Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Systematic Review

COVID-19: A literature review of the impact on diagnostic radiography students

D. Astirbadi [a], P. Lockwood [b, *]

[a] Imaging Department, Medway Maritime Hospital, Medway NHS Foundation Trust, Gillingham, Kent, United Kingdom
[b] School of Allied Health Professions, Faculty of Medicine, Health and Social Care, Canterbury Christ Church University, Kent, United Kingdom

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ABSTRACT

Introduction: COVID-19 is a highly contagious viral disease declared a global pandemic in March 2020. Throughout the pandemic, radiography students have been working in hospitals on the frontline. The review aimed to search for evidence of the impact COVID-19 has had on diagnostic radiography students and consider whether additional support and learning needs to be implemented.
Methods: A literature search strategy applied keywords, BOOLEAN search operators, and eligibility criteria on PubMed, Medline, and Google Scholar databases. Cormack's (2000) critique framework was chosen to methodologically appraise the mixed-method studies to evaluate the quality, validity and rigour.
Results: The search decisions were displayed in a PRISMA flowchart to evidence the process to identify the found articles comprised of two surveys, two semi-structured interviews and one case study. The findings identified common and reoccurring themes of personal protective equipment, mental wellbeing, accommodation and travel, assessments and learning, and transitioning to registration.
Conclusion: The literature suggests that students felt positive impacts of the pandemic, such as being prepared for registration. However, negative effects included the fear of contracting the virus, anxieties of working with ill patients, impracticalities of accommodation and travel during clinical placement, and the adaption to online learning.
Implications for practice: Clinical staff and universities need to work together to ensure students are mentally and physically supported during the pandemic. Regular meetings and agreed channels of communication with students will allow any issues to be brought to attention and addressed. In addition, employers should recognise that newly qualified radiographers will need extra support.

Introduction

The coronavirus disease 2019 (COVID-19) was first detected in China in December 2019 and declared a global pandemic by the World Health Organisation in March 2020.[1,2] Although there is no officially defined start or end date of the first two waves of COVID-19 within England (ONS, 2021), the first wave (categorised as a period of increased transmission and infections) of COVID-19 is estimated to have occurred between March 2020 (start of Test and Trace data, with national interventions starting the 23rd March 2020) peaking early April 2020, and ending around the gradual lifting of restrictions at the end of May 2020 (between 13th May and 4th July 2020). These dates are estimates as set by the Office for National Statistics[2] (ONS, 2021) based upon when the COVID Infection Surveys (CIS) started produce positivity rate estimates (26th April 2020) and the reporting of the R (reproduction of secondary infections produced by a single infected person) number by the Scientific Advisory Group for Emergencies (SAGE) (29th May 2020).

The second COVID wave in England is estimated to have occurred around the beginning of September 2020 due to the Alpha variant, peaking in mid-November 2020, with a fall before peaking infection levels again in December 2020–January 2021 before ending late April 2021[3] (ONS, 2021) as shown in Fig. 1. Currently the Delta variant first recorded in March 2021 in the UK (India in Autumn 2020) became the dominant COVID-19 transmission in the UK from July 2021 over the Alpha variant[3] (PHE, 2021) and continues to increase in transmission across the UK, and potentially the rise in current infections. It is expected that the COVID-19

* Corresponding author.
E-mail address: paul.lockwood@canterbury.ac.uk (P. Lockwood).

