectional data on outpatient physician workload

from a nationwide survey. Our current understanding of the integrated evaluation model for comprehensively assessing physician workload is rather limited. Previous research often simply adopted either objective workload or mental workload as the measure of physicians' workload in various healthcare settings. Such kind of study, although important might have failed to comprehensively reflect their real workload. This study fills the literature by developing an integrated evaluation model for physician workload, and can help provide a solid foundation for hospital managers to accurately identify those with high workload as individuals who need interventions in priority, who would otherwise be missed in either objective workload or mental workload.

Literature Review

Concepts and Definitions of Workload

Workload is a multidimensional and multifaceted concept that remains inconsistent definitions worldwide (7), literally meaning the amount of workloads a human operator undertakes per unit time. Even without consensus on a definition, workload has become a topic of increasing importance with increasing attention to the adverse effects of increased workload, especially in the medical field. Workload is generally considered to comprise the following two large aspects: objective workload that is simply reflected by the quantity of work tasks, and mental workload that reflects the mental strains resulting from a human operator performing a work task under a specific environmental or operational condition as well as the capability of the human operator to respond to task demands (16). Currently, the onset of modern technology and automation has greatly shifted the workload paradigm from the physical domain to the mental domain (16, 17), and some researchers thereby used mental workload as the measure of an individual's workload (18). Mental workload is also a term referring to the cost of completing a work task, and it can be defined as the amount of brain or cognitive resources used/consumed per unit time to reach the acceptable performance required by the work task (19). Currently, mental workload is widely accepted to be defined as the portion of a human operator's limited capacity actually required to perform a specific task under the assumption that humans have a fixed amount of processing capacity; and the task inherently requires processing resources, and the more difficult the task, the higher the processing capacity required for acceptable objective and subjective performance (16, 17).

Measurement of Workload

With respect to the workload measurement, the number of work tasks is often used to measure objective workload. For example, some single indicators such as working hours per week, and outpatient volume per shift (4, 11, 12) are used as the measure of physician workload in outpatient clinic. Such kind of the measurement of workload although simple and easy to be tracked and intervened in real time, might have failed to diagnose causes and determine the nature of workload, and explain the relation between the nature of a work task and the characteristics of the operator. In contrast, currently, there are three primary methods for measuring mental workload, mainly including subjective assessments, task-based performance measures, and physiological measures (16, 17, 20). Each of these methods can be applied in isolation, but they may be also measured concurrently to obtain a more comprehensive assessment of mental workload (16).

Subjective assessments concentrating on different aspects of mental workload require a human operator to distinguish a level of workload in indications on scales in post-task responses. The NASA-Task Load Index (NASA-TLX) scale, widely used in measuring or diagnosing mental workload in human factors and ergonomics, has proven to be a sensitive, valid and reliable assessment tool (21, 22), and can be used for quantifying perceived workload in various healthcare settings (23). In the same vein, the Subjective Workload Assessment Technology (SWAT) is a subjective rating technique used for assessing mental workload (24). Over the years, different researchers have localized these scales to be suitable for the measurement of mental workload in various settings in their own countries. For example, given that there are few instruments for measuring or diagnosing Chinese physicians' mental workload, our research team developed a mental workload scale verified with good reliability and validity based on the combination of dimensions of NASA-TLX and SWAT in 2018 (7). Although subjective measures of mental workload are with high face validity, ease of use, participant acceptability, low cost and known sensitivity to workload variation, there remain some methodological issues to be solved, such as trading off the intrusiveness of live ratings against the retrospective bias of post-task ratings (16, 17, 19). Accordingly, once a work task is finished, workload evaluation of the human operator is carried out immediately, possibly minimizing the recall bias.

Task-based performance measures are based on the performance variables (e.g., reaction times, accuracy, and error rates) of a human operator in performing work tasks as assessment indicators of mental workload under an underlying assumption that increased processing required for higher levels of workload would degrade the performance of the task being performed, mainly including primary and secondary task measures (17). Performance is considered as a measure of primary and secondary task achievement and can indicate spare capacity. Primary task measure is based on techniques of direct registration of the human operator's capability to perform the primary task at an acceptable level in the natural or simulated work environment (for example, with respect to acceptably low error likelihood), whereas in secondary task measures, monitoring attention to and workload resulting from a primary task may be indirectly reflected by assessing the performance on a secondary task, since in any real-world dual task situation where one task takes priority over the other, the performance on the secondary task (e.g., errors and time) can be highly associated with the spare capacity unused by the primary task (17). A primary task analysis is the most fundamental means of assessing mental workload using these measures (16). Task analysis includes any methods of evaluating what actions a human operator performs and why these actions are being performed based on a time-motion study; and these methods involve the structured decomposition of work activities and classification

of these activities as a series of tasks, processes, or classes (17). However, the insensitivity of some of the measurements based on these performance-based techniques is one disadvantage, since there is not a simple linear, but an inverted U relationship between mental workload and job performance. That is, a work task with a low demanding mental workload could achieve an excellent performance during the beginning stage of the task, but then the performance will be degraded as the human operator becomes fatigued or distracted, possibly leading to confounded results (19). Accordingly, using task performance techniques with other mental workload assessment methods may improve the quality of the measurement (19).

Physiological measures are the third type of mental workload assessments, as a natural type of mental workload index, under the underlying assumption that changes of mental workload level of a human operator can be reflected by the changes in some physiological indicators of the human operator corresponding to different task demands. Previous studies have used physiological parameters such as heart rate, heart rate variability, brain activity, event-related brain potential, galvanic skin resistance, breathing rate, pupil diameter and blink rates to assess the human operator's state (16, 17, 25). Although measuring physiological parameters for mental workload evaluation has been fairly well-validated with decreased intrusiveness, much of the research done involves a controlled experiment with controlled stimuli, since on the one hand, many other factors that have no relation to mental workload, might also cause changes in certain physiological parameters (15), and on the other hand, the accuracy of physiological data depends to a large extent on the performance and precision of the sensors (19). In addition to these above-mentioned measures for physician workload, workload was frequently tracked as relative value units (26).

Physician Work Tasks Tethered to Outpatient Practice

Identifying tasks refines the measurement of workload associated with these tasks. Work tasks tethered to outpatient practice can be generalized as the sum of a series of work activities necessary for physicians to provide outpatients with complete medical services that meet their reasonable demands. In our previous study, we decomposed and further classified all work activities physicians performed during outpatient encounters into the two large groups based on a time-motion task analysis on 32 Chinese physicians from public tertiary hospitals: physician-patient communication work tasks (comprising six categories of work tasks) characterized by direct patient interaction, and non-physician-patient communication work tasks (comprising seven categories of work tasks) characterized by paperwork (27). Research indicated that gaining insight into the effort associated with work tasks could make workload assessments more robust, since task analysis might facilitate workload measurement by the individual work components or subtasks to be measured (28). The definition of the detailed work tasks performed by physicians in outpatient practice can provide a solid foundation for the present study to further seek to comprehensively assess physician workload with the consideration of the content and nature of work tasks tethered to outpatient practice.

Evaluation Framework for Physician Workload

Previous studies have investigated the physician workload in various working settings [e.g., emergency department (16, 23), clinical care (18, 25)] using single methods noted in the literature review or a combination of these methods (16); however, most of them might have failed to comprehensively assess physician workload, since they either only focused on the objective workload (4) or mental workload using single or multiple metrics, or just simply measured both objective workload and mental workload to obtain a more comprehensive assessment of physician workload (16). It is obvious that such a single or non-integrated evaluation framework will not effectively solve comprehensive assessments of physician workload. To this end, some research has developed and applied a research model of factors affecting attending physician workload centered on physician, hospital, team and patient characteristics through in-depth semi-structured interviews and a modified Delphi technique (26, 29).

