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Perceptions of medical students towards online learning during the COVID-19 pandemic: a national cross-sectional survey of 2721 UK medical students

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3 **Perceptions of Medical Students Towards Online Learning During the COVID-19 Pandemic: a**
4 **national cross-sectional survey of 2721 UK medical students**
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Abstract

Objectives To investigate perceptions of medical students on the role of online learning in facilitating medical education during the COVID-19 pandemic

Design Cross-sectional, online national survey

Setting Responses collected online from 4th May to 11th May 2020 across 40 UK medical schools

Participants Medical students across all years from UK-registered medical schools

Main outcome measures The uses, experiences, perceived benefits and barriers of online learning during the COVID-19 pandemic.

Results 2721 medical students across 39 medical schools responded. Medical schools adapted to the pandemic in different ways. The changes included the development of new distance-learning platforms on which content was released, remote delivery of lectures using platforms and the use of question banks and other online active recall resources. A significant difference was found between time spent on online platforms before and during COVID-19, with 7.35% students before vs. 23.56% students during the pandemic spending >15 hours per week ($p<0.05$). The greatest perceived benefits of online learning platforms included their flexibility. Whereas the commonly perceived barriers to utilising online learning platforms included family distraction (26.76%) and poor internet connection (21.53%).

Conclusions Online learning has enabled the continuation of medical education during these unprecedented times. Moving forward from this pandemic, in order to maximise the benefits of both face-to-face and online learning, and to improve the efficacy of medical education in the future, we suggest medical schools resort to teaching formats such as team-based/problem-based learning. This utilises online teaching platforms allowing students to digest information in their own time but also allows students to then constructively discuss this material with peers. It has also been shown to be effective in terms of achieving learning outcomes. Beyond COVID-19, we anticipate further

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3 incorporation of online learning methods within traditional medical education. This may accompany
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5 the observed shift in medical practice towards virtual consultations.
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10 Article Summary

15 **Strengths & Limitations**

- 16 • The COVID-19 pandemic has undoubtedly impacted the delivery of medical education
17 with a sudden shift towards online learning platforms; to date, this is the first study
18 investigating the perceptions of medical students on these changes.
- 19 • This study is strengthened by its collection of responses from a large national cohort of
20 medical students from 39 out of 40 UK medical schools.
- 21 • The survey extensively explored the benefits of and barriers to online learning methods
22 with the potential to provide medical schools nationally with a direction for development
23 of resources.
- 24 • Survey responses may have been subject to recall bias, and limited by timing of the study
25 coinciding with the examination season where remote learning platforms may often be
26 resorted to.
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INTRODUCTION

Since the first case of coronavirus disease 2019 (COVID-19) in the United Kingdom (UK)(1), the World Health Organisation (WHO) has declared the COVID-19 outbreak as a global pandemic(2). The nationwide lockdown restrictions to control the spread of disease and “flatten the curve” have impacted all aspects of life(3–5); inevitably, medical education has also been affected, with the halting of lectures, clinical placements, and key examinations(6,7). Such measures have resulted in a sudden shift in teaching methods towards online learning. Online learning has played a key role in medical education over recent years(8–10), demonstrated several benefits in enhancing student learning(11). A recent systematic review suggested that offline and online learning are equivalent in terms of outcomes of examinations(12). Key drawbacks have also been highlighted, including time constraints to implement effective online learning(8).

The unprecedented COVID-19 pandemic has caused a sudden shift towards the exclusive adoption of online learning, forming the primary source of medical education and enabling students to continue to learn remotely(13). Teaching sessions have covered key clinical conditions, case studies and examination questions via live-streamed tutorials through platforms such as Zoom(6), shown to have high levels of engagement(14). With around 19.6% of the UK medical student demographic consisting of international students(15), many of whom have returned home, this allows individuals to access teaching regardless of location(6). Nevertheless, learning relying on the internet needs to be tailored towards different learning styles to enable it to be impactful and effective(13). However, whilst the benefits to pre-clinical years of blended learning has been shown, for example in anatomical teaching(16) and especially in a generation accustomed to using YouTube(17), there is limited understanding of the impact of exclusive online learning and its use in clinical years. Concerns have been raised regarding the quality of resources produced during the pandemic due to time constraints, particularly as these resources aim to compensate for lack of exposure(18). Indeed, a recent national

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3 Twitter discussion, involving representatives from the General Medical Council (GMC), NHS England
4 and WHO, found that a key concern amongst students was that remote learning impacted their ability
5 to develop clinical competence(19). This also highlighted the potential role of the professional use of
6 social media in facilitating medical education, as shown in surgical training(20).
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14 In the coming months, as lockdown restrictions ease, the need for social distancing will continue and
15 the possibility of medical students acting as vectors of COVID-19(21,22), as seen in the SARS epidemic
16 in Hong Kong(23), remains. Moreover, PPE shortages may form potential barriers to patient
17 interaction(24). Therefore, it is likely that e-learning and telemedicine will continue to form vital
18 sources of medical education. Many authors have suggested that digital health platforms for both
19 patients and students will remain an integral part of care even after the COVID-19 pandemic(25). Thus,
20 having a greater understanding of the perceived advantages and drawbacks will allow medical schools
21 to improve their delivery of online learning. The COVID-19 pandemic has put us in a unique position
22 to evaluate the significance of online learning platforms in medical education. Whilst many students
23 have acknowledged the impact of COVID-19 on their education(6,21) and explored their role during
24 the pandemic(26,27), to date no study has investigated the outlook of medical students on the effect
25 of these changes. Therefore, we aimed to investigate their perceptions on the role of online learning
26 in facilitating their education during the COVID-19 pandemic. Improving our understanding of this
27 could help develop medical school curricula in the future.
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METHODOLOGY

Questionnaire design and distribution

This was a prospective, observational study conducted on a national level via an online survey. A 20-item questionnaire was devised following a literature search on current online learning methods and the effects of COVID-19 on medical education in the UK (Appendix I). Questions exploring the experiences of online learning were based on sections I-IV of the Dundee Ready Education Environment Measure (DREEM)(28), a validated questionnaire designed to measure the educational environment of medical schools and healthcare professionals(29). These were 5-point Likert-type questions, ranging from strongly agree to strongly disagree. The remaining items in the questionnaire comprised a mixture of question styles. Certain questions were conditional. The items were initially drafted and informally discussed with a group of medical students before undergoing a careful review and editing process. The final questions explored the following three themes:

1. General demographics
2. The use and experience of online learning during the COVID-19 pandemic
3. Perceived benefits and barriers of online learning

The survey was created using Qualtrics, an online survey software (Version XM, 2019, Provo, UT(30)), and distributed by medical students recruited nationally in order to maximise outreach to all 40 registered UK medical schools(31). The survey was accessible via an anonymous link and open for a one-week period (04/05/20 – 11/05/20).

Participants

Undergraduate and postgraduate medical students across all years (years 1-5 and intercalated year) from all 40 registered UK medical schools(31) were eligible to participate.

Patient and Public Involvement

As this study focused on medical students, patients or the general public were not involved in the study design. However, medical students were involved with the piloting of the survey as well as its distribution across medical schools.

Participant consent and ethical considerations

Participation was voluntary, and participants were informed prior to starting the survey that all data collected was non-identifiable and would only be used for research purposes. A mandatory selection box consenting to participation and confirming that this was the first time completing this survey was included at the beginning of the survey, ensuring a 100% consent rate and preventing multiple responses. Ethical approval was requested from Imperial College London and was deemed not to be required as all data was anonymised, with informed consent taken from all participants.

Data analysis

Data was exported from Qualtrics to Microsoft Excel (Excel version 16.29, 2019). Qualtrics and GraphPad Prism (Prism version 8.2.1, 2019) were both used to generate graphs and calculate descriptive statistics for the survey responses to explore patterns in responses. Multiple responses were accounted for by identifying unique IP addresses.

Wilcoxon test was used to compare hours of online learning usage before and after COVID-19. This was conducted following the Shapiro-Wilk and Kolmogorov-Smirnov normality tests which found the data set to be non-gaussian in distribution. *P*-values <0.05 were considered to be statistically significant.

RESULTS

Cohort demographics

Of the 2721 responses collected, 68.06% (n=1852) of respondents were female, 31.53% (n=858) were male, and 0.40% (n=11) identified as other. Responses were collected from 39 medical schools across the UK, from medical students across all years (Table 1).

Table 1. A table outlining the demographics (gender, university, and year of medical school) of students responding to the survey (n=2721).

Demographic		Proportion of students, % (n)
Gender	Male	68.06 (1852)
	Female	31.53 (858)
	Other	0.40 (11)
University	University of Aberdeen School of Medicine and Dentistry	1.76 (48)
	Anglia Ruskin University School of Medicine	2.21 (60)
	Aston University Medical School	0.07 (2)
	Barts and The London School of Medicine and Dentistry	6.39 (174)
	University of Birmingham College of Medical and Dental Sciences	1.76 (48)
	Brighton and Sussex Medical School	0.44 (12)
	University of Bristol Medical School	3.20 (87)
	University of Buckingham Medical School	0.77 (21)
	University of Cambridge School of Clinical Medicine	1.29 (35)
	Cardiff University School of Medicine	9.22 (251)
	University of Dundee School of Medicine	0.40 (11)
	The University of Edinburgh Medical School	0.44 (12)
	University of Exeter Medical School	2.06 (56)
	University of Glasgow School of Medicine	0.70 (19)
	Hull York Medical School	3.86 (105)
	Imperial College London Faculty of Medicine	3.93 (107)
	Keele University School of Medicine	0.85 (23)
	Kent and Medway Medical School	0.04 (1)
	King's College London GKT School of Medical Education	10.11 (275)
	Lancaster University Medical School	0.15 (4)
	University of Leeds School of Medicine	4.96 (135)
	University of Leicester Medical School	2.87 (78)
	University of Liverpool School of Medicine	8.38 (228)
	University of Manchester Medical School	4.52 (123)
	Newcastle University School of Medical Education	3.34 (91)
	Norwich Medical School	7.02 (191)
	University of Nottingham School of Medicine	3.31 (90)
	University of Nottingham - Lincoln Medical School	0.07 (2)
	University of Oxford Medical Sciences Division	2.24 (61)
	Plymouth University Peninsula Schools of Medicine and Dentistry	0.55 (15)
	Queen's University Belfast School of Medicine	0.92 (25)
	University of Sheffield Medical School	0.99 (27)

	University of Southampton School of Medicine	1.98 (54)
	University of St Andrews School of Medicine	0.33 (9)
	St George's, University of London	2.46 (67)
	University of Sunderland School of Medicine	0.00 (0)
	Swansea University Medical School	0.11 (3)
	University of Central Lancashire School of Medicine	1.73 (47)
	University College London Medical School	2.46 (67)
	University of Warwick Medical School	2.09 (57)
Year	Pre-clinical Year 1	23.19 (631)
	Pre-clinical Year 2	19.85 (540)
	Year 3	27.20 (740)
	Penultimate Clinical Year	20.62 (561)
	Final Clinical Year	4.52 (123)
	Intercalating	4.63 (126)

Student engagement with online learning platforms

Prior to the pandemic, students spent an average of 4-6 hours per week using online learning platforms. Students used a combination of video tutorials (27.71%), online question banks (26.18%), pre-recorded tutorials via their respective medical schools (20.96%) and online flashcards (15.99%). 4.46% of students utilised live tutorials via online platforms from their medical school (Figure 1). Other resources included the use of Anatomy TV, online notes such as Pulsenotes or TeachMeAnatomy, Acland's Anatomy videos, revision websites such as OSCE Stop and Zero To Finals, NICE guidelines, online textbooks and UpToDate, and BMJ Best Practice.