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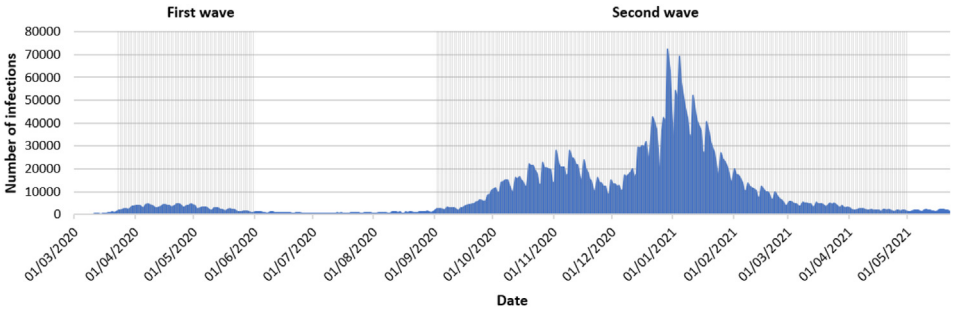

Figure 1. Number of COVID-19 infections in England between March 2020 and May 2021 by NHS Test and Trace.[2]

vaccination (Fig. 2) uptake by the UK population (aged 18 and over) will start to decrease future COVID-19 waves.[4]

COVID-19 is an acute and highly contagious viral disease with respiratory symptoms that resulted from the virus SARS-CoV-2 and is believed to be acquired from a zoonotic source.[5] The most common symptoms of the disease reported include a cough, fever, fatigue, dyspnea, and the loss of taste and smell.[6] Hospitalisation numbers have significantly increased during the pandemic, and radiographers have been working on the frontline throughout. Radiological examinations play a crucial role in the early diagnosis and management of infected patients.[7] In addition, radiography practice has had to adjust to new requirements to support efficient and safe imaging practices; therefore, it is essential to assess the wellbeing of radiographers.[8]

It is noted from studies by McNulty, England and Shanahan[9] and Foley, Paulo and Vassileva[10] that there is a wide variation of pre-qualification student training hours and years in clinical practice globally between diagnostic radiography programmes. This study is focused upon the UK pre-qualification diagnostic radiography students within the UK, which there is also a variation between Higher Education Institutes (HEIs) training hours within three year (English, Welsh and Northern Ireland) and four year (Scottish) programmes as there is no nationally set standard by the Health and Care Professions Council (HCPC, section 5.2[11]). The HCPC[11] states that all radiography students in the United Kingdom (UK) must complete an adequate amount of clinical placement, resulting in students attending clinical placement during the pandemic. Clinical placements are a vital part of preregistration as they prepare students for registration.[12] Third-year students were additionally provided with the opportunity of joining the temporary HCPC[13] register to assist imaging departments. Academic learning was moved online as all face-to-face teaching was suspended due to the government's risk of transmission and social distancing guidelines. According to Sahebi et al.[14] healthcare workers are susceptible to psychological stress, anxiety, and depression during a pandemic. This is due to concerns about exposure to the disease, transmitting the infection, long working hours, and challenging decisions, which radiography students may experience while being on placement.

Several articles have reported the apprehensions and experiences of multiple healthcare professionals before and during the pandemic. Robbins et al.[15] explored the impact of COVID-19 on $n = 108$ radiology trainees and their mental and physical wellbeing. Robbins et al.[15] found that the pandemic had negatively affected educational learning for 70% of the participants and had negatively impacted clinical training for 83% of participants. Additionally, Williams et al.[16] found that 62% of paramedic students in their study experienced high anxiety levels while working during the first COVID-19 outbreak. Hazell et al.[17] provide further detailed information from a literature review of 25 studies (of which n-162/669 participants were radiography students) investigating the clinical readiness of students based on how much simulation based learning students had. The findings indicated that with increased use of simulation training practice readiness was enhanced. These findings (pre-COVID) support the move of learning and training to online during the pandemic, to prepare students for clinical practice and reduce anxiety.