Workload is also influenced in part by the nature of the work task in question (28). Research indicated that physician workload is increased with complexity of medical cases or medical care (16, 18, 23, 26, 30, 31), and the well-known RBRVS (resource-based relative value scale, RBRVS) model, widely used for medical workers' performance appraisal, revealed that these patient factors such as complexity, and severity of the patient's disease had a positive impact on the physician workload. Thus, patient complexity should be considered into the comprehensive assessment framework of physician workload. However, there has little research into the application of patient complexity as an adjustment coefficient to adjust the physician workload. Moreover, research also revealed that practice size and quality of medical services were key factors influencing physician workload (23, 26, 32); and physician workload is increased with number of patients seen (18, 23, 33), and the higher the quality of medical care provided by physicians, the more their resources are consumed, ultimately resulting in a higher workload (34), whereas in turn, increased workload might reduce medical quality (5, 7–9). Thus, practice size and quality of medical services should be also considered. Moreover, there has little research into assessment of physicians' outpatient workload at task level based on the content of work tasks performed (35) in outpatient settings. Some studies addressed the assessment of physician workload at task level (named task-level workload in the rest of the paper) in emergency department (16), internal medicine (28), clinical radiation oncology (36, 37), and general practice (38). Such kind of study provides a reasonable method to quantify physician workload for detailed activities, which may be useful to monitor workload for more granular tasks within activities.

When drawing insights from previous studies on assessments of physician workload, we proposed a comprehensive evaluation framework for physician workload based on the combination of objective workload and task-level mental workload also with the consideration of quality of provided medical services and served patient complexity (see **Figure 1**). This evaluation framework guided our study to develop an integrated evaluation model for physician comprehensive workload tethered to outpatient

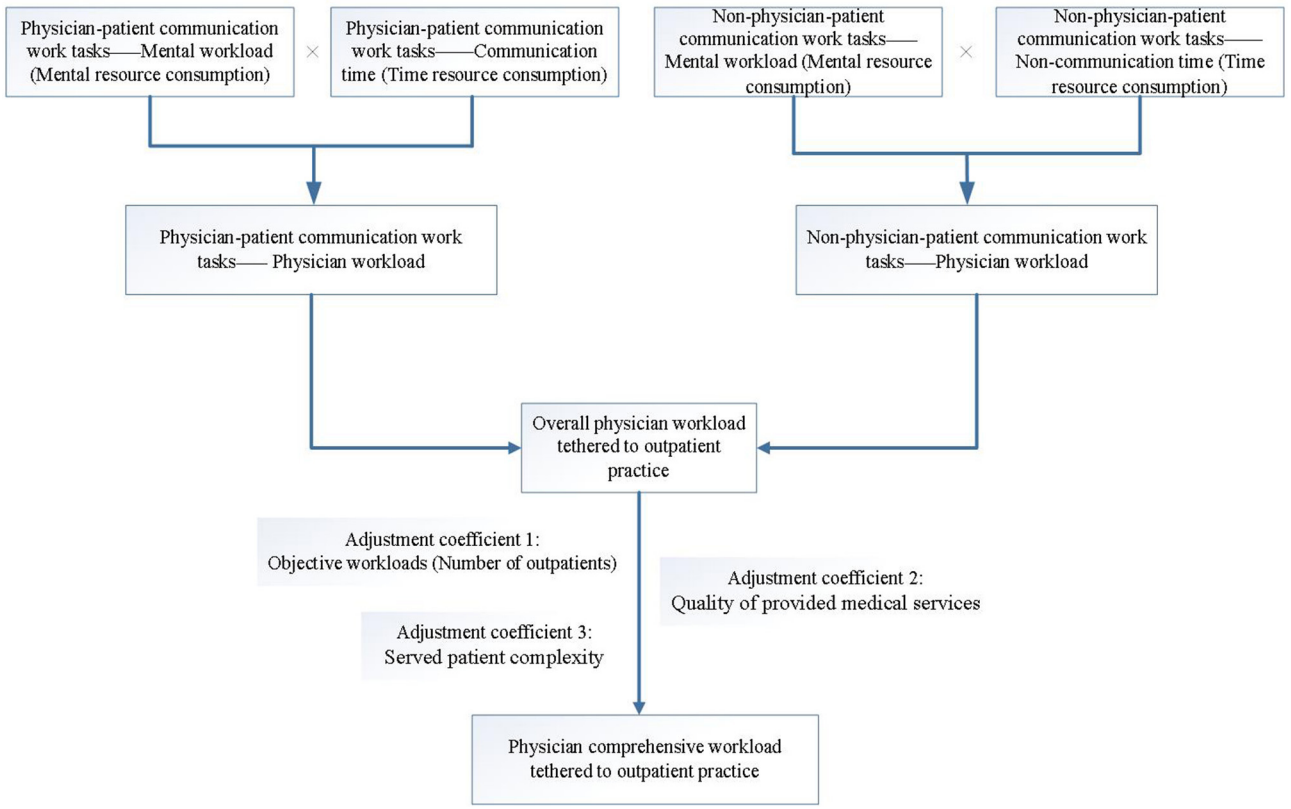

FIGURE 1 | Comprehensive evaluation framework for physician workload tethered to outpatient practice.

practice, and further perform a physician comprehensive workload analysis among Chinese physicians.

METHODS

Through this paper, we performed a physician comprehensive workload analysis among Chinese physicians according to our proposed comprehensive evaluation framework for physician workload tethered to outpatient practice using cross-sectional data on outpatient physician workload from a nationwide survey.

Calculation Procedure of Comprehensive Physician Workload

According to our proposed comprehensive evaluation framework for physician workload tethered to outpatient practice, we further developed an integrated evaluation model for physician comprehensive workload (*PCW*) tethered to outpatient practice, where PCW comprises two parts (that is, physician workload tethered to physician-patient communication work tasks, and physician workload tethered to non-physician-patient communication work tasks), and is further adjusted together by objective workload, quality of provided medical services, and served patient complexity (Equation 1).

$$PCW_i = \left(PW_{Communication_i} + PW_{Non-communication_i}\right) * R_{ovi} * R_{pc_i} * R_{ps_i} \quad (1)$$

PCW_i is the value of physician comprehensive workload tethered to outpatient practice of the *i*th physician, $PW_{Communication_i}$ is the value of physician workload of the *i*th physician while performing physician-patient communication work tasks, $PW_{Non-communication_i}$ is the value of physician workload of the *i*th physician while performing non-physician-patient communication work tasks; and R_{ov}, R_{pc}, and R_{ps} are used as adjustment coefficients for *PCW*; and therein R_{ovi} represents the objective workload of the *i*th physician, reflected by the number of outpatients serviced per day of the *i*th physician, R_{pc_i} represents the complexity of the patient served by the *i*th physician in the diagnosis and treatment, reflected by the ratio of the number of outpatients serviced per day admitted to the hospital by the *i*th physician for further diagnosis or treatment to the number of outpatients seen per day by the *i*th physician, and R_{ps_i} represents the quality of medical services provided by the *i*th physician, reflected by the patient satisfaction rated by the *i*th physician in this study. Given that mental workload can be defined as the amount of mental resources used/consumed per unit time to reach the acceptable performance required by the work task (19), representing the occupancy rate of an individual's mental resources on the work task, physician workload tethered

to a specific work task can be therefore defined as the mental resources consumed by the work task multiplied by the time resources required by the work task (Equation 2, 3).

$$PW_{Communication\,i} = PMW_{Communication\,i} * T_{Communication\,i} \quad (2)$$

$PMW_{Communication_i}$ is the value of mental workload of the *i*th physician, reflecting mental resource consumption while performing physician-patient communication work tasks, whereas $T_{Communication\,i}$ represents the time resources required by the physician-patient communication work tasks performed by the *i*th physician.

$$PW_{Non-communication\,i} = PMW_{Non-communication\,i} * T_{Non-communication\,i} \quad (3)$$

Likewise, $PW_{Non-communication\,i}$ is the value of physician workload of the *i*th physician, reflecting mental resource consumption while performing non-physician-patient communication work tasks, whereas $T_{Non-communication\,i}$ represents the time resources required by the non-physician-patient communication work tasks performed by the *i*th physician.