During the pandemic, students spent an average of 7-10 hours using online learning platforms, compared to 4-6 hours prior to the pandemic. The difference in hours prior to and during the COVID-19 pandemic were found to be significant ($p < 0.05$). Similar numbers of students spent <1 hour on online learning platforms before and during the pandemic. However, there was an increase in numbers of students spending longer periods of time on online learning platforms, for example 7.35% (n=200) vs. 19.70% (n=641) of students spent >15 hours on online learning platforms before and during the pandemic (Figure 2). 57.28% of students reported that they were now taking examinations remotely, whilst the rest had examinations that had been postponed or cancelled.

Medical school adaptations to COVID-19

Medical schools adapted to the pandemic in a combination of ways with 28.48% of students reporting their medical school to adapting to remote learning through the delivery of live tutorials via online platforms. Moreover, 42.19% of students reported that their medical school either introduced new resources to existing learning platforms or created a new online learning platform with new resources. Other medical schools have either a) not implemented anything as the curriculum had already been covered, or b) delayed teaching with the introduction of a question bank.

The online learning provided as an alternative by the medical schools followed a pre-set curriculum for 66.12% (n=1799) of students, was designed following student requests for 3.38% (n=92) of students, or using a combination of both for 30.50% (n=830) of students. This shows that student opinion was considered in the delivery of online learning.

Furthermore, 59.73% of students found that online teaching sessions have been interactive, with students finding the opportunity to interact via the chat box or by directly speaking to the lecturer. Some students have also specified that having small group sizes, group discussions, online case simulations and quizzes have been useful in increasing their engagement.

Student perception of online learning

Students ranked their experience of online learning using a Likert scale with 1 being strongly disagree and 5 being strongly agree (Table 2). Students agreed that learning online was engaging, enjoyable and allowed room for questions. However, students appeared to want online learning to be more interactive and did not find it as effective as face to face teaching.

Table 2. A table displaying students' perceptions on their experiences of online learning, ranked on a Likert scale from 1-5, where 1=strongly disagree and 5=strongly agree. Likert scores have been shown as mean \pm standard deviation (\pm SD)

Statement	Mean	\pm SD
The teaching is often stimulating	2.75	1.18
I find it easy to engage in the lesson	2.55	1.30
I feel able to ask the questions I want	2.70	1.53
I enjoy the online teaching	2.62	1.37
I would like the online teaching to be more interactive	3.04	1.44
I feel that online teaching is as effective as face-face teaching	1.92	1.45
I prefer online teaching to face-face teaching	1.69	1.48
The teachers are well prepared for the teaching sessions	3.36	1.42
I feel I am being well prepared for my profession	2.28	1.33
My internet connection can be problematic	2.53	1.74

The main advantages of online learning appeared to be that it saves students time on travelling (19.82%), the flexibility it provides (19.52%), the ability for students to learn at their own pace (18.63%), it is more comfortable (15.84%), and it cuts costs (14.24%) (Figure 3A). Other medical students (n=82) also commented that it provides time efficiency, allows more time for students to focus on preparing for clinical placements, reduces anxiety, and being able to be in a different country.

On the other hand, students stated that family distractions (26.76%), internet connection (21.53%), timing of tutorials (17.31%), anxiety (11.08%), and lack of space (11.03%) as barriers to effective online learning (Figure 3B). Students also commented on experiencing a lack of motivation, difficulty concentrating and asking questions, and a lack of contact with colleagues as further limitations.

Role of online learning in clinical teaching

75.99% (n=1842) of medical students felt that online learning had not successfully replaced the clinical teaching they received via direct patient contact, with 82.17% (n=1986) of students feeling they cannot learn practical clinical skills through online learning. This shows that clinical skills remain a pertinent barrier to online learning of medical students.

Student perception on effectiveness of online learning

Students ranked the effectiveness of online learning with 1 being most effective and 5 being least effective. Video tutorials e.g. YouTube/Osmosis appeared to be the most effective, followed by online question banks, and live tutorials, whilst students commented using a variety of other sources.

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DISCUSSION

With the rise of COVID-19, it is unsurprising that many medical institutions have resorted to online education platforms. However, online education has been used preceding this pandemic. Here, we discuss how this pandemic has shaped the use of online learning currently as well as its application in the future of medical education.

Our study found a significant difference ($p < 0.05$) in the time spent on online learning platforms before and during the pandemic, with a greater number of hours spent amidst the pandemic. This result was expected as the primary source of education and engagement of students with their medical schools was online. This is in addition to the normative use of online learning resources before the pandemic and forced isolation. This is despite that many students reported the cancellation of clinical examinations and conversion of written examinations into open book, which would arguably reduce student engagement with any learning platform. Nevertheless, students recognise the importance of their studies for their future careers as clinicians, this is in accordance with the duties of medical students outlined by the GMC(32).

The development of innovative educational projects has been initiated to enhance remote medical education(19). A rise in external resources and teaching programs such as Osmosis, BiteMedicine, Becoming A Doctor and Sustaining Medical education in a Lockdown Environment (SMILE) has allowed many teaching sessions to be made available to medical students across the country. Hence, students may learn from a wider community of professionals. However, the high flow of resources causes a proliferation of choice which may increase burnout rates. Schwartz claimed that this choice overload is due to the failure of universities on fulfilling their education role to their students(33,34). Yet, the increase in demand suggests that students desire this flexible curriculum.

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3 The accessibility of online material may have contributed to a high absenteeism and increase
4 disengagement in medical schools; limited interaction with lecturers may add to this(35). To tackle
5 this, Evans *et al.* suggested incorporating online Q&A sessions to improve student engagement(13),
6 based on a previous model advising the use of synchronous learning(36). Synchronous learning is
7 defined as a social learning environment alongside answering questions live(37). This active
8 communication between lecturers and students allows ambiguous concepts to be addressed
9 immediately to increase student involvement, creating a more active learning environment. Indeed,
10 our results show that students would like online teaching sessions to be more interactive.
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23 To students, the main advantages of online learning are the time and money saved from the lack of
24 travel, its flexibility and the ability for students to learn at their own pace (Figure 3A). However, Zureick
25 *et al.* showed that watching pre-recorded lectures negatively correlated with learning success, with
26 higher reported rates of distractions and interruptions(38). Yet, there are benefits of online
27 lectures(14) which can enable students to anonymously ask and answer questions, potentially
28 encouraging further engagement from those who would not otherwise participate in a live lecture.
29 Alternatively, with the afore mentioned distractions that students may face, the lack of focus may
30 result in a decrease in participation. Although students found small group teaching beneficial, it may
31 strip students of anonymity, reducing voluntary participation.
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46 The main barriers to online learning appear to be family distractions, internet connection and the
47 timing of tutorials (Figure 3B). This may disadvantage students with large families or with limited
48 internet access. Moreover, the mental health of students, recently shown to be impacted by the
49 COVID-19 pandemic(39), may be adversely affected as indicated by the free text responses. This may
50 be, in part, attributed to the lack of interaction with friends and colleagues leading to a rise in anxiety.
51 Alternatively, with exams being open book and with an unrestricted setting, students may be less
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3 prone to exam anxiety(40). Although, this does not address the family and noise disturbances which
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5 may still affect exam performance.
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10 On the other hand, medical students are being asked to 'step-up' and join the front-line of doctors
11 tackling COVID-19(41). As well as the early graduation of UK medical students(42), many universities
12 have given their students the opportunity to volunteer. For example, the University of Birmingham
13 has facilitated for over 700 medical students to volunteer in the NHS(27). Although medical schools
14 have halted clinical placements, this opportunity could provide more exposure, undoubtedly
15 impacting the development of medical students. However, for those who are not volunteering due to
16 living with vulnerable family members or having health conditions themselves, this would then put
17 them at a disadvantage as their peers continue to gain clinical exposure.
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30 As lockdown restrictions ease and students slowly return to medical school, clinical placements may
31 incorporate more virtual aspects as healthcare evolves(22). Indeed, new platforms have been
32 developed by the NHS (e.g. NHS NearMe) which have shown that video consultations are better than
33 telephone consultations in reducing medical error and improving patient outcomes(31). However,
34 Professor Martin Marshall, chairman of the RCGP, has highlighted that most consultations are still
35 taking place over the phone as opposed to video calls(43). This may be subject to change with a
36 demographic who are increasingly familiar with the use of the internet. Additionally, in Germany,
37 online platforms as observed in Dermatology may "provide a safe and efficient alternative for face-
38 face outpatient care"(25), abiding by social distancing rules.
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52 Furthermore, the digitalisation of medical teaching could play a significant role in the future of medical
53 schools. Allowing users to tailor their learning and acquire new skills through the chaotic nature of an
54 amplitude of resources could halt the development of medical students. Having discussed benefits of
55 both face-to-face and remote teaching as well as the future of healthcare online, we suggest that in
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3 order to maximise the benefits of these learning methods, a mixture of online and in person teaching
4 should be utilised moving forward. This can be incorporated into an effective learning method such
5 as problem-based learning or team-based learning which have been shown to improve learning
6 outcomes(44,45). Students are set online materials to study and are then are expected to discuss
7 content in person in a group tutorial(46). This allows students to study at their own pace, in a manner
8 suitable to them, while also holding them accountable for their own learning.
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19 **Limitations and Future work**

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23 This is the first study to look at the impact of COVID-19 on online learning across the UK, with
24 responses from 39/40 medical schools. One of the strengths of this study is its large sample size of
25 2792 medical student across all pre-clinical and clinical years. However, this study also had some
26 limitations. Some medical schools may have been disproportionately represented with larger numbers
27 of responses from some schools e.g. Kings College London, compared to newer medical schools such
28 as Aston or Kent, potentially skewing results due to sample bias. Furthermore, some aspects of this
29 survey depended on participants' memory perhaps influencing their reporting, introducing elements
30 of recall bias. Also, it is important to note that the period covered is usually when students have
31 examinations, hence students may have been spending more time on online learning platforms
32 regardless. In addition, since this survey, medical schools may have updated their online resources.
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34 To truly measure the impact of COVID-19 on student utilisation of online learning, a more in-depth,
35 qualitative analysis such as focus groups conducted in collaboration with medical schools is required
36 to gather more accurate results, such as the effects on examination performance.
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Author Contributions

SD contributed to the study concept and design, and developed the questionnaire. SD recruited collaborators for survey distribution and data collection. SD supervised the project, had full access to the data, controlled the decision to publish, and accepts full responsibility for the conduct of this study, as the guarantor. AH and SD contributed equally to this study as joint first authors. AH developed and designed the questionnaire, contributed to data acquisition and interpretation, writing and critical revision of the manuscript. AH is the corresponding author and managed project administration. MS developed the questionnaire, contributed to data acquisition and interpretation, and writing and critical revision of the manuscript. AA developed the questionnaire, and contributed to data visualisation and presentation, and writing and critical revision of the manuscript. LA performed data analysis, interpretation, visualisation and presentation, and contributed to writing and critical revision of the manuscript. All authors approved the final version to be published and are accountable for all aspects of the work. Sixteen students were involved with survey distribution and data collection.