This literature review aims to explore the Impact of COVID-19 on diagnostic radiography students, specifically to explore any barriers to clinical placement and academic learning within the literature. It is hoped the outcomes will allow a consideration of any requirements for additional support and learning that could be implemented to help increase student's clinical education on placement,[18] or extra support in preceptorship programmes for radiographers qualifying during the COVID-19 pandemic to help them transition from preregistration student to qualified practitioner.[19,20]

Method

A search strategy was used to identify studies based on the impact of COVID-19 on diagnostic radiography students. The research method used a systematic literature search to identify published papers on the subject to answer the aims of the study through appraising

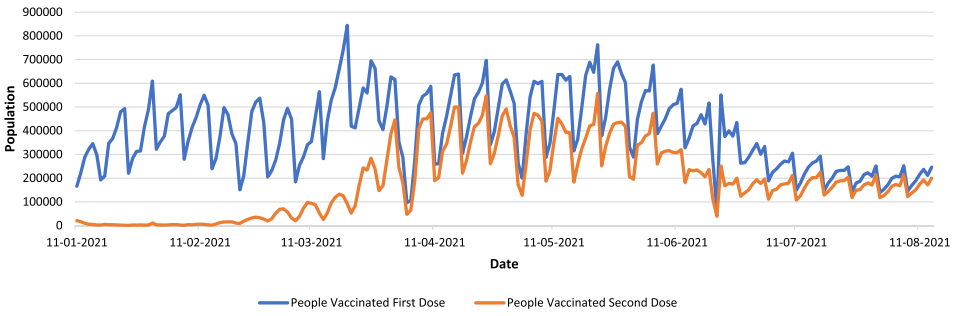

Figure 2. Number of COVID-19 vaccinations in the UK.[4]

and analysing the relevant found papers.[21] Literature searches are important to the radiography profession as they provide a unique body of knowledge drawn from a wide range of published literature.[22] Multiple databases were searched, including PubMed, Medline, and Google Scholar. These established databases provided material relevant to the topic and are acknowledged as reliable sources of information as indicated by Atkinson and Ciprana.[23]

Keywords were used alongside the Boolean operating terms 'OR' and 'AND' to refine the search (Table 1). The use of Boolean search operators allowed the search to be broadened, limited, and defined, resulting in articles that matched the requirements.[24]Asterisks were also applied to expand the search to find words that started with the same letters. Once articles had been selected, they were quality assessed using a mixed-method critiquing framework by Cormack[25] justified by Caldwell et al.[26] for criteria to evaluate research critically.

Inclusion and exclusion criteria were essential in further refining the search strategy.[27] A date limit of 2019–2021 was applied to the search (Table 2). This date inclusion was chosen due to COVID-19 being first detected in December 2019. Primary research papers were used to capture insight into the impact of the pandemic of COVID-19. International studies were included to explore the research topic from a global perspective. Additionally, although the study focusing on diagnostic radiography students, articles including the opinions of therapeutic radiographers were included to find more literature.

The found studies were assessed against the critique framework[25] for reporting quality, and rigour in method and a summary of the outputs will be presented in a matrix table. Each article found in the literature search will also be categorised as to when it was conducted (or published if no research timeframe provided) to its corresponding COVID-19 wave. The research presented within this literature review was selected from materials within the public domain and was exempt from institutional ethical review and did not contain any direct primary research involving human participants (Declaration of Helsinki[28]).

Results

The initial search returned 88 articles that were then reduced to 25 by removing duplicate articles from across the databases. A review of the titles and abstracts were then conducted and displayed (Fig. 3) in a Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) flow diagram.[29] PRISMA flow diagrams allow the search process to be displayed clearly, to enable reproduction by others. After screening and reading the abstracts of the 25 articles, a further 20 were excluded by not meeting the inclusion criteria (radiography students, keywords, date of study) or not being relevant to the research question. The final five articles that met the inclusion criteria, providing sufficient quality and rigour in method when assessed against the critique framework,[25] were then reviewed (Table 3).

Table 1
Keywords and Boolean search operators.

Database	Syntax
PubMed Medline Google Scholar	"Diagnostic radiography students" OR "Diagnostic radiography undergraduate" OR "student radiographer" OR "Undergraduate radiographer" AND "COVID-19″ OR "COVID" OR "Coronavirus"

Table 2
Eligibility criteria.