Measures

Mental workload was assessed using the Chinese version of physician mental workload scale developed by our research team in 2018 based on the combination of dimensions of the NASA-TLX and SWAT frameworks (7). The Chinese version of physician mental workload scale has been verified to have good reliability and validity (Cronbach alpha = 0.81), indicating a reliable instrument for diagnosing the mental workload of Chinese physicians comprises six dimensions and 12 items regarding different aspects of workload (mental demands, MD; physical demands, PD; temporal demands, TD; perceived risk, PR; frustration level, FL; and performance, Pe) (7); and all items were scored on a 10-point bipolar scale ranging from 0 to 100. The average score of all items of a corresponding dimension was the dimension score, whereas each dimension score was multiplied by the weight of the corresponding dimension, and the sum of the scores was the total score of mental workload, where the weight of each dimension was equal to the number of times that dimension was selected divided by a total of 15 comparisons based on pairwise comparisons of six dimensions of physician mental workload scale (7). In this study, the Chinese version of physician mental workload scale was used to measure physician mental workload while performing physician-patient communication work tasks (Equation 4) and non-physician-patient communication work tasks, respectively (Equation 5).

$$PMW_{Communication\,i} = MD_i * W_{MDi} + PD_i * W_{PDi} + TD_i * W_{TDi} + PR_i * W_{PRi} + FL_i * W_{FLi} + Pe_i * W_{Pei} \quad (4)$$

$PMW_{Communication_i}$ is the overall mental workload score of the *i*th physician while performing physician-patient communication work task, and MD_i, PD_i, TD_i, PR_i, FL_i, and Pe_i is the average score of each dimension the *i*th physician rated, respectively, and W with a subscript is the weighting coefficient of the corresponding dimension of the *i*th physician.

$$PMW_{Non-communication\,i} = MD_i * W_{MDi} + PD_i * W_{PDi} + TD_i * W_{TDi} + PR_i * W_{PRi} + FL_i * W_{FLi} + Pe_i * W_{Pei} \quad (5)$$

$PW_{Non-communication_i}$ is the overall mental workload score of the *i*th physician while performing non-physician-patient communication work tasks, and likewise, MD_i, PD_i, TD_i, PR_i, FL_i, and Pe_i is the average score of each dimension the *i*th physician rated, respectively, and W with a subscript is the weighting coefficient of the corresponding dimension of the *i*th physician.

For objective workload, we used the number of outpatients serviced per day as the measure in outpatient practice, since it can better reflect the quantity of work tasks associated with patients than other indicators, such as outpatient working hours. For quality of provided medical services, previous research indicated that patient satisfaction is an important indicator of measuring the quality of medical services (39), and therefore was simply used as a measure of quality of provided medical services in this study.

Given that it is difficult to quantity the complexity of the patient serviced by physicians in outpatient clinics in the diagnosis and treatment also with no accepted measures, patient difficulty served by a physician in the diagnosis and treatment could be simply measured based on the question that "did you have any patients that you perceived as difficult?" reported in previous research (23) and another study reported some domains such as number of major comorbidities, major complications, and operation could be used as a measure of patient complexity by surgical specialty (40). And accordingly, we used the ratio of the number of outpatients serviced per day admitted to the hospital by a physician for further diagnosis or treatment to the number of outpatients seen per day by the physician as the measure of served patient complexity in this study; and to avoid that the ratio was zero, we normalized this ratio and added 1, that is, 1 represents the reference value. For time resource consumption, time resource consumption in physician-patient communication work tasks was measured by the communication time during each outpatient encounter, and likewise, time resource consumed on non-physician-patient communication work tasks was measured by the non-communication time during each outpatient encounter.

Questionnaire Design

According to our proposed integrated evaluation model for physician workload, based on the Chinese version of physician mental workload scale developed by our research team in 2018, we therefore developed a survey questionnaire to perform a PCW analysis among Chinese physicians.

The survey questionnaire included three parts. The first part was designed to measure the mental workload of physicians while performing physician-patient communication work tasks in outpatient practice, including 6 dimensions and 12 items of Chinese version of physician mental workload scale, where these

TABLE 1 | Main characteristics of the participating physicians ($N = 1,934$).

Characteristics	*N* (%)	Characteristics	*N* (%)
Gender		Area	
Male	1,047 (54.1)	Eastern China	735 (38.0)
Female	887 (45.9)	Central China	685 (35.4)
Age (years)		Western China	514 (26.6)
20–30	433 (22.4)	Hospital level	
31–40	852 (44.1)	Tertiary A hospital	1,234 (63.8)
41–55	587 (30.4)	Tertiary B hospital	215 (11.1)
>55	62 (3.2)	Secondary hospital	447 (23.1)
Marital status		First-tier hospital	38 (2.0)
Unmarried	305 (15.8)	Department	
Married	1,585 (82.0)	Internal	585 (30.2)
Divorced	36 (1.9)	Surgical	481 (24.9)
Widowed	8 (0.4)	Obstetrics and gynecology	192 (9.9)
Educational level		Pediatrics	163 (8.4)
Doctorate	228 (11.8)	Others	513 (26.5)
Master	776 (40.1)	Working hours per week	
Undergraduate	857 (44.3)	≤ 40	180 (9.3)
Junior college	59 (3.1)	41–60	1062 (54.9)
Others	14 (0.7)	>60	692 (35.8)
Professional title		Outpatient working hours per week	
Senior	212 (11.0)	≤8	584 (30.2)
Associate senior	548 (28.3)	∼16	440 (22.8)
Intermediate	699 (36.1)	∼24	440 (22.8)
Junior	450 (23.3)	∼40	268 (13.9)
Others	25 (1.3)	>40	202 (10.4)
Working years in the current medical institution		Self-rated health status	
1–5	596 (30.8)	Very poor	23 (1.2)
6–10	503 (26.0)	Poor	105 (5.4)
11–15	335 (17.3)	Fair	902 (46.6)
16–20	206 (10.7)	Good	624 (32.3)
>20	294 (15.2)	Very good	280 (14.5)
Hospital nature		Number of outpatients serviced per day (Mean ± SD)	43.20 ± 24.81
Public general hospital	1,812 (93.7)	Number of outpatients serviced per day admitted to the hospital (Mean ± SD)	4.22 ± 3.85
Public specialized hospital	98 (5.1)	Self-rated outpatient satisfaction (Mean ± SD)	80.59 ± 14.75
Private general hospital	11 (0.6)	Physician-patient communication time per visit (Mean ± SD/minutes)	6.02 ± 3.89
Private specialized hospital	13 (0.7)	Non-physician-patient communication time per visit (Mean ± SD/minutes)	3.95 ± 3.30

dimensions were further compared two by two making able to collect the weights of each dimension. Likewise, the second part was designed to assess the mental workload of physicians while performing non-physician-patient communication work tasks in outpatient practice using the Chinese version of physician mental workload scale. Data on participants' characteristics including gender, age, marital status, educational level, average monthly income and professional title, average monthly income, professional title, working years in the current medical institution, area, hospital level, hospital nature, personnel, department, working hours per week, outpatient working hours per week, self-rated health status and physician-patient communication time and non-physician-patient communication time, as well as these related adjustment coefficients for *PCW* (that is, number of outpatients serviced per day, outpatient satisfaction, and number of outpatients serviced per day admitted to the hospital for further diagnosis or treatment) (details seen from **Table 1**) were collected in the third part.

Specifically, outpatient satisfaction was measured based on the question on a 20-point bipolar scale ranging from 0 to 100, that is, "Overall, how many scores did you perceive that your outpatients rate for your outpatient services?". The number of outpatients serviced per day was measured based on the question that "on average, how many outpatients did you serve daily?", and the number of outpatients serviced per day admitted to the hospital for further diagnosis or treatment was further measured based on the question that "how many outpatients you serviced were admitted to the hospital for further diagnosis or

treatment per day?" Physician-patient communication time was measured based on the question that "how many minutes do you spend on physician-patient communication work tasks on average during each outpatient encounter?", and likewise, non-physician-patient communication time was measured based on the question that "how many minutes do you spend on non-physician-patient communication work tasks on average during each outpatient encounter?".