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41 **Competing Interests**

42 All authors have completed the ICMJE Unified Competing Interest form (available on request from the
43 corresponding author) and declare: no support from any organisation for the submitted work; no
44 financial relationships with any organisations that might have an interest in the submitted work in the
45 previous three years, no other relationships or activities that could appear to have influenced the
46 submitted work.
47
48
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54 **Data sharing**

1
2
3 Raw data are available upon request from the corresponding author
4
5 (aleena.hossain16@imperial.ac.uk). Due to the anonymous nature of the survey, it was not possible
6
7 to disseminate the results of this study to the participants.
8
9

10 11 12 **Transparency statement**

13
14 The lead author confirms that the manuscript is an honest, accurate, and transparent account of the
15
16 study; no important aspects of the study have been omitted; and any discrepancies from the study as
17
18 originally planned have been explained.
19

20 21 22 **Ethical approval**

23
24 Ethical approval was requested from Imperial College London and was deemed not to be required as
25
26 all data was anonymised, with informed consent taken from all participants. The work was carried out
27
28 in accordance with the Declaration of Helsinki, including, but not limited to the anonymity of
29
30 participants being guaranteed and the informed consent of participants being obtained.
31
32
33

34 35 36 **Funding**

37
38 This research received no specific grant from any funding agency in the public, commercial or not-
39
40 for-profit sectors.
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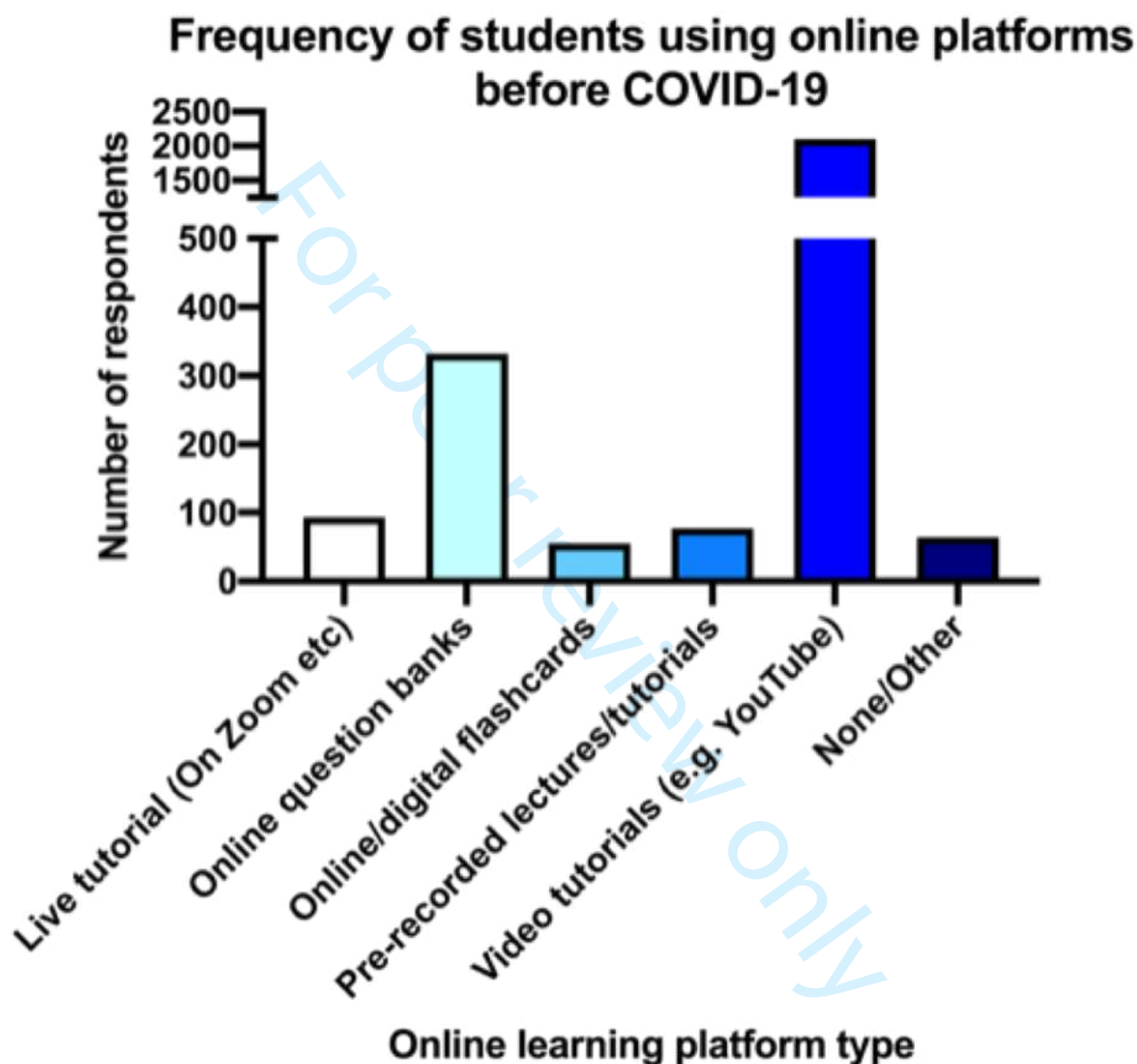
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Figure Legends

Figure 1. Students were asked about the different types of online learning platforms they used before the COVID-19 pandemic as represented by this bar chart (n=2721).

Figure 2. Students were asked the approximate number of hours spent on online learning platforms before and during the COVID-19 pandemic as represented by this bar chart (n=2721). A Wilcoxon test was then conducted which found the difference to be significant ($p < 0.05$).

Figure 3. A bar chart outlining the advantages of and barriers to online learning. A- Students were provided with a list of potential ways in which online learning was advantageous and they were asked to select all which applied to them. They were also given the option to input their own statements (n=2721). B- Students were provided with a list of potential barriers to the benefits they may receive from online learning and they were asked to select all which applied to them. They were also given the option to input their own statements (n=2721).



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Figure 1. Students were asked about the different types of online learning platforms they used before the COVID-19 pandemic as represented by this bar chart (n=2721).

Number of hours spent on online platforms before and during COVID-19 pandemic

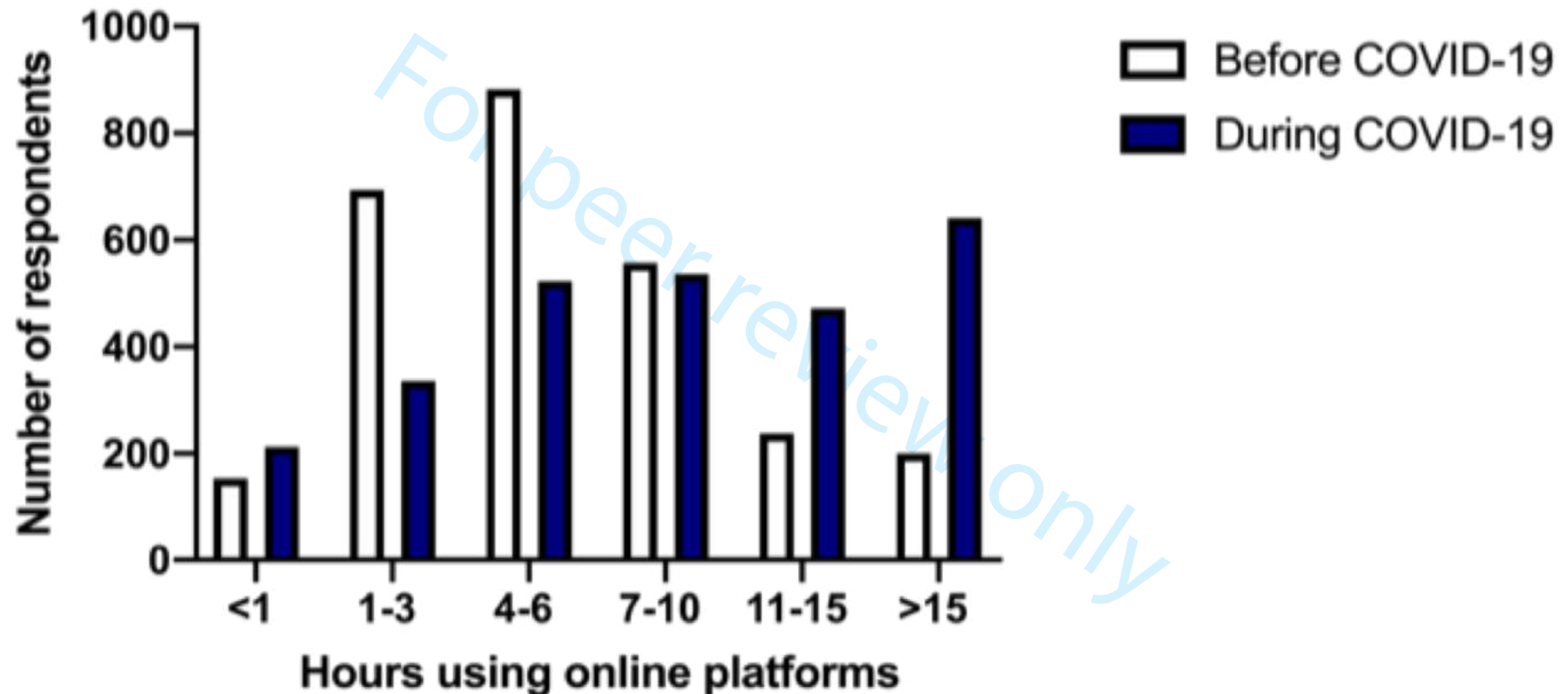


Figure 2. Students were asked the approximate number of hours spent on online learning platforms before and during the COVID-19 pandemic as represented by this bar chart (n=2721). A Wilcoxon test was then conducted which found the difference to be significant ($p < 0.05$).

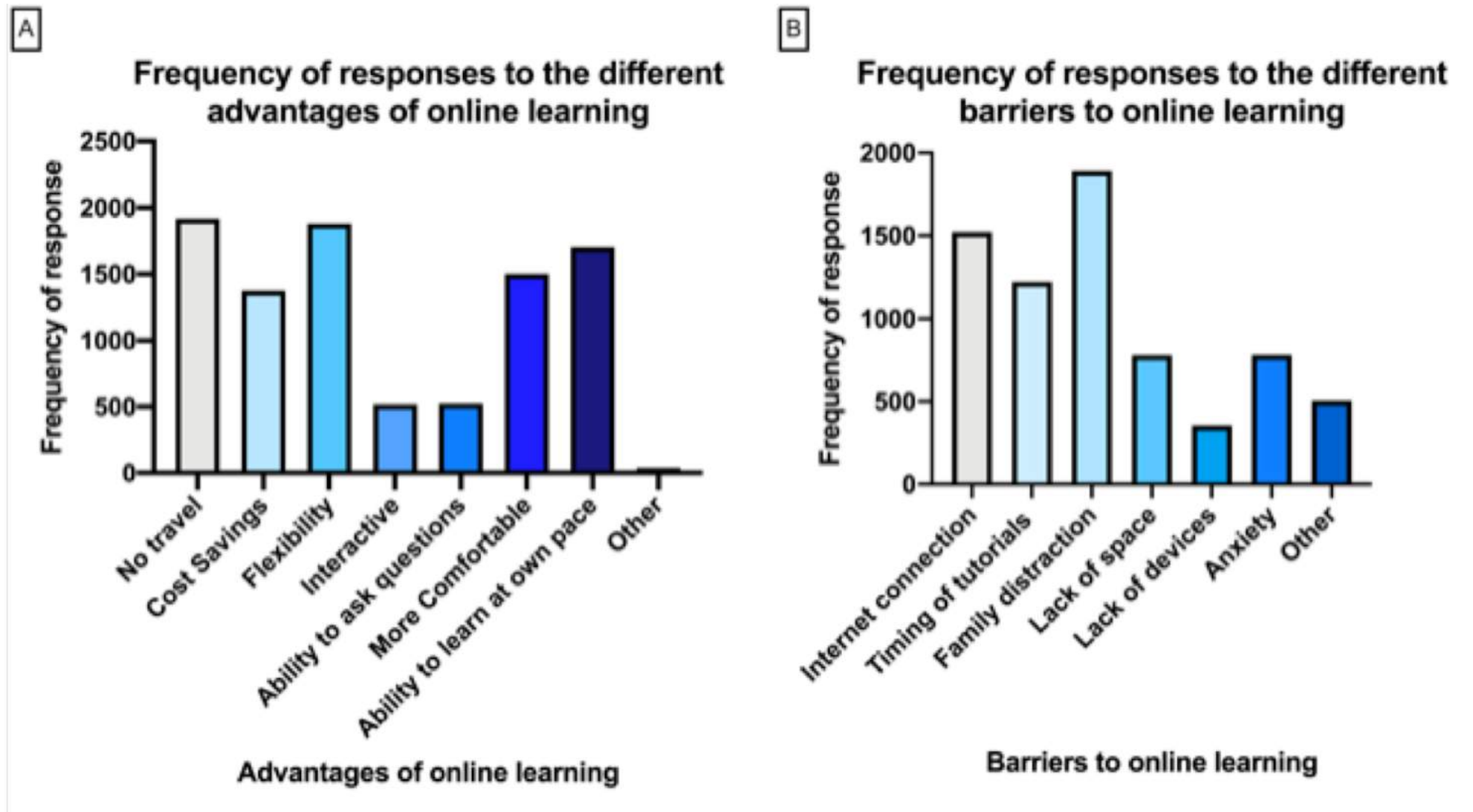


Figure 3. A bar chart outlining the advantages of and barriers to online learning. **A-** Students were provided with a list of potential ways in which online learning was advantageous and they were asked to select all which applied to them. They were also given the option to input their own statements (n=2721). **B-** Students were provided with a list of potential barriers to the benefits they may receive from online learning and they were asked to select all which applied to them. They were also given the option to input their own statements (n=2721).