Inclusion	Exclusion
▪ Articles from 2019 to 2021	▪ Articles before COVID-19 pandemic
▪ Written in the English language	▪ Written in all other languages
▪ Abstract containing keywords	▪ Abstract not containing keywords
▪ Studies involving radiography students only	▪ Studies involving nursing/ medical students
▪ Articles containing primary research	▪ Literature reviews and grey literature
▪ Full articles	▪ Abstract/thesis

The five studies included a range of research methods: two quantitative surveys, two qualitative semi-structured interviews, and one qualitative case study. Participants included: diagnostic radiography students, therapeutic radiography students, clinical liaison radiographers (clinical radiographer staff with overall responsibility of students within their department) and university educators. Table 3 provides a detailed description of each study included in this review and the outcomes of the articles.

Five common themes emerged from the analysis: assessments and learning; accommodation and travel; personal protective equipment (PPE); mental wellbeing; transition to registration.

Clinical assessments and learning

Rainford et al.[30] found that almost 47.9% of students who attended clinical placement between January and June 2020 identified completing clinical assessments as one of their main challenges. A similar study by Tay et al.[31] supported this outcome. It noted students reported problems with meeting the learning objectives for assessments due to the limited number and types of cases encountered during the pandemic. Furthermore, students from the study stated that staff didn't have the time to teach due to the pandemic's stressful environment.

Campus and online assessments and learning

Online learning also posed a difficulty for students during the pandemic. Teo et al.[32] found that the transition to online learning impacted students significantly. Students felt no "*rigid schedule to adhere to*" without physical lessons, resulting in students having "*to plan their study schedule*".[32] Additionally, Teo et al.[32] revealed that not every student had a suitable environment for home learning, causing difficulties.

Accommodation and travel

Rainford et al.[30] found that 92.7% of participants cohabited with family members, friends, and flatmates. Moreover, a quarter of these students lived with a family member with an underlying health condition, and 4.4% suffered from underlying health issues themselves. Travel to and from placement and accommodation was also raised as a concern by 30% of the participants in the study. Courtier et al.[33] likewise identified student concerns with accommodation during the pandemic, illustrated by a student left without housing for a month due to not being able to attend new house viewings. Two other students from the study complained that their accommodation in the pandemic was far away from their clinical placement site. Public transport was affected by the pandemic, which in turn caused issues for students. One student said, "*trains were all on Sunday timetables, so there was never one early enough, so I walked. It took an hour, but I walked in every morning*".[33] While another student acknowledged, "*If I couldn't drive, that would cause an issue as there's no other method of transport*".[33] Although Courtier et al.[33] interviewed therapy radiography students the examples are