Before the formal survey began, we performed a pilot survey on site in October 2020, to validate the measurement tool in a total of 10 physicians who just finished the provision of the outpatient services in the outpatient clinic of a tertiary public hospital in Wuhan, Hubei, and context-specific adjustments were made to improve the accuracy and clarity of the questionnaire according to the feedback from the pilot survey.

Study Sampling

This cross-sectional nationwide survey recruited physicians in Eastern, Central, and Western China through a stratified convenience sampling method. In order to improve the sample representativeness, two provinces were selected in the Eastern, Central, and Western regions, respectively. That is, a total of six provinces were selected. According to the standard for the division of China Eastern, Central, and Western regions from the current China Health Statistics Yearbook, Guangdong and Zhejiang provinces were selected in Eastern China, Hubei and Henan provinces were selected in Central China, and Chongqing municipality and Guangxi Zhuang autonomous region were selected in Western China. Considering the potential differences in the different levels of hospitals, typical sampling was then used to select two tertiary public hospitals and two secondary public hospitals in each selected province. Thus, a total of 24 public hospitals (including 12 tertiary and 12 secondary public hospitals) were mainly selected nationwide in China. Among the selected hospitals, four departments including Internal, Surgical, Obstetrics and gynecology, and Pediatrics were further selected as the main research departments, where targeted physicians were selected by random sampling. Given that we aimed to assess the physician workload tethered to outpatient practice, the targeted population in this nationwide survey was physicians who just provided medical services to outpatients in the consulting room in outpatient clinics, those who had to have been working for $\geq$4 months in the outpatient clinic, and those who had to be employed full-time for $\geq$1 year in their current institution.

Data Collection

This nationwide survey was carried out from November, 2020 to February, 2021. In order to improve the efficiency of data collection in each selected hospital, a unique QR code of the electronic questionnaire was generated for each hospital using the web-based survey tool called wenjuanxing. An informed consent of the outpatient managers in each selected hospital was requested and obtained before the beginning of the survey, and they were invited and volunteered as the role of the project manager in their hospitals during this online survey. Subsequently, the QR code of the electronic questionnaire was sent to these outpatient managers of the corresponding hospital, and they then sent the QR code to the targeted department groups of physicians via WeChat or Tencent QQ group, in which physicians who met the inclusion criteria for the targeted population were invited to participate in this questionnaire survey.

Participants could scan the QR code of the electronic questionnaire via their phones to access and fill in the electronic questionnaire. Prior to the survey, we first introduced the purpose of the survey, and the definition of physician mental workload and its related work tasks including physician-patient communication and non-physician-patient communication work tasks during outpatient encounters. After an individual's consent was obtained, the survey was conducted accordingly. During filling in the questionnaire, participants were first asked to complete the assessment of mental workload while performing physician-patient communication work tasks, and were then allowed to report their mental workload while performing non-physician-patient communication work tasks. Furthermore, all participants who completed the questionnaire were also encouraged to share the survey website link to their Wechat Circle of Friends, WeChat or Tencent QQ group, where some physicians who met the inclusion criteria for the targeted population could be invited and participate in this questionnaire survey.

Statistical Analysis

Descriptive analysis was used to summarize to data on participant characteristics, and PCW of the participating physicians. Data were summarized as frequencies (n) and percentages (%) for categorical variables, and mean and standard deviation ($M \pm SD$) for continuous variables.

There is still lack of consensus on what should be considered as a threshold value for a high or excessive workload internationally, and previous research usually classified individuals with high workload among physicians simply using the quartiles (35, 41), threshold values for workload (50% of overall workload) (42) or high workload corresponding to composite NASA-TLX scores of >55 (43) or >60 (44). To discriminate the relative comprehensive workload level among the participating physicians, the PCW was divided into four different levels using $M - SD$, M and $M + SD$ as cut points based on the measurement results of PCW, namely I-type ($PCW \leq M - SD$), II-type ($M - SD < PCW \leq M$), III-type ($M < PCW \leq M + SD$) and IV-type ($PCW > M + SD$), respectively, which can be distinguished as having relative low (low PCW physicians), medium (medium PCW physicians), high (high PCW physicians) and very high (very high PCW physicians) levels of PCW. Therefore, four distinctive groups of PCW physicians were identified, and each participating physician was assigned into one of the PCW physician groups.

Multiple linear regression model was established to identify the significant factors that influenced PCW tethered to outpatient practice. Given that data on PCW did not follow a normal distribution, we therefore converted the PCW into $\ln(PCW)$ to meet the normal distribution, before the regression to improve the accuracy of parameters estimation. Previous research revealed that individual characteristics were the key factors that

TABLE 2 | Distribution of participating physicians at different levels of scores of physician comprehensive workload tethered to outpatient practice ($N = 1,934$).

Physician comprehensive workload	*N*	Proportion (%)	Cumulative proportion (%)
(0,200]	70	3.6	3.6
(200,400]	284	14.7	18.3
(400,600]	377	19.5	37.8
(600,800]	358	18.5	56.3
(800,1,000]	288	14.9	71.2
(1,000,1,200]	241	12.5	83.7
(1,200,1,400]	134	6.9	90.6
(1,400,1,600]	77	4.0	94.6
(1,600,1,800]	40	2.0	96.6
(1,800,5,400)	65	3.4	100.0

influenced mental workload (45), and therefore, all demographic variables were set as independent variables and included in the model.

Moreover, chi-square (χ^2) tests were then performed to explore the differences in the four distinctive groups of PCW physicians across characteristics; and multinomial logistic regression was further used to identify the significant predictors of four groups of PCW physicians regarding their comprehensive workload, and therein the variables on characteristics were set as independent variables. Data analyses were performed using STATA 15.0 software. $P < 0.10$ (optimally, $p < 0.05$) was considered statistically significant.

RESULTS

Participant Characteristics

Overall, 2,038 online responses were collected and 1,934 eligible responses were received, with an effective recovery rate of 94.9%. **Table 1** shows the detailed characteristics of the 1,934 samples. Of these participating physicians, 54.1% were female, 44.1% were aged 31 to 40 years, 63.8% were from tertiary A hospitals, 38.0% were from Eastern China, and most were from the 4 major departments (Internal, Surgical, Obstetrics and gynecology, and Pediatrics), which accounted for 73.5%. The participating physicians serviced an average of 43.20 (SD = 24.81) patients per day in outpatient clinics and therein reported an average of 4.22 (SD = 3.85) patients admitted into the hospital for further diagnosis or treatment. Moreover, the mean score of outpatient satisfaction rated by physicians was 80.59 (SD = 14.75).

Assessments of Physician Comprehensive Workload Tethered to Outpatient Practice

According to our developed integrated evaluation model for physician workload proposed in this study, measurement results showed that the mean score of PCW tethered to outpatient practice among the 1,934 participating physicians was 811.30 (SD = 494.98), ranging from 68.87 to 5399.20. **Table 2** further shows the number of participating physicians at different levels of PCW scores, with concentrating on between 200 and 1,200. Among these participating physicians, 14.7% ($n = 284$) scored between 200 and 400, 19.5% ($n = 377$) scored between 400 and 600, 18.5% ($n = 358$) scored between 600 and 800, 14.9% ($n = 288$) scored between 800 and 100, and 12.5% ($n = 241$) scored between 1,000 and 1,200, together accounting for 80.1%, whereas only 6.9% ($n = 134$) scored between 1,200 and 1,400, and <10% (9.4%; $n = 182$) scored more than 1,400. Moreover, 42.9% ($n = 830$) scored higher than the average score of the total sample.