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Appendix

Appendix I – Online Questionnaire

For peer review only

Covid-19, Online Learning & Medical Education

Thank you for your interest in completing our short survey investigating the role of online learning in facilitating medical education during the Covid-19 pandemic in the UK. The data collected is **non-identifiable** and will be used for research purposes.

This survey will close on Monday 11th May at 10pm.

Please tick the box to proceed:

I consent to my information being used for research purposes and this is my first time completing this survey.

Survey Code:

Background

1. Which UK Medical School do you attend?

2. What year are you in?

3. What is your gender?

Online Learning & Medical Education

4. Prior to the Covid-19 pandemic, which online learning platforms/resources did you engage with? (Please select all which apply)

Video tutorials e.g. Youtube/Osmosis

Live tutorials via Zoom/similar platforms by **Medical School**

Live tutorials via Zoom/similar platforms by **other sources**

Online question banks

Online/Digital Flashcards e.g. Brainscape, Anki

Pre-recorded tutorials via Medical School specific online learning platform

None

Other - please specify

5. Which method of online learning do you find the most effective? Please rank the following methods from 1-5 (1=most effective, 5=least effective)

Video tutorials e.g. Youtube/Osmosis

Live tutorials via Zoom/similar platforms

Online question banks

Online/Digital Flashcards e.g. Brainscape, Anki

Other - please specify:

1
2
3
4 6. Prior to the Covid-19 pandemic, how many hours per week did
5 you spend on average on online learning?
6
7

8
9

10 7. During the current Covid-19 pandemic, how has your medical
11 school adapted teaching for your year? (Please select all which
12 apply)
13
14
15

16 Introduced a new online learning platform with new resources
17

18 Introduced new resources to an existing online learning platform
19

20 Delivered live tutorials via Zoom/similar platforms
21

22 Delivered pre-recorded tutorials
23

24 Other - please specify:
25
26

27
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32

33 8. Are these online teaching sessions interactive?
34
35

36 Yes
37

38 No
39

40 Majority are
41

42 Majority are not
43
44
45
46

47 8b. What makes your teaching sessions interactive? (Please
48 select all which apply)
49
50
51

52 Opportunity to interact via chat box
53

54 Opportunity to interact via speech
55

56 Live quiz
57
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Other - please specify:

9. Does the online learning follow a pre-set curriculum, or is it based on student requests?

- Pre-set curriculum
- Student requests
- Combination of both

10. During the current Covid-19 pandemic, how many hours per week do you spend on average on online learning?

Student Perceptions of Online Learning

11. Please rank the following statements on your experience of online learning from 1-5 (1=Strongly disagree, 5 = Strongly agree)

0 1 2 3 4 5

The teaching is often stimulating

I find it easy to engage in the lesson

I feel able to ask the questions I want

I enjoy the online teaching

1
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5 I would like the online teaching to be more interactive
6
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12 I feel that online teaching is as effective as face-face teaching
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19 I prefer online teaching to face-face teaching
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26 The teachers are well prepared for the teaching sessions
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33 I feel I am being well prepared for my profession
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40 My internet connection can be problematic
41
42

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46 12. What aspects of online learning do you enjoy? (Please select
47 all which apply)
48
49

50
51 No travel

Ability to ask questions

52
53 Cost savings

More comfortable

54
55 Interactive

Ability to learn at own pace
56
57
58
59
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Flexibility

Other - please specify:

13. What do you feel are the barriers to online learning? (Please select all which apply)

Internet connection

Lack of space

Timing of tutorials

Lack of devices

Family distractions

Anxiety

Other - please specify:

Role of Online Learning in Clinical Teaching

14a. Do you feel online learning has successfully replaced the clinical teaching you receive from direct patient contact?

Yes
 No
 Yes, to some extent
 N/A

14b. Do you feel able to learn practical clinical skills through online learning?

Yes
 No
 Yes, to some extent
 N/A

15. Have your examinations been affected by Covid-19?

Yes

No

N/A

1
2
3
4 15b. How have your written examinations been affected?
5
6

- 7 ✓
8 Written exams will take place remotely online
9 Written exams have been postponed
10 Written exams have been cancelled
11 N/A

12
13 15c. How have your practical examinations been affected?
14

- 15 ✓
16 Practical exams will take place with modifications (e.g. virtual patients)
17 Practical exams have been postponed
18 Practical exams have been cancelled
19 N/A
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STROBE Statement—Checklist of items that should be included in reports of *cohort studies*

	Item No	Recommendation	Page No
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up (b) For matched studies, give matching criteria and number of exposed and unexposed	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6
Bias	9	Describe any efforts to address potential sources of bias	6-7
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) If applicable, explain how loss to follow-up was addressed (e) Describe any sensitivity analyses	7
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram	8-9
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest (c) Summarise follow-up time (eg, average and total amount)	8-9
Outcome data	15*	Report numbers of outcome events or summary measures over time	8-12

1	Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8-12
2			(b) Report category boundaries when continuous variables were categorized	
3			(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
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9	Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	8-12
10				
11	Discussion			
12				
13	Key results	18	Summarise key results with reference to study objectives	13-16
14				
15	Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16
16				
17	Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-16
18				
19				
20	Generalisability	21	Discuss the generalisability (external validity) of the study results	13-16
21				
22	Other information			
23				
24	Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	19
25				

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at <http://www.strobe-statement.org>.

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Perceptions of Medical Students Towards Online Teaching During the COVID-19 Pandemic: a national cross-sectional survey of 2721 UK medical students

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3 **Perceptions of Medical Students Towards Online Teaching During the COVID-19 Pandemic: a**
4 **national cross-sectional survey of 2721 UK medical students**
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6

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2
3 1 **Abstract**
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8 **Objectives** To investigate perceptions of medical students on the role of online teaching in facilitating
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10 medical education during the COVID-19 pandemic
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12 5 **Design** Cross-sectional, online national survey
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14 6 **Setting** Responses collected online from 4th May to 11th May 2020 across 40 UK medical schools
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16 7 **Participants** Medical students across all years from UK-registered medical schools
17

18 8 **Main outcome measures** The uses, experiences, perceived benefits and barriers of online teaching
19
20 during the COVID-19 pandemic.
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23 10 **Results** 2721 medical students across 39 medical schools responded. Medical schools adapted to the
24
25 pandemic in different ways. The changes included the development of new distance-learning
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27 platforms on which content was released, remote delivery of lectures using platforms and the use of
28
29 question banks and other online active recall resources. A significant difference was found between
30
31 time spent on online platforms before and during COVID-19, with 7.35% students before vs. 23.56%
32
33 students during the pandemic spending >15 hours per week ($p<0.05$). The greatest perceived benefits
34
35 of online teaching platforms included their flexibility. Whereas the commonly perceived barriers to
36
37 utilising online teaching platforms included family distraction (26.76%) and poor internet connection
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39 (21.53%).
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43 19 **Conclusions** Online teaching has enabled the continuation of medical education during these
44
45 unprecedented times. Moving forward from this pandemic, in order to maximise the benefits of both
46
47 face-to-face and online teaching and to improve the efficacy of medical education in the future, we
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49 suggest medical schools resort to teaching formats such as team-based/problem-based learning. This
50
51 utilises online teaching platforms allowing students to digest information in their own time but also
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53 allows students to then constructively discuss this material with peers. It has also been shown to be
54
55 effective in terms of achieving learning outcomes. Beyond COVID-19, we anticipate further
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3 26 incorporation of online teaching methods within traditional medical education. This may accompany
4
5 27 the observed shift in medical practice towards virtual consultations.
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10 29 **Article Summary**
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15 **Strengths & Limitations**

- 16 • The COVID-19 pandemic has undoubtedly impacted the delivery of medical education
17 with a sudden shift towards online teaching platforms; to date, this is the first study
18 investigating the perceptions of medical students on these changes.
- 19 • This study is strengthened by its collection of responses from a large national cohort of
20 medical students from 39 out of 40 UK medical schools.
- 21 • The survey extensively explored the benefits of and barriers to online teaching methods
22 with the potential to provide medical schools nationally with a direction for development
23 of resources.
- 24 • Survey responses may have been subject to recall bias, and limited by timing of the study
25 coinciding with the examination season where remote learning platforms may often be
26 resorted to.
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review only

32 INTRODUCTION

33
34 Since the first case of coronavirus disease 2019 (COVID-19) in the United Kingdom (UK)(1), the World
35 Health Organisation (WHO) has declared the COVID-19 outbreak as a global pandemic(2). The
36 nationwide lockdown restrictions to control the spread of disease and “flatten the curve” have
37 impacted all aspects of life(3–5); inevitably, medical education has also been affected, with the halting
38 of lectures, clinical placements, and key examinations(6,7). Such measures have resulted in a sudden
39 shift in teaching methods towards online teaching. Online teaching has played a key role in medical
40 education over recent years(8–10), demonstrated several benefits in enhancing student learning(11).
41 A recent systematic review suggested that offline and online teaching are equivalent in terms of
42 outcomes of examinations(12). Key drawbacks have also been highlighted, including time constraints
43 to implement effective online teaching (8).

44
45 The unprecedented COVID-19 pandemic has caused a sudden shift towards the exclusive adoption of
46 online teaching, forming the primary source of medical education and enabling students to continue
47 to learn remotely(13). Teaching sessions have covered key clinical conditions, case studies and
48 examination questions via live-streamed tutorials through platforms such as Zoom(6), shown to have
49 high levels of engagement(14). With around 19.6% of the UK medical student demographic consisting
50 of international students(15), many of whom have returned home, this allows individuals to access
51 teaching regardless of location(6). Nevertheless, learning relying on the internet needs to be tailored
52 towards different learning styles to enable it to be impactful and effective(13). However, whilst the
53 benefits to pre-clinical years of blended learning has been shown, for example in anatomical
54 teaching(16) and especially in a generation accustomed to using YouTube(17), there is limited
55 understanding of the impact of exclusive online teaching and its use in clinical years. Concerns have
56 been raised regarding the quality of resources produced during the pandemic due to time constraints,
57 particularly as these resources aim to compensate for lack of exposure(18). Indeed, a recent national

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3 58 Twitter discussion, involving representatives from the General Medical Council (GMC), NHS England
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5 59 and WHO, found that a key concern amongst students was that remote learning impacted their ability
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7 60 to develop clinical competence(19). This also highlighted the potential role of the professional use of
8
9 61 social media in facilitating medical education, as shown in surgical training(20).
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14 63 In the coming months, as lockdown restrictions ease, the need for social distancing will continue and
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16 64 the possibility of medical students acting as vectors of COVID-19(21,22), as seen in the SARS epidemic
17
18 65 in Hong Kong(23), remains. Moreover, PPE shortages may form potential barriers to patient
19
20 66 interaction(24). Therefore, it is likely that e-learning and telemedicine will continue to form vital
21
22 67 sources of medical education. Many authors have suggested that digital health platforms for both
23
24 68 patients and students will remain an integral part of care even after the COVID-19 pandemic(25). Thus,
25
26 69 having a greater understanding of the perceived advantages and drawbacks will allow medical schools
27
28 70 to improve their delivery of online teaching. The COVID-19 pandemic has put us in a unique position
29
30 71 to evaluate the significance of online teaching platforms in medical education. Whilst many students
31
32 72 have acknowledged the impact of COVID-19 on their education(6,21) and explored their role during
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34 73 the pandemic(26,27), to date no study has investigated the outlook of medical students on the effect
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36 74 of these changes. Therefore, we aimed to investigate their perceptions on the role of online teaching
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38 75 in facilitating their education during the COVID-19 pandemic. Improving our understanding of this
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40 76 could help develop medical school curricula in the future.
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78 **METHODOLOGY**