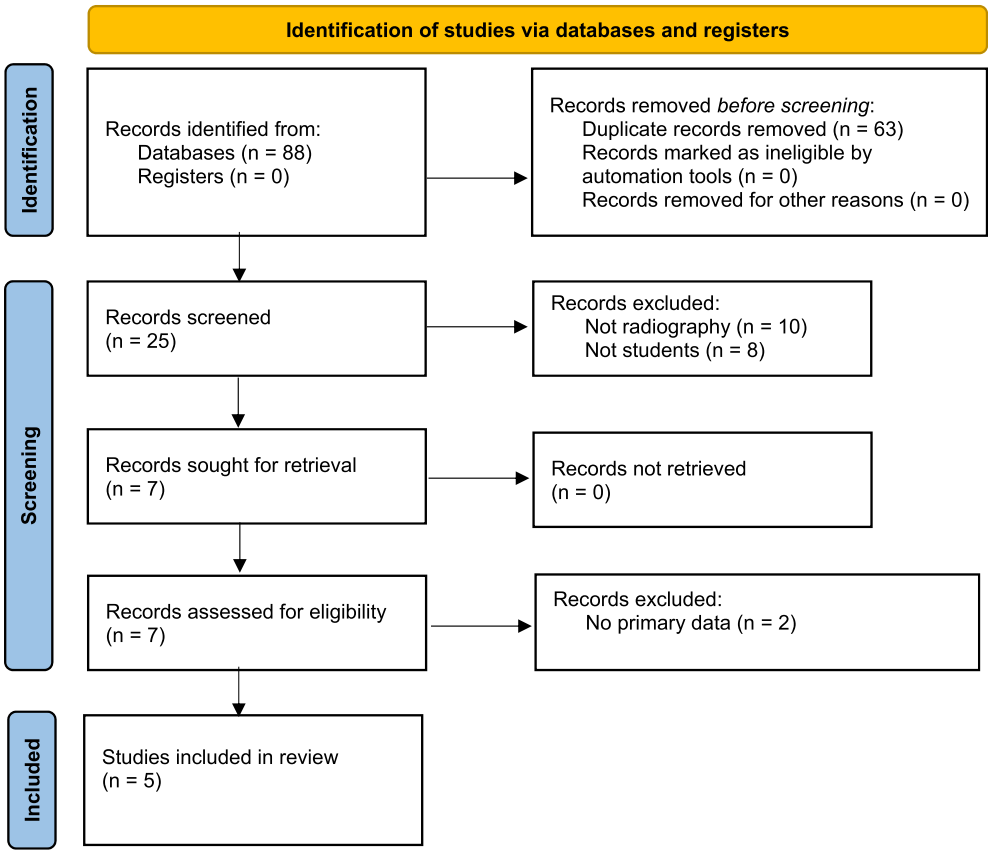

Figure 3. Summary of literature review search records using PRISMA 2020[29] flow diagram for new systematic reviews.

equally important to understand the experience of all radiography students during the pandemic.

Mental wellbeing related to clinical work

Rainford et al.[30] found when students were asked if they had concerns before commencing clinical placements during the pandemic, only 16.3% indicated that they were *"Not worried at all"*. Those who expressed concerns were *"Extremely worried"* (10.5%), *"Very worried"'* (16.0%), *"Somewhat worried"'* (35.2%), or *"Slightly worried"* (22.0%).[30] Tay et al.[31] supported these findings as 51% of third and 54% of second-year reporting concerns and anxiety about resuming placement in the pandemic. Students expressed fears of contracting the virus at placement and passing it to family members. Teo et al.[32] stated that the top concern of all the students was the risk of contracting the virus and wrote that they experienced "*fear and worry about one's health*".[32] This case study also identified that students felt anxiety about contracting the virus and infecting their family members. Cushen-Brewster et al.[34] also revealed how participants in the study described how working with large numbers of critically ill patients had an emotional impact. One student wrote, "*We were dealing with some pretty poorly patients, and that brought its own challenges …. it does scare me a bit*".[34] Courtier et al.[33] found that students had anxiety due to "*having to learn all the new extras of covid and all the regulations, and not being able to do the things we would normally do*".[33]

Mental wellbeing related to campus/online life

Furthermore, Cushen-Brewster et al.[34] noted that many felt disappointed that they were unable to say goodbye to their classmates due to the pandemic. One student wrote, "*I was gutted … I really wanted to have the full experience as a student*".[34] Another student wrote, "*It did feel a bit abrupt – the end of our student status*".[34] However, these findings from Courtier et al.[33] and Cushen-Brewster et al.[34] were from small sample sizes. It cannot be assumed that all final year students felt this way.