Discrimination of Relative Physician Comprehensive Workload Level and Its Characteristics

To discriminate the relative comprehensive workload level among the participating physicians, the PCW was divided into four different levels using $M - SD$, M and $M + SD$ as cut points based on the measurement results of PCW, namely I-type ($PCW \leq 316.32$), II-type ($316.32 < PCW \leq 811.30$), III-type ($811.30 < PCW \leq 1306.28$), and IV-type ($PCW > 1306.28$), respectively, which can therefore be distinguished as having relative low (low PCW physicians), medium (medium PCW physicians), high (high PCW physicians) and very high (very high PCW physicians) levels of PCW. Therefore, four distinctive groups of PCW physicians were identified; and of these participating physicians, 11.2% ($n = 236$) were classified as very high PCW physicians, compared with 11.6% as low PCW physicians, 45.5% as medium PCW physicians and 30.7% as high PCW physicians.

Table 3 further presents the significant characteristics of the participating physicians at different levels of PCW tethered to outpatient practice. Chi-square tests indicated that there was a significant difference in the four levels of PCW for gender ($\chi^2 = 36.523$, $p < 0.001$), educational level ($\chi^2 = 22.135$, $p = 0.008$), average monthly income ($\chi^2 = 18.878$, $p = 0.026$), professional title ($\chi^2 = 28.729$, $p = 0.001$), working years in the current medical institution ($\chi^2 = 23.979$, $p = 0.020$), area ($\chi^2 = 37.058$, $p < 0.001$), hospital level ($\chi^2 = 40.095$, $p < 0.001$), department ($\chi^2 = 75.682$, $p < 0.001$), working hours per week ($\chi^2 = 16.088$, $p = 0.013$), and outpatient working hours per week ($\chi^2 = 43.052$, $p < 0.001$).

When compared with those classified as the other groups, physicians classified as very high PCW physician group, tended to be those who were female, those who had a lower educational level, lower average monthly incomes, lower professional titles and longer working years in the current medical institution, and those who were from Western China, worked in tertiary A hospitals, and Internal or Surgical, and worked no more than 40 h per week and longer outpatient hours per week.

Factors Associated With Physician Comprehensive Workload

Table 4 presents the results derived from multiple linear regression analysis. The model included all independent variables on characteristics, and there existed only four significant variables in the model.

TABLE 3 | Significant characteristics of participating physicians with different levels of comprehensive workload tethered to outpatient practice ($N = 1,934$).

Characteristics (*N*, %)	Low PCW physician (*N* = 224)	Medium PCW physician (*N* = 880)	High PCW physician (*N* = 594)	Very high PCW physician (*N* = 236)	χ^2	*p*-value
Gender					36.523	<0.001
Male	135 (60.3)	527 (59.9)	283 (47.6)	102 (43.2)		
Female	89(39.7)	353 (40.1)	311 (52.4)	134 (56.8)		
Educational level					22.135	0.008
Doctorate	17 (7.6)	120 (13.6)	66 (11.1)	25 (10.6)		
Master	81 (36.2)	358 (40.7)	260(43.8)	77 (32.6)		
Undergraduate	116 (51.8)	370 (42.0)	250 (42.1)	121 (51.3)		
Junior college	7 (3.1)	25 (2.8)	16 (2.7)	11 (4.7)		
Others	3 (1.3)	7 (0.8)	2 (0.3)	2 (0.8)		
Average monthly income (RMB)					18.878	0.026
≤5,000	48 (21.4)	181 (20.6)	98 (16.5)	49 (20.8)		
5,001–10,000	122 (54.5)	383 (43.9)	283 (47.6)	112 (47.5)		
10,001–15,000	37 (16.5)	185 (21.0)	137 (23.1)	47 (19.9)		
>15,000	17 (7.6)	128 (14.5)	76 (12.8)	28 (11.9)		
Professional title					28.729	0.001
Senior	15 (6.7)	116 (13.2)	57 (9.6)	24 (10.2)		
Associate senior	58 (25.9)	226 (25.7)	208 (35.0)	56 (23.7)		
Intermediate	87 (35.9)	312 (35.5)	206 (34.7)	94 (39.8)		
Junior	61 (27.2)	209 (23.8)	120 (20.2)	60 (25.4)		
Others	3 (1.3)	17 (1.9)	3 (0.5)	2 (0.8)		
Working years in the current medical institution					23.979	0.020
1–5	78 (34.8)	283 (32.2)	168 (28.3)	67 (28.4)		
6–10	58 (25.9)	217 (24.7)	179 (30.1)	49 (20.8)		
11–15	38 (17.0)	149 (16.9)	101 (17.0)	47 (19.9)		
16–20	23 (10.3)	81 (9.2)	64 (10.8)	38 (16.1)		
>20	27 (12.1)	150 (17.0)	82(13.8)	35 (14.8)		
Area					37.058	<0.001
Eastern China	64 (28.6)	358 (40.7)	243 (40.9)	70 (29.7)		
Central China	108 (48.2)	305(34.7)	194 (32.7)	78 (33.1)		
Western China	52 (23.2)	217 (24.7)	157 (26.4)	88 (37.3)		
Hospital level					40.095	<0.001
Tertiary A hospital	118(52.7)	595 (67.6)	375 (63.1)	146 (61.9)		
Tertiary B hospital	28 (12.5)	83 (9.4)	91 (15.3)	13 (5.5)		
Secondary hospital	66 (29.5)	184 (20.9)	122 (20.5)	75 (31.8)		
First-tier hospital	12 (5.4)	18 (2.0)	6 (1.0)	2 (0.8)		
Department					75.682	<0.001
Internal	66 (29.5)	260 (29.5)	188 (31.6)	71(30.1)		
Surgical	61 (27.2)	265 (30.1)	102 (17.2)	53 (22.5)		
Obstetrics and Gynecology	19 (8.5)	64 (7.3)	96 (16.2)	13 (5.5)		
Pediatrics	21 (9.4)	72 (8.2)	58 (9.8)	12 (5.1)		
Others	57 (25.4)	219 (24.9)	150 (25.3)	87 (36.9)		
Working hours per week					16.088	0.013
≤ 40	28 (12.5)	89 (10.1)	35 (5.9)	28 (11.9)		
41–60	124 (55.4)	475 (54.0)	346 (58.2)	117 (49.6)		
>60	72 (32.1)	316 (35.9)	213 (35.9)	91 (38.6)		
Outpatient working hours per week					43.052	<0.001
≤8	79 (35.3)	301 (34.2)	155 (26.1)	49 (20.8)		
∼16	51 (22.8)	210 (23.9)	127 (21.4)	52 (22.0)		
∼24	47 (21.0)	179 (10.3)	158 (26.6)	56 (23.7)		
∼40	34 (15.2)	110 (12.5)	84 (14.1)	40 (16.9)		
>40	13 (5.8)	80 (9.1)	70 (11.8)	39 (16.5)		

TABLE 4 | Factors associated with the physician comprehensive workload ($N = 1,934$; df = 1,886).

Independent variables	β	SE	*t*-test	*p*-value	VIF
Constant	6.353	0.103	61.67	<0.001	
Gender (ref: Male)					
Female	0.115	0.0336	3.41	0.001	1.38
Area (ref: Central China)					
Eastern China	0.104	0.0356	2.92	0.004	1.60
Western China	0.134	0.0400	3.36	0.001	1.53
Working hours per week (ref: >60)					
≤40	−0.156	0.601	−2.59	0.010	1.36
41–60	−0.0817	0.0313	−2.61	0.009	1.30
Outpatient working hours per week (ref: ≤8)					
∼16	0.0372	0.0383	0.97	0.331	1.42
∼24	0.123	0.0415	2.97	0.003	1.50
∼40	0.129	0.0505	2.56	0.010	1.48
>40	0.250	0.0513	4.89	<0.001	1.38

SE, standard error; VIF, variance inflation factor (mean VIF = 1.87, ranging from 1.15–4.78).