79 80 **Questionnaire design and distribution**

81 This was a cross-sectional study conducted on a national level via an online survey. A 20-item
82 questionnaire was devised following a literature search on current online teaching methods and the
83 effects of COVID-19 on medical education in the UK (Appendix I). Questions exploring the experiences
84 of online teaching were based on sections I-IV of the Dundee Ready Education Environment Measure
85 (DREEM)(28), a validated questionnaire designed to measure the educational environment of medical
86 schools and healthcare professionals(29). These were 5-point Likert-type questions, ranging from
87 strongly disagree to strongly agree. The remaining items in the questionnaire comprised a mixture of
88 question styles. Certain questions were conditional. Open-ended text responses were also collected
89 and underwent thematic analysis whereby responses were categorised. The question items were
90 initially drafted and informally discussed with a group of medical students before undergoing a careful
91 review and editing process. The final questions explored the following three themes:

- 92 1. General demographics
- 93 2. The use and experience of online teaching during the COVID-19 pandemic
- 94 3. Perceived benefits and barriers of online teaching

95
96 The survey was created using Qualtrics, an online survey software (Version XM, 2019, Provo, UT(30)),
97 and distributed by medical students recruited nationally via social media, with an interest in sharing a
98 national survey, in order to maximise outreach to all 40 registered UK medical schools(31). The survey
99 was accessible via an anonymous link and open for a one-week period (04/05/20–11/05/20).

100

101 **Participants**

102 All 42,190 undergraduate and graduate entry medical students(32) across all years (years 1-5 and
103 intercalated year) from 40 registered UK medical schools(31) were eligible to participate.

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3 105 **Patient and Public Involvement**
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7 107 As this study focused on medical students, patients or the general public were not involved in the
8
9 108 study design. However, medical students were involved with the piloting of the survey as well as its
10
11 109 distribution across medical schools.
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16 111 **Participant consent and ethical considerations**
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18 112 Participation was voluntary, and participants were informed prior to starting the survey that all data
19
20 113 collected was non-identifiable and would only be used for research purposes. A mandatory selection
21
22 114 box consenting to participation and confirming that that this was the first time completing this survey
23
24 115 was included at the beginning of the survey, ensuring a 100% consent rate and preventing multiple
25
26 116 responses. Ethical approval was requested from Imperial College London and was deemed not to be
27
28 117 required as all data was anonymised, with informed consent taken from all participants.
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34 119 **Data analysis**
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36 120 Data was exported from Qualtrics to Microsoft Excel (Excel version 16.29, 2019). Qualtrics and
37
38 121 GraphPad Prism (Prism version 8.2.1, 2019) were both used to generate graphs and calculate
39
40 122 descriptive statistics for the survey responses to explore patterns in responses. Multiple responses
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42 123 were accounted for by identifying unique IP addresses.
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48 125 Wilcoxon test was used to compare hours of online teaching usage before and during COVID-19
49
50 126 overall, whilst Mann-Whitney U test was utilised in a sub-group analysis comparing usage between
51
52 127 pre-clinical and clinical students. These were conducted following the Shapiro-Wilk and Kolmogorov-
53
54 128 Smirnov normality tests which found the data set to be non-gaussian in distribution. *P*-values <0.05
55
56 129 were considered statistically significant.
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130 **RESULTS**

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132 **Cohort demographics**

133 Of the 2721 responses collected, 68.06% (n=1852) of respondents were female, 31.53% (n=858) were
 134 male, and 0.40% (n=11) identified as other, contrasting against the population of UK medical students,
 135 which comprises of 55% females and 45% males(32). Responses were collected from 39 medical
 136 schools across the UK, from medical students across all years (Table 1). Due to the inability to track
 137 the survey distribution, it was not possible to calculate a response rate. However, non-response bias
 138 was minimised by ensuring the survey was shared by a variety of medical students via a range of
 139 platforms.

Table 1. A table outlining the demographics (gender, university, and year of medical school) of students responding to the survey (n=2721).

Demographic		Proportion of students, % (n)
Gender	Male	31.53 (858)
	Female	68.06 (1852)
	Other	0.40 (11)
University	University of Aberdeen School of Medicine and Dentistry	1.76 (48)
	Anglia Ruskin University School of Medicine	2.21 (60)
	Aston University Medical School	0.07 (2)
	Barts and The London School of Medicine and Dentistry	6.39 (174)
	University of Birmingham College of Medical and Dental Sciences	1.76 (48)
	Brighton and Sussex Medical School	0.44 (12)
	University of Bristol Medical School	3.20 (87)
	University of Buckingham Medical School	0.77 (21)
	University of Cambridge School of Clinical Medicine	1.29 (35)
	Cardiff University School of Medicine	9.22 (251)
	University of Dundee School of Medicine	0.40 (11)
	The University of Edinburgh Medical School	0.44 (12)
	University of Exeter Medical School	2.06 (56)
	University of Glasgow School of Medicine	0.70 (19)
	Hull York Medical School	3.86 (105)
	Imperial College London Faculty of Medicine	3.93 (107)
	Keele University School of Medicine	0.85 (23)
	Kent and Medway Medical School	0.04 (1)
	King's College London GKT School of Medical Education	10.11 (275)
Lancaster University Medical School	0.15 (4)	
University of Leeds School of Medicine	4.96 (135)	

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4		University of Leicester Medical School	2.87 (78)
5		University of Liverpool School of Medicine	8.38 (228)
6		University of Manchester Medical School	4.52 (123)
7		Newcastle University School of Medical Education	3.34 (91)
8		Norwich Medical School	7.02 (191)
9		University of Nottingham School of Medicine	3.31 (90)
10		University of Nottingham - Lincoln Medical School	0.07 (2)
11		University of Oxford Medical Sciences Division	2.24 (61)
12		Plymouth University Peninsula Schools of Medicine and Dentistry	0.55 (15)
13		Queen's University Belfast School of Medicine	0.92 (25)
14		University of Sheffield Medical School	0.99 (27)
15		University of Southampton School of Medicine	1.98 (54)
16		University of St Andrews School of Medicine	0.33 (9)
17		St George's, University of London	2.46 (67)
18		University of Sunderland School of Medicine	0.00 (0)
19		Swansea University Medical School	0.11 (3)
20		University of Central Lancashire School of Medicine	1.73 (47)
21		University College London Medical School	2.46 (67)
22		University of Warwick Medical School	2.09 (57)
23			
24	Year	Pre-clinical Year 1	23.19 (631)
25		Pre-clinical Year 2	19.85 (540)
26		Year 3	27.20 (740)
27		Penultimate Clinical Year	20.62 (561)
28		Final Clinical Year	4.52 (123)
29		Intercalating	4.63 (126)

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143 **Student engagement with online teaching platforms**

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145 Prior to the pandemic, students spent an average of 4-6 hours per week using online teaching

146 platforms. Students used a combination of video tutorials (27.71%), online question banks (26.18%),

147 pre-recorded tutorials via their respective medical schools (20.96%) and online flashcards (15.99%).

148 4.46% of students utilised live tutorials via online platforms from their medical school, while 1.79%

149 used live tutorials from other sources (Figure 1). Other resources included the use of Anatomy TV,

150 online notes such as Pulsenotes or TeachMeAnatomy, Acland's Anatomy videos, revision websites e.g.

151 OSCE Stop and Zero To Finals, NICE guidelines, online textbooks and UpToDate, and BMJ Best Practice.

152

153 Students then ranked the effectiveness of online teaching platforms with 1 being most effective and

154 5 being least effective. Video tutorials e.g. YouTube/Osmosis appeared to be the most effective,

155 followed by online question banks, and live tutorials, whilst students commented using a variety of

156 other sources. However, following sub-analysis and exclusion of intercalating students, unlike pre-

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3 157 clinical students, clinical students found live tutorials to be the most effective, although rankings for
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5 158 the remaining platforms were similar.

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10 160 During the pandemic, students spent an average of 7-10 hours using online teaching platforms,
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12 161 compared to 4-6 hours prior to the pandemic. The difference in hours prior to and during the COVID-
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14 162 19 pandemic were found to be significant ($p<0.05$). Similar numbers of students spent <1 hour on
15
16 163 online teaching platforms before and during the pandemic. However, there was an increase in
17
18 164 numbers of students spending longer periods of time on online teaching platforms, for example 7.35%
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20 165 (n=200) vs. 19.70% (n=641) of students spent >15 hours on online teaching platforms before and
21
22 166 during the pandemic (Figure 2A). Following sub-analysis, before the pandemic, clinical and pre-clinical
23
24 167 students spent similar times on online teaching (Figure 2Bi), whereas during the pandemic differences
25
26 168 in periods were found to be significant ($p<0.001$) (Figure 2Bii), with a greater proportion of pre-clinical
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28 169 students spending >15 hours (28.69% vs. 20.01%). 57.28% of students reported that they were now
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30 170 taking examinations remotely; the remaining reported having postponed or cancelled examinations.

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35 36 172 **Medical school adaptations to COVID-19**

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41 174 Medical schools adapted to the pandemic in a combination of ways with 28.48% of students reporting
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43 175 their medical school to adapting to remote learning through the delivery of live tutorials via online
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45 176 platforms. Moreover, 42.19% of students reported that their medical school either introduced new
46
47 177 resources to existing learning platforms or created a new online teaching platform with new
48
49 178 resources. Other medical schools have either a) not implemented anything as the curriculum had
50
51 179 already been covered, or b) delayed teaching with the introduction of a question bank.

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57 181 The online teaching provided as an alternative by the medical schools followed a pre-set curriculum
58
59 182 for 66.12% (n=1799) of students, was designed following student requests for 3.38% (n=92) of

183 students, or using a combination of both for 30.50% (n=830) of students. This shows that student
 184 opinion was considered in the delivery of online teaching.

185
 186 Furthermore, 59.73% of students found that online teaching sessions have been interactive, with
 187 students finding the opportunity to interact via the chat box or by directly speaking to the lecturer.
 188 Some students have also specified that having small group sizes, group discussions, online case
 189 simulations and quizzes have been useful in increasing their engagement.

190

191 **Student perception of online teaching**

192

193 Students ranked their experience of online teaching using a Likert scale with 1 being strongly disagree
 194 and 5 being strongly agree (Table 2). Students agreed that learning online was engaging, enjoyable
 195 and allowed room for questions. However, students appeared to want online teaching to be more
 196 interactive and did not find it as effective as face-to-face teaching.