Personal protective equipment

Rainford et al.[30] found that only 39.2% of students felt either "*extremely confident*" or "*very confident*" using PPE on placement interacting with COVID patients. Cushen-Brewster et al.[34] indicated students wearing full PPE stated that "*It was [difficult]. I had heard of people being in there for 2 or 3 h in the kit, that was hard. You very quickly got very hot, we joked that we probably lost a couple of stone just sweating it out!*".[34] Courtier et al.[33] highlighted the struggle of learning how to apply PPE, with a student reporting, "*A lot of what we have learnt is going to be different doing it for the first time, like the PPE*".[33]

Readiness for registration

Rainford et al.[30] found that 35.4% of all students indicated that they were "*Not at all worried*" about being a radiographer. However, education institutions should take note that the remaining 64.6% expressed varying levels of concern. Conversely, Cushen-Brewster et al.[34] found that students realised that they were much more ready to practice than they realised. One student wrote, "*I definitely know a lot more than I thought I did, and I should definitely be more confident in my abilities*".[34] Courtier et al.[33] also found that students felt prepared for registration, with one student stating, "*I think I'm*

Table 3
Summary of the included studies.

Author	Year	Country	COVID wave	Method(s)	Sample size	Findings	Themes
Rainford et al.[30]	2021	International	End of First UK wave	Quantitative survey	$n = 1277$	▪ 25.8% Lived with a vulnerable family member ▪ 40.3% Had direct exposure to COVID-19 patients ▪ 50.5% Reported satisfied with communication about placements ▪ 39.2% Reported confidence with PPE ▪ 73.3% Felt worried about placement ▪ 90.1% Felt personally effected by COVID-19	▪ Assessments & Learning ▪ PPE ▪ Mental wellbeing ▪ Transition to registration
Cushen-Brewster et al.[34]	2021	UK	Start of Second UK wave	Qualitative semi-structured interviews	$n = 17$	▪ Students felt prepared to start work as a radiographer after being on the HCPC temporary register ▪ Students struggled to work will ill patients ▪ Students felt anxious about spreading COVID-19 ▪ Students reported sadness the end of university could not be oncampus	▪ PPE ▪ Mental wellbeing ▪ Transition to registration ▪ Accommodation & Travel
Courtier et al.[33]	2021	UK	End of First UK wave	Qualitative semi-structured interviews	$n = 11$	▪ Students reported anxiety about attending placement and contracting COVID-19 ▪ Students struggled with placement travel ▪ Students felt prepared to transition to registration ▪ Students reported disappointment not celebrating the end of the degree	▪ Mental wellbeing ▪ Transition to registration ▪ Accommodation & Travel
Tay et al.[31]	2020	Singapore	After first Singapore wave	Qualitative and Quantitative survey	$n = 91$	▪ 51% Of third years & 54% of second year students reported concerns being on placment during COVID-19 ▪ Concerns included contracting COVID-19, completing clinical assessments, learning objectives	▪ Assessments & Learning ▪ Mental wellbeing
Teo et al.[32]	2020	Singapore	After first Singapore wave	Commentary	$n = 4$	▪ Students reported disruption in learning due to COVID-19 ▪ Students reported struggling with E-learning on placement ▪ Students reported anxiety regarding transmission of COVID-19 working with patients ▪ Students reported positives of being more adaptive and resilient	▪ Assessments & Learning ▪ PPE ▪ Mental wellbeing

at the point in my life where I'm so ready to be part of a workforce, and a workforce I am really proud to be part of".[33]

Discussion

The results identified were comparable to studies on radiology trainees,[10] paramedic students[11] and nursing students with similar findings on learning, mental wellbeing, PPE, preparedness for registration, from UK[35] and international studies.[36] Understanding the impact that COVID-19 has on radiography students will allow radiology departments, educational institutions, and professional bodies to evaluate their training and programs.[37] In addition, the HCPC[13] is working with stakeholders across the sector to address the different impacts caused by the pandemic to offer additional support to students.

As universities were closed during the lockdown, lectures were shifted to home-based online learning. Lectures were delivered through synchronous web conferences, asynchronous pre-recorded videos, and discussion boards. Although the review highlighted issues with online education, studies in recent years have shown the efficiency of blended learning combining e-learning with physical lectures, with increased learning rates and student satisfaction.[38] This suggests that universities could deliver e-learning asynchronous with face-to-face learning for maximum benefits for future cohorts with further reviews. The Council of Deans[39] explain that universities in the UK are doing everything

possible to ensure academic progress is not disrupted by the pandemic.