Gender, area, working hours per week, and outpatient working hours per week significantly ($p < 0.05$) influenced PCW tethered to outpatient practice. Females experienced a higher PCW in outpatient practice than males ($\beta = 0.115$, $p = 0.001$). For area, physicians from Eastern or Western China experienced a higher PCW than those from Central China ($\beta = 0.104$, $p = 0.004$; $\beta = 0.134$, $p = 0.001$, respectively). For working hours per week, compared to those who worked >60 h per week, physicians with shorter working hours per week had a lower PCW in outpatient practice ($\beta = -0.156$, $p = 0.010$; $\beta = -0.0817$, $p = 0.009$, respectively). Meanwhile, physicians with longer outpatient working hours per week tended to experience a higher PCW in outpatient practice; compared to those who worked no more than 8 h per week, physicians with longer working hours in outpatient practice had a higher PCW ($\beta = 0.123$, $p = 0.003$; $\beta = 0.129$, $p = 0.010$, $\beta = 0.250$, $p < 0.001$; respectively). Moreover, the results of the variance inflation factor (VIF) showed that all values of the VIF ranged from 1.15 to 4.78, indicating that there was no collinearity among these independent variables included in the model.

Determinants of Relative Levels of Physician Comprehensive Workload

Multinomial logistic regression was further used to identify the significant predictors of the physicians belonging to different groups of PCW physicians. **Table 5** shows the results of multinomial logistic regression analysis. Using very high PCW physician group as the base outcome, we gained the following results (**Table 5**).

Compared to males, female physicians were less likely to be assigned into the low [Relative Risk Ratio (RRR) = 0.370, $p < 0.001$], medium (RRR = 0.427, $p < 0.001$) or high (RRR = 0.509, $p < 0.001$) PCW physician groups as compared with the odds of very high PCW physician group. Physicians with higher age were more likely to be assigned into the very high PCW physician group; compared to those aged 20–30 years, physicians with an increased age were less likely to be assigned into the high PCW physician group (RRR = 0.506, $p = 0.035$; RRR = 0.392, $p = 0.020$; RRR = 0.323, $p = 0.057 < 0.10$, respectively) as compared with the odds of very high PCW physician group. Compared to those with a master degree, physicians with undergraduate or junior college degrees were less likely to be assigned into the medium PCW physician group (RRR = 0.653, $p = 0.030$; RRR = 0.456, $p = 0.089$ <0.10, respectively), and physicians with undergraduate degrees were also less likely to be assigned into the high PCW physician group (RRR = 0.690, $p = 0.071$ <0.10) as compared with the odds of very high PCW physician group. Compared to those with junior titles, physicians with associate senior titles were more likely to be assigned into the low (RRR = 2.119, $p = 0.079$ <0.10), medium (RRR = 1.864, $p = 0.072$ <0.10) or high (RRR = 3.903, $p < 0.001$) PCW physician groups, and physicians with senior titles were also more likely to be assigned into the high PCW physician group (RRR = 2.564, $p = 0.043$) as compared with the odds of very high PCW physician group. Moreover, physicians who worked in the current medical institution for 11–15 or 16–20 years were less likely than those with 6–10 working years in the current medical institution to be assigned into the medium (RRR = 0.627, $p = 0.063$ <0.10; RRR = 0.526, $p = 0.015$, respectively) or high (RRR = 0.388, $p = 0.003$; RRR = 0.367, $p = 0.003$) PCW physician groups as compared with the odds of very high PCW physician group.

Compared to those from Western China, physicians from Eastern or Central China were more likely to be assigned into medium (RRR = 1.573, $p = 0.028$; RRR = 1.677, $p = 0.016$, respectively) or high (RRR = 1.627, $p = 0.017$; RRR = 1.457, $p = 0.081$ <0.10) PCW physician groups, and physicians from Central China were also more likely to be assigned into the low PCW physician group (RRR = 1.957, $p = 0.010$) as compared with the odds of very high PCW physician group. Physicians who worked in tertiary B hospitals were more likely than those from tertiary A hospitals to be assigned into low (RRR = 2.075, $p = 0.074$ <0.10) or high (RRR = 1.987, $p = 0.057$ <0.10)

TABLE 5 | Multinomial logistic regression result: significant determinants of different groups of PCW physicians.

	Low PCW physician		Medium PCW physician		High PCW physician	
Variables	**RRR (95% CI)**	***p***	**RRR (95% CI)**	***p***	**RRR (95% CI)**	***p***
Gender (ref: Male)						
Female	0.370 (0.236,0.580)	<0.001***	0.427 (0.299,0.609)	<0.001***	0.509 (0.351,0.739)	<0.001***
Age (ref: 20–30 years)						
31–40	0.901 (0.436,1.860)	0.778	0.969 (0.531,1.768)	0.917	0.506 (0.269,0.952)	0.035**
41–55	0.529 (0.209,1.341)	0.180	0.883 (0.414,1.881)	0.747	0.392 (0.178,0.865)	0.020**
>55	0.439 (0.108,1.793)	0.251	0.440 (0.144,1.341)	0.149	0.323 (0.101,1.032)	0.057*
Educational level (ref: Master)						
Doctorate	0.700 (0.319,1.537)	0.374	0.900 (0.511,1.585)	0.715	0.751 (0.412,1.366)	0.348
Undergraduate	0.784 (0.480,1.283)	0.333	0.653 (0.445,0.959)	0.030**	0.690 (0.461,1.032)	0.071*
Junior college	0.380 (0.112,1.292)	0.121	0.456 (0.184,1.129)	0.089*	0.685 (0.263,1.783)	0.438
Others	N/A	N/A	N/A	N/A	N/A	N/A
Professional title (ref: Junior title)						
Senior	1.310 (0.427,4.020)	0.636	1.713 (0.731,4.016)	0.216	2.564 (1.028,6.393)	0.043**
Associate senior	2.119 (0.917,4.896)	0.079*	1.864 (0.945,3.677)	0.072*	3.903 (1.895,8.041)	<0.001***
Intermediate	1.092 (0.561,2.125)	0.797	1.101 (0.639,1.895)	0.729	1.617 (0.901,2.903)	0.107
Others	N/A	N/A	N/A	N/A	N/A	N/A
Working years in the current medical institution (ref: 6–10 years)						
1–5	1.064 (0.569,1.988)	0.847	0.951(0.568,1.591)	0.847	0.728 (0.424,1.252)	0.252
11–15	0.682 (0.365,1.274)	0.230	0.627 (0.383,1.026)	0.063*	0.526 (0.314,0.881)	0.015**
16–20	0.520 (0.233,1.162)	0.111	0.388 (0.207,0.728)	0.003***	0.367 (0.191,705)	0.003***
>20	0.889 (0.360,2.198)	0.800	0.886 (0.444,1.768)	0.731	0.609 (0.295,1.259)	0.181
Area (ref: Western China)						
Eastern China	1.095 (0.641,1.873)	0.739	1.573 (1.051,2.354)	0.028**	1.677 (1.099,2.558)	0.016**
Central China	1.957 (1.177,3.254)	0.010**	1.627 (1.090,2.430)	0.017**	1.457 (0.955,2.222)	0.081*
Hospital level (ref: Tertiary A hospital)						
Tertiary B hospital	2.075 (0.931,4.621)	0.074*	1.437 (0.720,2.869)	0.304	1.987 (0.981,4.024)	0.057*
Secondary hospital	1.278 (0768,2.129)	0.345	0.846 (0.564,1.268)	0.418	0.824 (0.536,1.265)	0.043**
First-tier hospital	N/A	N/A	N/A	N/A	N/A	N/A
Department (ref: Pediatrics)						
Internal	0.451 (0.196,1.042)	0.062*	0.490 (246,0.987)	0.046***	0.482 (0.234,0.987)	0.046**
Surgical	0.388 (0.160,0.940)	0.036**	0.433 (0.206,0.908)	0.027**	0.227 (0.227,0.491)	<0.001***
Obstetrics and Gynecology	0.868 (0.299,2.523)	0.796	0.816 (0.334,1.993)	0.656	1.170 (0.477,2.869)	0.731
Others	0.338 (0.147,0.779)	0.011**	0.351 (0.175,0.703)	0.003***	0.330 (0.162,0.672)	0.002***
Working hours per week (ref: 41–60)						
≤40	0.815 (0.419,1.585)	0.547	0.775 (0.453,1.327)	0.353	0.439 (0.240,0.802)	0.007***
>60	0.585 (0.376,0.911)	0.018**	0.730 (0.516,1.033)	0.075*	0.826 (0.575,1.187)	0.302
Outpatient working hours per week (ref: ≤8)						
∼16	0.575 (0.332,0.998)	0.049**	0.623 (0.397,0.976)	0.039**	0.700 (0.434,1.130)	0.144
∼24	0.416 (0.237,0.730)	0.002***	0.468 (0.298,0.734)	0.001***	0.723 (0.450,1.162)	0.180
∼40	0.473 (0.245,0.911)	0.025**	0.521 (0.308,0.882)	0.015**	0.848 (0.488,1.474)	0.559
>40	0.170 (0.0769,0.375)	<0.001***	0.370 (0.215,0.638)	<0.001***	0.610 (0.346,1.074)	0.086*