197

Table 2. A table displaying students' perceptions on their experiences of online teaching, ranked on a Likert scale from 1-5, where 1=strongly disagree and 5=strongly agree. Likert scores have been shown as mean \pm standard deviation (\pm SD)

Statement	Mean	\pm SD
The teaching is often stimulating	2.75	1.18
I find it easy to engage in the lesson	2.55	1.30
I feel able to ask the questions I want	2.70	1.53
I enjoy the online teaching	2.62	1.37
I would like the online teaching to be more interactive	3.04	1.44
I feel that online teaching is as effective as face-to-face teaching	1.92	1.45
I prefer online teaching to face-to-face teaching	1.69	1.48
The teachers are well prepared for the teaching sessions	3.36	1.42
I feel I am being well prepared for my profession	2.28	1.33
My internet connection can be problematic	2.53	1.74

198

199

200 The main advantages of online teaching appeared to be that it saves students time on travelling
 201 (19.82%), provides flexibility (19.52%), the ability for students to learn at their own pace (18.63%), it
 202 is more comfortable (15.84%), and it cuts costs (14.24%) (Figure 3A). Other medical students (n=82)

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3 203 also commented that it provides time efficiency, allows more time for students to focus on
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5 204 preparing for clinical placements, reduces anxiety, and being able to be in a different country.
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10 206 On the other hand, students stated that family distractions (26.76%), internet connection (21.53%),
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12 207 timing of tutorials (17.31%), anxiety (11.08%), and lack of space (11.03%) as barriers to effective online
13
14 208 teaching (Figure 3B). Students (n=81) commented on experiencing a lack of motivation, difficulty
15
16 209 concentrating and asking questions, and a lack of contact with colleagues as further limitations.
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19 210

20 211 **Role of online teaching in clinical teaching**

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22
23 213 75.99% (n=1842) of medical students felt that online teaching had not successfully replaced the clinical
24
25 214 teaching they received via direct patient contact, with 82.17% (n=1986) feeling they cannot learn
26
27 215 practical clinical skills through online teaching. This shows that clinical skills remain a pertinent barrier
28
29 216 to online teaching of medical students.
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35 218 **Student perception on effectiveness of online teaching**

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38 220 Students ranked the effectiveness of online teaching with 1 being most effective and 5 being least
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40 221 effective. Video tutorials e.g. YouTube/Osmosis appeared to be the most effective, followed by online
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42 222 question banks, and live tutorials, whilst students commented using a variety of other sources.
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3 223 **DISCUSSION**
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7 225 **Background**
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10 226 With the rise of COVID-19, it is unsurprising that many medical institutions have resorted to online
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12 227 education platforms. However, online education has been used preceding this pandemic. Here, we
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14 228 discuss how this pandemic has shaped the use of online teaching currently as well as its application in
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16 229 the future of medical education.
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21 231 **The impact of COVID-19 on uptake of online teaching**
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24 232 Our study found a significant difference ($p<0.05$) in the time spent on online teaching platforms before
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26 233 and during the pandemic, with a greater number of hours spent amidst the pandemic, particularly
27
28 234 amongst pre-clinical students. This result was expected as the primary source of education and
29
30 235 engagement of students with their medical schools was online. This is in addition to the normative
31
32 236 use of online teaching resources before the pandemic and forced isolation. This is despite that many
33
34 237 students reported the cancellation of clinical examinations and conversion of written examinations
35
36 238 into open book, which would arguably reduce student engagement with any learning platform.
37
38 239 Indeed, this may have accounted for the greater proportion of pre-clinical students engaging with
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40 240 online teaching for more than 15 hours, than clinical students.
41

42 242 The development of innovative educational projects has been initiated to enhance remote medical
43
44 243 education(19). A rise in external resources and teaching programs such as Osmosis, BiteMedicine,
45
46 244 Becoming A Doctor and Sustaining Medical education in a Lockdown Environment (SMILE) has allowed
47
48 245 many teaching sessions to be available to medical students across the country. Hence, students may
49
50 246 learn from a wider community of professionals. However, the high flow of resources causes a
51
52 247 proliferation of choice which may increase burnout rates. Schwartz claimed that this choice overload
53
54 248 is due to the failure of universities on fulfilling their education role to their students(33,34). Yet, the
55
56 249 increase in demand suggests that students desire this flexible curriculum.
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3 251 The accessibility of online material may have contributed to a high absenteeism and increase
4
5 252 disengagement in medical schools; limited interaction with lecturers may add to this(35). To tackle
6
7 253 this, Evans *et al.* suggested incorporating online Q&A sessions to improve student engagement(13),
8
9
10 254 based on a previous model advising the use of synchronous learning(36). Synchronous learning is
11
12 255 defined as a social learning environment alongside answering questions live(37). This active
13
14 256 communication between lecturers and students allows ambiguous concepts to be addressed
15
16 257 immediately to increase student involvement, creating a more active learning environment. Indeed,
17
18 258 our results show that students would like online teaching sessions to be more interactive.
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22 23 260 **Student perception of online teaching**

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25 261 Students scored their experiences of online compared to face-to-face teaching to be lower, with an
26
27 262 average of 1.69 scored for preference for online teaching, and 2.55 for engagement in lessons (Table
28
29 263 2), suggesting most students prefer face-to-face teaching. Furthermore, previous studies utilizing the
30
31 264 DREEM survey found higher average scores for educational environments(38–40). The discrepancies
32
33 265 found may have been due to students comparing their current experiences to previous face-to-face
34
35 266 teaching. However, given that students are currently solely limited to online teaching, responses may
36
37 267 not truly reflect the efficacy of online teaching. Nevertheless, as online teaching has become
38
39 268 mainstream, it is paramount to analyse its efficacy compared to previous methods for further
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41 269 development.
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48 271 Furthermore, unlike teaching evaluated by DREEM previously, the current pandemic caused a sudden
49
50 272 shift towards the use of online teaching on a large scale, allowing for inconsistencies with
51
52 273 underdeveloped medical curricula, many teachers being inadequately prepared and technical
53
54 274 difficulties(8). Therefore, the low scores of student experiences may be due to the unexpected,
55
56 275 sudden introduction of online teaching. Despite the relatively high score of 3.36 for teacher
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58 276 preparation(38–45), the quality of the sessions delivered may have been impacted by several factors
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3 277 such as poor internet connection, family distractions and the timing of the tutorials, as demonstrated
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5 278 by our results. In the future, medical schools must carefully build an infrastructure comprising of
6
7 279 technologically versatile lecturers to deliver well-organised, succinct tutorials, games and resources,
8
9 280 especially given the lack of awareness of “conscientious online lecture design” amongst medical
10
11 281 educators(46).

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15
16 283 The low score of 2.28 for being “well prepared for my profession” (Table 2), compared to previous
17
18 284 studies reporting up to 3.18(39,41,44,45,47), is striking, mirroring concerns that remote or online
19
20 285 teaching may compromise the clinical competence and confidence of students(19). The loss of
21
22 286 immediate feedback may have contributed to this, as generally students and doctors prefer face-to-
23
24 287 face sessions for communication(48) and feedback purposes(49). Nonetheless, it is important to note
25
26 288 that students often do not feel completely prepared for their profession(50).

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31
32 290 Moreover, overall video tutorials (e.g. YouTube or Osmosis), were ranked as the most effective online
33
34 291 resources, compared to live tutorials, particularly for pre-clinical students. Reasons for this may
35
36 292 include the short, organized and aesthetic nature of pre-recorded videos(51). In comparison, live
37
38 293 tutorials tend to be longer, face technical difficulties and are less engaging. Despite these challenges,
39
40 294 live tutorials were perceived to be the most effective by clinical students. This may be due to the
41
42 295 sessions’ synchronous nature, allowing for real time discussions to occur, reflecting clinical practice.

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48 297 Notably, in this study, distinctions between the different forms of online teaching were not made
49
50 298 when investigating students’ perceptions. Rather, it was an evaluation of online teaching as a whole,
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52 299 which may have impacted the results, as teaching modalities are often specific to the topic being
53
54 300 taught(46). Furthermore, student preferences may depend on the purpose of engaging with
55
56 301 resources, for example for learning new content versus revision(52), or for short-term versus long-
57
58 302 term knowledge retention(53).

303

304 Benefits and barriers of online teaching

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306 To students, the main advantages of online teaching are the time and money saved from the lack of
307 travel, its flexibility and the ability for students to learn at their own pace (Figure 3A). Further benefits
308 of live online lectures(14) include opportunities for students to anonymously ask and answer
309 questions, potentially encouraging further engagement from those who would not otherwise
310 participate in a live lecture, due to the less intimidating environment online(54). However, these
311 benefits may not be applicable to all forms of online teaching. For example, the limited synchronous
312 aspects of pre-recorded content may deter students due to the lack of opportunities to interact with
313 lecturers(55). Also, watching pre-recorded lectures, alongside the possibility of attending face-to-face
314 lecture, has been shown to negatively correlate with learning success(56).

315

316 The main barriers to online teaching appear to be family distractions, internet connection and the
317 timing of tutorials (Figure 3B). This may disadvantage students with large families or with limited
318 internet access. Moreover, the mental health of students, recently shown to be impacted by the
319 COVID-19 pandemic(57), may be adversely affected as indicated by the free text responses. This may
320 be, in part, attributed to the lack of interaction with friends and colleagues leading to a rise in anxiety.
321 Alternatively, with exams being open book and with an unrestricted setting, students may be less
322 prone to exam anxiety(58). Although, this does not address the family and noise disturbances which
323 may still affect exam performance.

324

325 Medical student role during the COVID-19 pandemic

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327 On the other hand, medical students are being asked to 'step-up' and join the front-line of doctors
328 tackling COVID-19(59). As well as the early graduation of UK medical students(60), many universities

1
2
3 329 have given their students the opportunity to volunteer. For example, the University of Birmingham
4
5 330 has facilitated for over 700 medical students to volunteer in the NHS(27). Although medical schools
6
7 331 have halted clinical placements, this opportunity could provide more exposure, undoubtedly
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9 332 impacting the development of medical students. However, for those who are not volunteering due to
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11 333 living with vulnerable family members or having health conditions themselves, this would then put
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13 334 them at a disadvantage as their peers continue to gain clinical exposure.
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19 335
20 336 As lockdown restrictions ease and students slowly return to medical school, clinical placements may
21 337 incorporate more virtual aspects as healthcare evolves(22). Indeed, new platforms have been
22 338 developed by the NHS (e.g. NHS NearMe) which have shown that video consultations are better than
23 339 telephone consultations in reducing medical error and improving patient outcomes(31). However,
24 340 Professor Martin Marshall, chairman of the RCGP, has highlighted that most consultations are still
25 341 taking place over the phone as opposed to video calls(61). This may be subject to change with a
26 342 demographic who are increasingly familiar with the use of the internet. Additionally, in Germany,
27 343 online platforms as observed in Dermatology may “provide a safe and efficient alternative for face-to-
28 344 face outpatient care”(25), abiding by social distancing rules.
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41 346 **Future direction of online teaching**

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45 348 Furthermore, the digitalisation of medical teaching could play a significant role in the future of medical
46 349 schools. Allowing users to tailor their learning and acquire new skills through the chaotic nature of an
47 350 amplitude of resources could halt the development of medical students. Having discussed benefits of
48 351 both face-to-face and remote teaching as well as the future of healthcare online, we suggest that in
49 352 order to maximise the benefits of these learning methods, a mixture of online and in-person teaching
50 353 should be utilised moving forward. This can be incorporated into an effective learning method such
51 354 as problem-based learning (PBL) or team-based learning (TBL) which have been shown to improve
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3 355 learning outcomes(62,63), student motivation and understanding(64). Students are set online
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5 356 materials to study and are then are expected to discuss content in person in a group tutorial(65). This
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7 357 allows students to study at their own pace, in a manner suitable to them, while also holding them
8
9 358 accountable for their own learning. While students find PBL sessions to be interactive and to improve
10
11 359 self-directed learning(66,67), TBL has been found to be more engaging and “conducive to learning” in
12
13 360 pre-clinical settings, due to smaller groups, ensuring timely tutor feedback(68).
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19 362 Compared to face-to-face teaching, students in this study felt less satisfied with online teaching and
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21 363 ill-prepared for their profession. With many of these students due to graduate as doctors in the next
22
23 364 few years, this is concerning, highlighting the need for medical schools to improve their delivery of
24
25 365 medical education given that online teaching is here to stay. Hence, we suggest that until innovative
26
27 366 solutions are generated, medical schools adopt TBL or PBL learning styles for efficiently delivering
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29 367 high-yielded teaching.
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34 369 **Limitations and Future work**