The issues with cohabiting need to be addressed as it is widely evidenced to increase the risk of COVID-19 spread, which presents an additional risk to those with underlying conditions. Negri and La Vecchia[40] surveyed 14,374 students and lecturers from the University of Milan during the first wave of COVID-19 and found that 10% of the community was affected by COVID-19 while cohabiting. Universities need to consider specific student concerns about the risk of transmitting COVID-19 due to living with family and friends and use appropriate measures and protocols to support this. This is because the disease can easily be spread through contact and direct transmission, and even indirect transmission through hard surfaces, resulting in the rapid spread of the disease.[5]

To help reduce fears of spreading the virus to family and friends, vaccinations are now available to radiography students in the UK.[41] Likewise though it is expected there will be the potential of future waves of COVID-19 due to variants of the infection, which it is hoped will be lessened with the UK vaccination programme.[4] To lessen the concerns around public transport, the World Health Organisation[42] has recommended the use of social distancing and face masks on all public transport. The Student Loans Company[43] have stated that they will continue to support students financially and have stated that students should not be required to pay for accommodation that has been closed due to the pandemic.

The NHS People Plan[44] emphasises the need for staff to acknowledge the impact of working in stressful environments. They suggest that a coordinated approach needs to be adopted to improve the support for individual's clinical experience and for caring for their health and wellbeing. The Society of Radiographers[45] suggests that it appears reasonable to state a potentially greater dependency on clinical staff to identify and liaise with the educational institutions about concerns over student wellbeing, if they are observed whilst on clinical placement. In addition, Health Education England[46] recommends that while students are on clinical placement during the pandemic, regular breaks should be taken to reduce fatigue. It is also suggested that students be made aware of where they can access local support such as Occupation Health, psychological support, and access to counselling.

Many students in the review had issues with wearing PPE and correctly applying it. This concern requires the attention of personnel at the universities and on clinical placements. The Health and Safety at Work Act[47] states the employer has a duty of care to staff that cannot be ignored, meaning students should be adequately trained to ensure safety. The Society of Radiographers[45] advises members that they must be provided with the minimal appropriate PPE when dealing with all patients, and risk assessments should be carried out to minimise any potential risks. Teo et al.[32] provided examples of a university introducing infection control refresher courses that focus on handwashing, alcohol-based hand rub, and donning and doffing to help students feel more confident using PPE, which other universities could implement and further develop.

Limitations of this review included a lack of published articles to review at the time of writing due to COVID-19 being current and ongoing. The pandemic impacts will continue to be seen over the next few years, so more effects are likely to be observed. It is also expected that there might be delayed completion and publication of studies from the first two waves of COVID that will expand upon these findings and so further literature reviews are recommended to achieve additional information on the impact to assessments and learning; accommodation and travel; PPE; mental wellbeing and transition to registration and continued research into the impact from future COVID-19 waves.

Conclusion

This research aimed to identify the impact of COVID-19 on student radiographers so that help could be offered to current students and plans be made to support students in the forthcoming academic year. Literature, whilst limited for Radiography has demonstrated impact particularly during the first and second wave of COVID-19. Clinical staff and universities need to work together to ensure students are mentally and physically supported during future waves of the pandemic with vaccinations and boosters for future variants against increased waves of transmission and infection. Regular meetings and thorough communication with students will allow any issues to be brought to attention and addressed. Clinical staff at placements should be aware of any essential information about the students they are hosting, including medical conditions and family living situations, to ensure further safety. Employers should recognise that newly qualified radiographers may need extra support in a preceptorship programme when transitioning from student to radiographer.

Conflict of interest statement

None.

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