*Base outcome: very high PCW physician group; *p < 0.1; **p < 0.05; ***p < 0.01; RRR, relative risk ratio; CI, confidence interval; ref, reference group; N/A, not applicable.*

PCW physician groups. Compared to those worked in Pediatrics, physicians who worked in Internal or Surgical were less likely to be assigned into the low (RRR = 0.451, $p = 0.062 < 0.10$; RRR = 0.388, $p = 0.036$, respectively), medium (RRR = 0.490, $p = 0.046$; RRR = 0.433, $p = 0.027$, respectively) or high (RRR = 0.482, $p = 0.046$; RRR = 0.227 $p < 0.001$, respectively) PCW physician groups as compared with the odds of very high PCW physician group.

Moreover, compared to those who worked 41–60 h per week, physicians who worked >60 h per week were less likely to be assigned into the low (RRR = 0.585, $p = 0.018$) or medium (RRR = 0.730, $p = 0.075 < 0.10$) PCW physician groups, and physicians

who worked no more than 40 h per week were less likely to be assigned into the high (RRR = 0.439, $p = 0.007$) PCW physician group. In addition, physicians with longer outpatient working hours per week were more likely to be assigned into the very high PCW physician group; compared to those with no more than 8 working hours in outpatient practice, physicians with longer outpatient working hours (>8 working hours per week) were less likely to be assigned into the low (RRR = 0.575, $p = 0.049$; RRR = 0.416, $p = 0.002$; RRR = 0.473, $p = 0.025$; RRR = 0.170, $p < 0.001$, respectively) or medium (RRR = 0.623, $p = 0.039$; RRR = 0.468, $p = 0.001$; RRR = 0.521, $p = 0.015$; RRR = 0.370, $p < 0.001$, respectively) PCW physician groups as compared with the odds of very high PCW physician group.

DISCUSSIONS

Principal Findings

Overall, the mean score of PCW tethered to outpatient practice Chinese physicians experienced was 811.30 (SD = 494.98) with concentrating on between 200 and 1,200, together accounting for 80.1% of total samples, according to our developed integrated evaluation model. Multiple linear regression analysis showed that physicians who were female, and from Eastern or Western China, and those who worked more than 60 h per week and longer outpatient hours per week were more likely to experience a higher PCW in outpatient practice.

About 11.2% of Chinese physicians were identified as very high PCW physicians, compared with 11.6% as low PCW physicians, 45.5% medium PCW as physicians and 30.7% as high PCW physicians. This is a result of the combined effect of the mean and standard deviation of the PCW. Multinomial logistic regression analysis further indicated that physicians who were female, older, from Western China, those who had lower educational levels, lower professional titles, and longer working years in the current medical institution, and those who worked in tertiary A hospitals, and Internal or Surgical, and worked >60 h per week and longer outpatient hours per week were more likely to be very high PCW physicians.

Comparison to Prior Studies

Levels of Physician Comprehensive Workload Tethered to Outpatient Practice

This is the first study, to our knowledge, to develop an integrated evaluation model for comprehensively assessing physician workload tethered to outpatient practice based on the combination of objective workload and task-level mental workload also with the consideration of quality of provided medical services and served patient complexity. Previous research often simply used either objective workload or mental workload as a measure of physician workload in various healthcare settings (16, 18, 23, 25, 46), not to mention the comprehensive workload, which might have failed to reflect their real workload. This study revealed that the mean score of PCW Chinese physicians experienced in outpatient practice was 811.30 (SD = 494.98) with concentrating on between 200 and 1,200, together accounting for 80.1% of total samples, according to the integrated evaluation model, which indicates a high level of comprehensive workload. As noted in the Introduction, increased physician workload could adversely affect physicians themselves, and their patients and organizations. Therefore, hospital managers should consider paying more attention to work burden for Chinese physicians in outpatient practice to mitigate the potential negative effects caused by increased workload and even overwhelming workload.

Our analysis results further showed that gender, working hours per week, and outpatient working hours per week were significant factors that influenced PCW in outpatient practice. Similar conclusions were reported in our previous research on physician mental workload that physicians who were female and those who worked more hours per week, with more than 40 outpatient working hours per week were more likely to have high levels of mental workload in outpatient clinics (46). Our analysis also indicated that area was a significant factor that compared to those from Central China, physicians from Eastern or Western China were more likely to experience a higher PCW, whereas it was not significant factor, and other factors such as age, educational level, average monthly income, working years in the current medical institution, hospital level, and self-rated health status all significantly influenced physician mental workload reported in our previous research (46). The effect of area on PCW tethered to outpatient practice is closely related to the current dilemma in medical fields in China. These findings suggest that although there great individual variations existed when mental workload was used as a measure of physician workload, these individual differences among physicians were gradually eliminated when considering these factors as adjustment coefficients for physician workload (including objective workload, quality of provided medical services and served patient complexity), which indicates that on the one hand, mental workload simply used as the measure of physician workload might have failed to reflect the real work burden for physicians, thereby leading to inaccurate identification of individuals with high workload, misleading the targeted interventions of hospital managers, and ultimately resulting in a waste of human resources, and on the other hand, our proposed integrated evaluation model for physician workload might help comprehensively and reliably assess physician workload tethered to outpatient practice, possibly resulting in an enhanced human resources management for hospital mangers.

Determinants of Relative Levels of Physician Comprehensive Workload

Internationally, there is still lack of consensus on what should be considered as a threshold value for a high or excessive workload among physicians (35, 41–44), and therefore, how to discriminate and identify individuals with high workload within a specific group is an important topic that hospital managers pay great attention to, especially in current conditions where physicians in their institutions are suffering from adverse effects of increased workload and even overloads. Previous research usually identified individuals with high workload among evaluated physicians using the quartiles (35, 41), threshold values for workload (e.g., 50% of overall workload) (42) or high

workload corresponding to composite NASA-TLX scores of >55 (43) or >60 (44) through subjective evaluations, not to mention the comprehensive workload assessments. Even some research on a national survey assessed Chinese physicians' overall workload simply based on the question on a 5-point Likert scale that "I have a heavy workload," where these physicians who answered "strongly agree" or "agree" were classified as individuals with heavy workload (14). This study, to our best knowledge, is an early study discriminating and identifying individuals with high comprehensive workload among evaluated physicians based on combined effects of the mean and standard deviation of the PCW.