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39 371 This is the first study to look at the impact of COVID-19 on online teaching across the UK, with
40
41 372 responses from 39/40 medical schools. One of the strengths of this study is its large sample size of
42
43 373 2792 medical student across all pre-clinical and clinical years. Furthermore, the recruitment of a range
44
45 374 of medical students for survey distribution via a range of methods minimised potential response bias.
46
47 375 However, this study also had some limitations. Some medical schools may have been
48
49 376 disproportionately represented with larger numbers of responses from some schools e.g. Kings
50
51 377 College London, compared to newer medical schools such as Aston or Kent, potentially skewing results
52
53 378 due to sample bias. Additionally, 68.06% of participants were female, in comparison to 55% of UK
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55 379 medical students who are female(32); thus, the results may not be generalisable to the medical
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57 380 student population. Further, some aspects of this survey depended on participants’ memory perhaps
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3 381 influencing their reporting, introducing elements of recall bias. The survey did not evaluate the various
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5 382 ways different content may have been taught e.g. online lectures, games, or question banks;
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7 383 perceptions of game-based online anatomy teaching would have differed from online didactic lectures
8
9 384 on immunology. Thus, we cannot truly evaluate the types of online teaching provided. Also, it is
10
11 385 important to note that the period covered is usually when students have examinations, hence
12
13 386 students may have been spending more time on online teaching platforms regardless. In addition,
14
15 387 since this survey, medical schools may have updated their online resources. Lastly, student receptivity
16
17 388 to PBL/TBL methods should have been evaluated. To truly measure the impact of COVID-19 on student
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19 389 utilisation of online teaching, a more in-depth, qualitative analysis such as focus groups conducted in
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21 390 collaboration with medical schools is required to gather more accurate results, such as the effects on
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23 391 examination performance.
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393 **Author Contributions**

394 SD contributed to the study concept and design, and developed the questionnaire. SD recruited
395 collaborators for survey distribution and data collection. SD supervised the project, had full access to
396 the data, controlled the decision to publish, and accepts full responsibility for the conduct of this
397 study, as the guarantor. AH and SD contributed equally to this study as joint first authors. AH
398 developed and designed the questionnaire, contributed to data acquisition and interpretation, writing
399 and critical revision of the manuscript. AH is the corresponding author and managed project
400 administration. MS developed the questionnaire, contributed to data acquisition and interpretation,
401 and writing and critical revision of the manuscript. AA developed the questionnaire, and contributed
402 to data visualisation and presentation, and writing and critical revision of the manuscript. LA
403 performed data analysis, interpretation, visualisation and presentation, and contributed to writing
404 and critical revision of the manuscript. All authors approved the final version to be published and are
405 accountable for all aspects of the work. Sixteen students were involved with survey distribution and
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407

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41 436 **Competing Interests**

42
43 437 All authors have completed the ICMJE Unified Competing Interest form (available on request from the
44
45 438 corresponding author) and declare: no support from any organisation for the submitted work; no
46
47 439 financial relationships with any organisations that might have an interest in the submitted work in the
48
49 440 previous three years, no other relationships or activities that could appear to have influenced the
50
51 441 submitted work.
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56 442 57 443 **Data sharing** 58 59 60

1
2
3 444 Raw data are available upon request from the corresponding author (ah2716@ic.ac.uk). Due to the
4
5 445 anonymous nature of the survey, it was not possible to disseminate the results of this study to the
6
7 446 participants.
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10 447

11
12 448 **Transparency statement**

13
14 449 The lead author confirms that the manuscript is an honest, accurate, and transparent account of the
15
16 450 study; no important aspects of the study have been omitted; and any discrepancies from the study as
17
18 451 originally planned have been explained.
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21 452

22
23 453 **Ethical approval**

24
25 454 Ethical approval was requested from Imperial College London and was deemed not to be required as
26
27 455 all data was anonymised, with informed consent taken from all participants. The work was carried out
28
29 456 in accordance with the Declaration of Helsinki, including, but not limited to the anonymity of
30
31 457 participants being guaranteed and the informed consent of participants being obtained.
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34 458

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3 676 **Figure Legends**
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7 678 **Figure 1.** Students were asked about the different types of online teaching platforms they used before
8 the COVID-19 pandemic as represented by this bar chart (n=2721). Options included live tutorial by
9 the medical school, live tutorial by other sources, online question banks, online/digital flashcards, pre-
10 recorded lectures/tutorials, video tutorials e.g. YouTube, none, or other).
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18 683 **Figure 2.** Students were asked the approximate number of hours spent on online teaching platforms
19 before and during the COVID-19 pandemic (n=2721). A – A bar graph comparing the number of hours
20 spent on online platforms before and during the COVID-19 pandemic by students overall. A Wilcoxon
21 test was then conducted which found the difference to be significant ($p<0.05$). B i - A bar graph
22 comparing the number of hours spent on online platforms by pre-clinical and clinical students before
23 the COVID-19 pandemic. B ii - A bar graph comparing the number of hours spent on online platforms
24 by pre-clinical and clinical students during the COVID-19 pandemic. A Mann-Whitney U test found the
25 difference in time spent between the students during the COVID-19 pandemic to be significant
26 ($p<0.001$).
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42 694 **Figure 3.** A bar chart outlining the advantages of and barriers to online teaching. A – Students were
43 provided with a list of potential ways in which online teaching was advantageous and they were asked
44 to select all which applied to them. They were also given the option to input their own statements
45 (n=2721). B – Students were provided with a list of potential barriers to the benefits they may receive
46 from online teaching and they were asked to select all which applied to them. They were also given
47 the option to input their own statements (n=2721).
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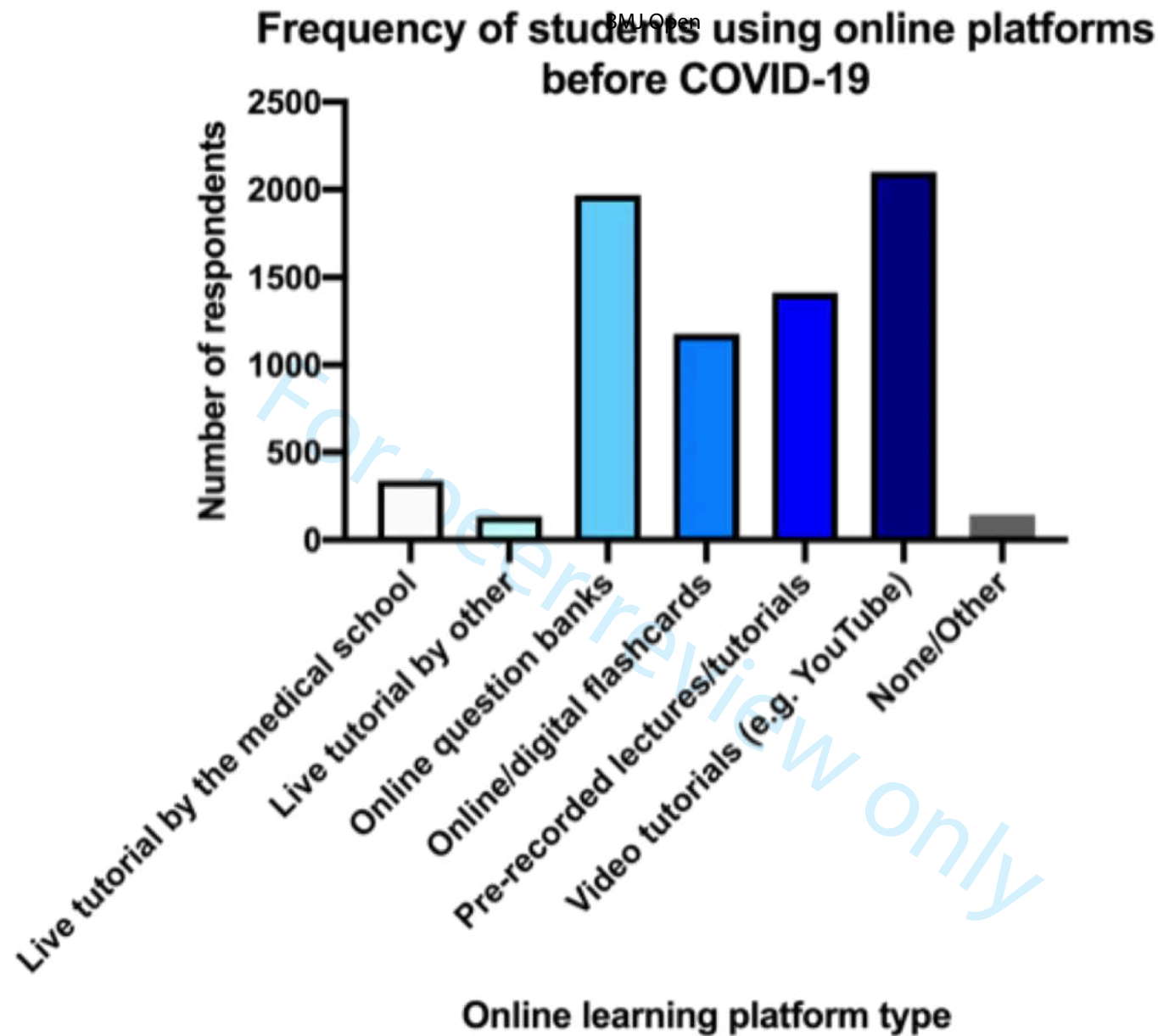
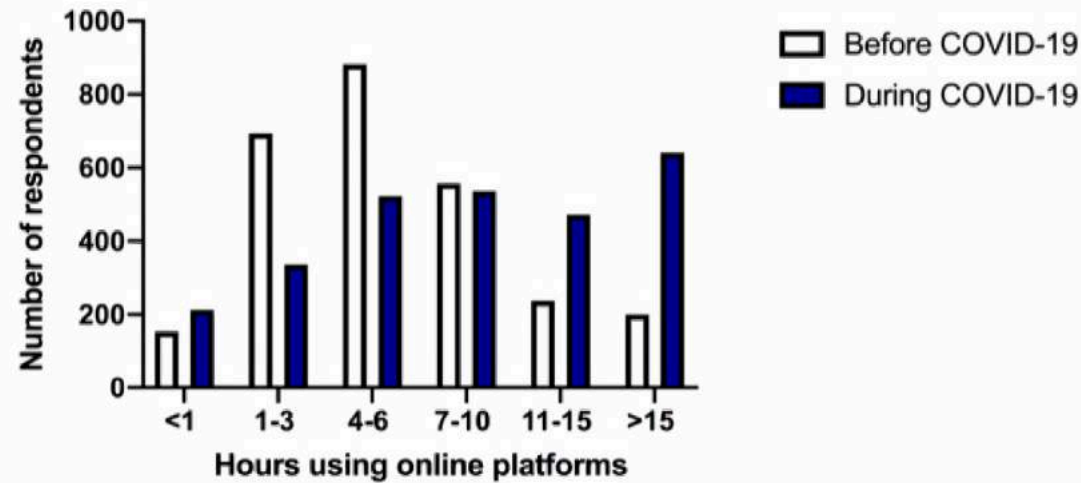


Figure 1. Students were asked about the different types of online teaching platforms they used before the COVID-19 pandemic as represented by this bar chart (n=2721). Options included live tutorials by the medical school, live tutorials by other sources, online question banks, online/digital flashcards, pre-recorded lectures/tutorials, video tutorials e.g. Youtube, none, or other).