Our analysis showed that four distinctive groups of PCW physicians were identified, and about 11.2% of Chinese physicians were identified as very high PCW physicians, compared with 11.6% as low PCW physicians, 45.5% as medium PCW physicians and 30.7% as high PCW physicians, whereas a much higher share of physicians with heavy workload (64.51%) was reported in a recent national survey from 136 public tertiary hospitals across all 31 provinces of China (14), and a lower share of physicians with high mental workload (33.8%) was reported in our previous research through latent profile analysis (46). This large difference could be explained by the scope of assessments of physician workload related to work tasks, the measurement tool of physician workload, or the determination method for high workload or heavy workload.

Our study further revealed that great individual variations across the four distinctive groups of PCW physicians existed. Despite a shortage of studies comparing individual differences across PCW physicians, several existing studies have pointed to great variations in subtypes of mental workload across individual characteristics among medical workers, thereby resulting in an accurate identification of the characteristics of individuals with high mental workload (46, 47). Our study indicated that gender, age, area, educational level, professional title, working years in the current medical institution, hospital level, department, working hours per week, and outpatient working hours per week were significant predictors of four distinctive groups of PCW physicians, and physicians who were female, older, from Western China, those who had lower educational levels, lower professional titles and longer working years in the current medical institution, and those who worked in tertiary A hospitals, and Internal or Surgical, and worked >60 h per week and longer outpatient hours per week were more likely to be very high PCW physicians in outpatient practice, which is mostly supported by the findings from our previous study on mental workload based on latent profile analyses that these physician characteristics, such as female, younger, lower educational levels, tertiary A hospitals, more working hours per week, more than 40 outpatient working hours per week, and 16–20 working years in the current medical institution were all significantly associated with higher mental workload of physicians while performing physician-patient communication work tasks in outpatient clinics (46). These existing differences across the characteristics suggest that physicians with high mental workload may not necessarily experience a heavy comprehensive workload in outpatient practice, and therefore, for hospital managers, mental workload simply used as the measure of physician workload may not be able to reflect the real workload, and further accurately determine and identify physicians with high workload as individuals who need interventions in priority, ultimately leading to a waste of limited human resources. These findings also suggest that our proposed integrated evaluation model for physician workload could be reliable for comprehensively assessing PCW tethered to outpatient practice to some extent.

With the rapidly aging population with chronic and age-related diseases and its subsequent demands for health care services (1), along with lack of a proportional growth in the number of physicians, increasingly heavy outpatient workload for physicians especially from high-level hospitals (tertiary A hospitals) is still a very prominent issue for Chinese health care system (11). A recent study indicated that from 1998 to 2016, there has been a trend of dramatically increased workload for Chinese physicians, potentially threatening not only their health but also the quality of medical services they provided (48). As noted in the Introduction, increased workload for physicians could have adverse effects on physicians themselves, and their patients and organizations. To reduce these adverse effects caused by increased workload and even overwhelming workload, it's critical to strengthen the assessment and management of physician workload. Given that there is an increased demand for more professional health workers in China (49), accurate identification of physicians with high workload or heavy workload is essential to optimize the allocation of limited human resources. Such a strategy should be based on comprehensively assessing physician workload rather than simply assessing either mental workload or objective workload, or both objective workload and mental workload together. Therefore, an integrated evaluation model for comprehensively assessing physician workload tethered to outpatient practice was developed in this study based on the combination of objective workload and task-level mental workload also with the consideration of quality of provided medical services and served patient complexity. To minimize these adverse effects caused by increased workload, especially in high time-pressure outpatient settings, we suggest that hospital managers should consider setting up a special department to be responsible for monitoring and management of physician comprehensive workload to, in turn, dynamically identify individuals who need interventions in priority. Such an outcome can further help hospital managers to strengthen the dynamical management of human resources in their institutions to, in turn, achieve higher organization performance, while mitigating the potential negative effects caused by increased workload.

LIMITATIONS

There were several limitations mentioned in this study. First, patient satisfaction is an important indicator of measuring the quality of medical services (39), and accordingly was used as a single indicator for measuring the quality of care provided medical services in our developed integrated evaluation model, but its self-reported measurement method by physicians might have resulted in biased measurement errors, and therefore,

further research is still needed to improve the measurement accuracy and precision of the quality of care provided medical services in the integrated evaluation model. Second, patient difficulty in the diagnosis and treatment could be simply measured based on the question that "did you have any patients that you perceived as difficult?" reported in previous research (23), and accordingly, the complexity of the patient served by the physician in the diagnosis and treatment was reflected by the ratio of the number of outpatients serviced per day admitted to the hospital by a physician for further diagnosis or treatment to the number of outpatients seen per day by the physician in this study; and if a physician did not service an outpatient who needs to be hospitalized, the ratio would be zero, resulting in zero PCW, which may have limited the generalizability of the ratio as a measure of patient complexity, and therefore, we normalized this ratio and added 1 (that is, 1 represents the reference value) to avoid that the ratio was zero, and our further research is needed to improve the measurement accuracy of seen patient complexity, and thereby further improve the applicability of our proposed integrated evaluation model for physician workload tethered to outpatient practice; and moreover, patient complexity was reflected only by a single indicator, which may have resulted in a measurement error to some extent. Third, quality of provided medical services and served patient complexity were all used as adjustment coefficients included in our proposed integrated evaluation model, and there are still many important factors that influenced physician workload, such as, interruptions and assistants, and therefore, more research is still needed to consider more factors included as adjustment coefficients to improve the reliability and stability of the proposed integrated evaluation model for physician workload. Moreover, some limitations on this cross-sectional national survey have been reported in our previous research (46), for example, data collection was self-reported by participating physicians via the online survey, and accordingly, there was no guarantee that the participating physicians in this study filled out the survey questionnaire just after finishing the provision of the outpatient services in outpatient practice, which might have resulted in a recall bias; and some lower responsiveness was received in some selected hospitals, which may have limited the sample size to some extent, and therefore, to improve the scale of the targeted physicians, we invited the outpatient managers in each selected hospital to play the role of the project manager in their hospitals during this online survey, and encouraged all participants who completed the questionnaire to share the survey website link to their Wechat Circle of Friends, WeChat or Tencent QQ group, where some physicians who met the inclusion criteria for the targeted population could be invited and participate in this questionnaire survey.

CONCLUSIONS

Chinese physicians experienced high levels of comprehensive workload in outpatient practice; and those who were female, and from Eastern or Western China, and those worked $>$ 60 h per week and longer outpatient hours per week were more likely to experience a higher PCW. About 11.2% of Chinese physicians were identified as very high PCW physicians, compared with 11.6% as low PCW physicians, 45.5% as medium PCW physicians and 30.7% as high PCW physicians. Great individual variations in four distinctive groups of PCW physicians existed. Physicians who were female, older, from Western China, those who had lower educational levels, lower professional titles and longer working years in the current medical institution, and those who worked in tertiary A hospitals, and Internal or Surgical, and worked $>$60 h per week and longer outpatient hours per week were more likely to be very high PCW physicians. Our work has a potential application for comprehensively assessing physician workload tethered to outpatient practice and could provide a solid foundation for hospital managers to further determine and accurately identify physicians with high workload, who would otherwise be missed in either objective workload or mental workload.

DATA AVAILABILITY STATEMENT

The datasets used and/or analyzed during the current study are available from the corresponding author on a reasonable request. Requests to access the datasets should be directed to hyh288@hotmail.com.

ETHICS STATEMENT

Ethics approval was obtained from the Ethics Committee of Tongji Medical College of Huazhong University of Science and Technology (No. IORG0003571). All the survey data were kept confidential and anonymous.

AUTHOR CONTRIBUTIONS

YH designed the study, obtained funding, participated in the collection, and performed revisions of the manuscript. DL contributed to the design of this study, the acquisition, analysis and interpretation of survey data, and drafted the manuscript. SL and CL participated in the data cleaning, contributed to the interpretation of the results, and performed revisions of the manuscript. YZ and JZ contributed to the interpretation of the results and performed revisions of the manuscript. JL and ZZ were involved in data cleaning and contributed to the interpretation of the results. All authors have read and approved the final version of the manuscript.

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