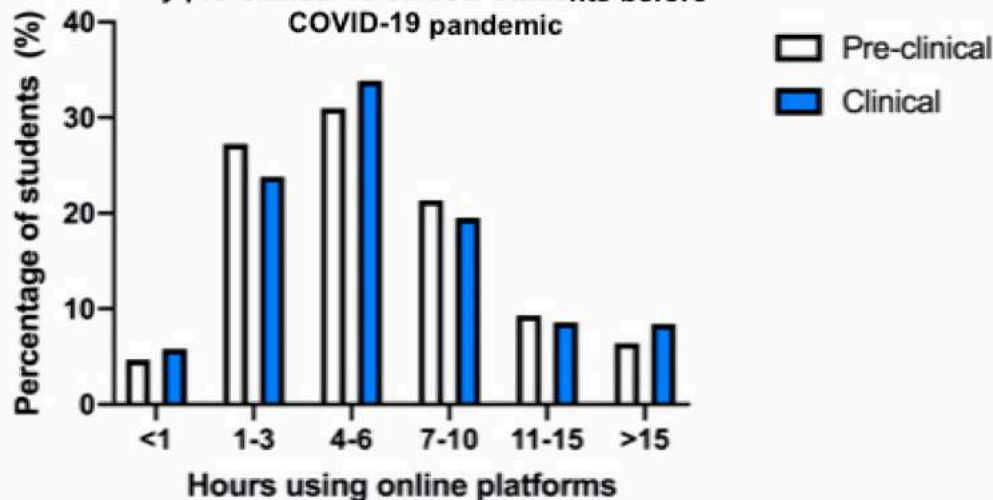
A

Number of hours spent on online platforms before and during COVID-19 pandemic



B i

Number of hours spent on online platforms by pre-clinical vs clinical students before COVID-19 pandemic



B ii

Number of hours spent on online platforms by pre-clinical vs clinical students during COVID-19 pandemic

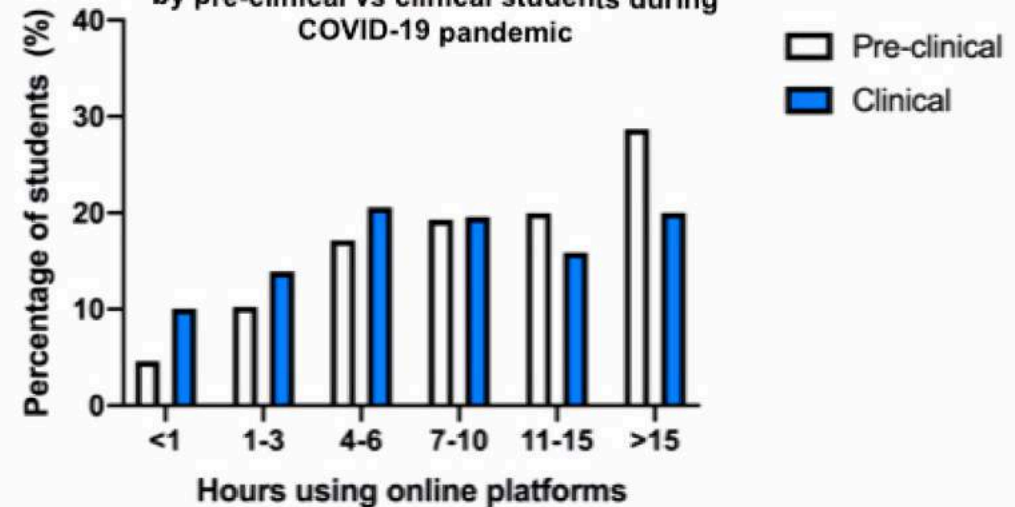
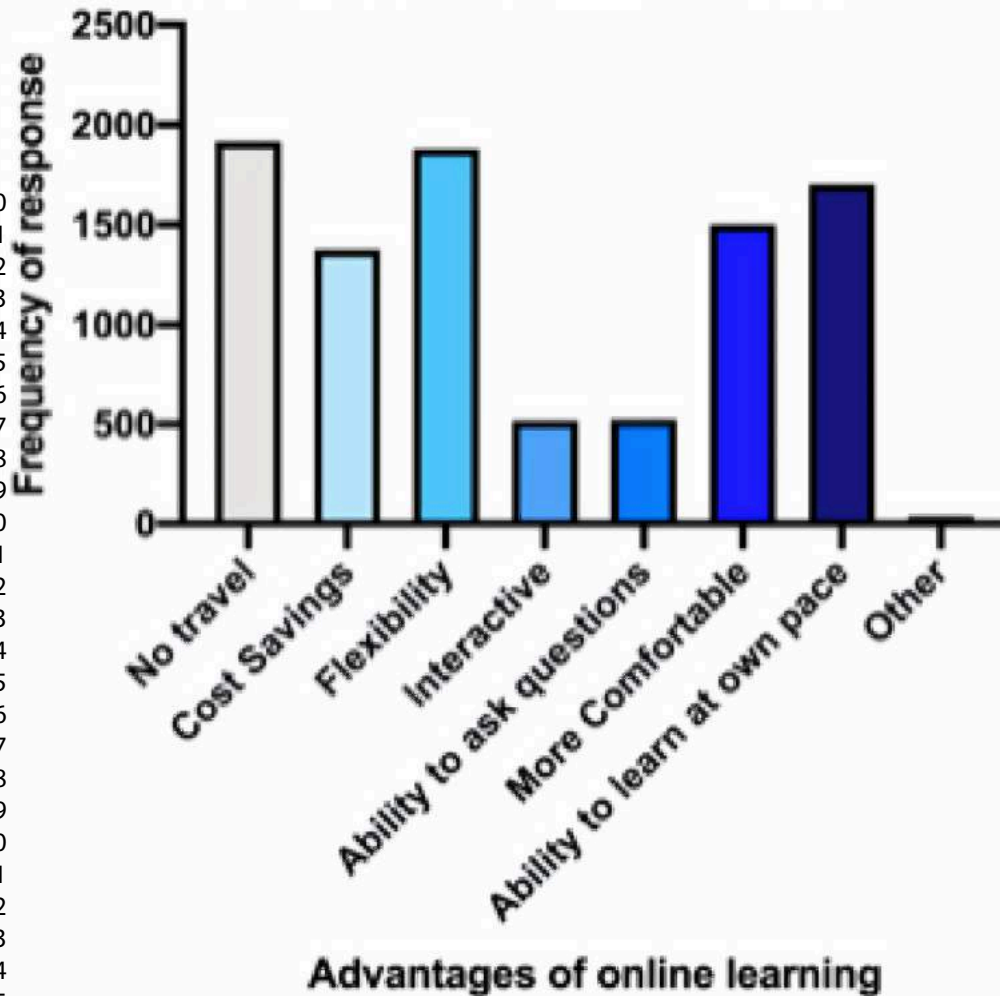


Figure 2. Students were asked the approximate number of hours spent on online teaching platforms before and during the COVID-19 pandemic (n=2721). A – A bar graph comparing the number of hours spent on online platforms before and during the COVID-19 pandemic by students overall. A Wilcoxon test was then conducted which found the difference to be significant ($p < 0.05$). B i - A bar graph comparing the number of hours spent on online platforms by pre-clinical and clinical students before the COVID-19 pandemic. B ii - A bar graph comparing the number of hours spent on online platforms by pre-clinical and clinical students during the COVID-19 pandemic. A Mann-Whitney U test found the difference in time spent between the students during the COVID-19 pandemic to be significant ($p < 0.001$).

A

B

Frequency of responses to the different advantages of online teaching



Frequency of responses to the different advantages of online teaching

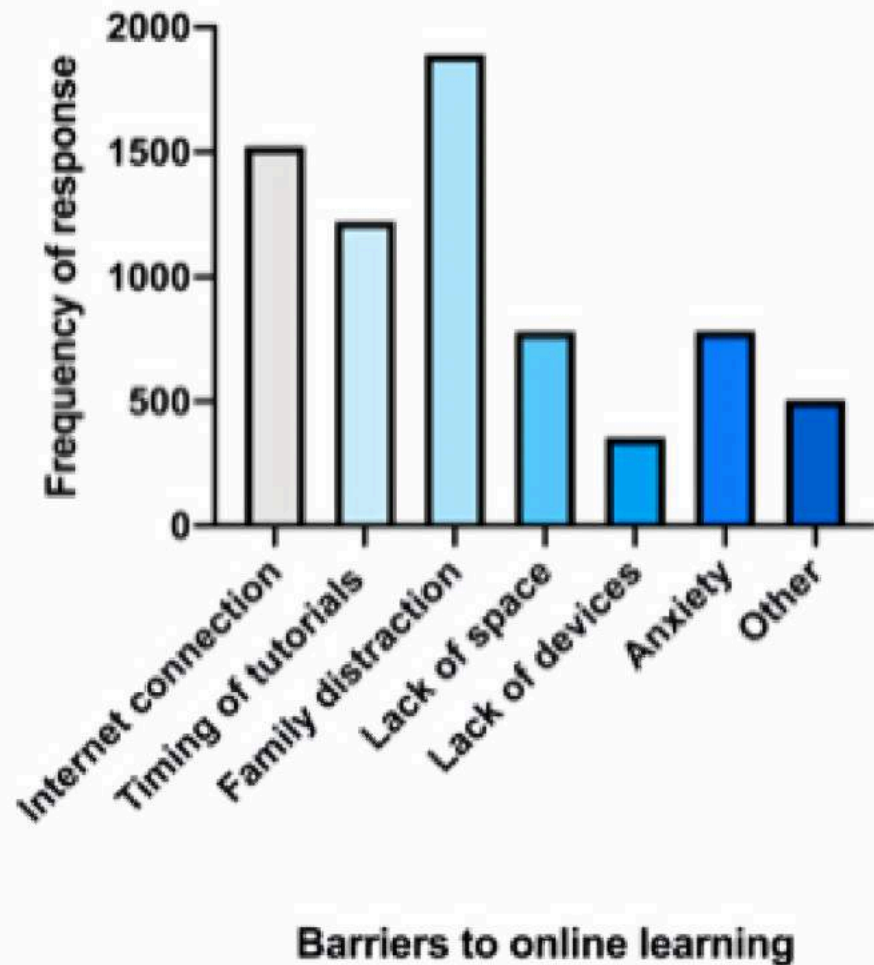


Figure 3. A bar chart outlining the advantages of and barriers to online teaching. **A-** Students were provided with a list of potential ways in which online teaching was advantageous and they were asked to select all which applied to them. They were also given the option to input their own statements (n=2721). **B-** Students were provided with a list of potential barriers to the benefits they may receive from online teaching and they were asked to select all which applied to them. They were also given the option to input their own statements (n=2721).

Appendix

Appendix I – Online Questionnaire

Covid-19, Online Learning & Medical Education

Thank you for your interest in completing our short survey investigating the role of online learning in facilitating medical education during the Covid-19 pandemic in the UK. The data collected is **non-identifiable** and will be used for research purposes.

This survey will close on Monday 11th May at 10pm.

Please tick the box to proceed:

I consent to my information being used for research purposes and this is my first time completing this survey.

Survey Code:

Background

1. Which UK Medical School do you attend?

2. What year are you in?

3. What is your gender?

Online Learning & Medical Education

4. Prior to the Covid-19 pandemic, which online learning platforms/resources did you engage with? (Please select all which apply)

Video tutorials e.g. Youtube/Osmosis

Live tutorials via Zoom/similar platforms by **Medical School**

Live tutorials via Zoom/similar platforms by **other sources**

Online question banks

Online/Digital Flashcards e.g. Brainscape, Anki

Pre-recorded tutorials via Medical School specific online learning platform

None

Other - please specify

5. Which method of online learning do you find the most effective? Please rank the following methods from 1-5 (1=most effective, 5=least effective)

Video tutorials e.g. Youtube/Osmosis

Live tutorials via Zoom/similar platforms

Online question banks

Online/Digital Flashcards e.g. Brainscape, Anki

Other - please specify:

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4 6. Prior to the Covid-19 pandemic, how many hours per week did
5 you spend on average on online learning?
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10 7. During the current Covid-19 pandemic, how has your medical
11 school adapted teaching for your year? (Please select all which
12 apply)
13
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16 Introduced a new online learning platform with new resources

17 Introduced new resources to an existing online learning platform

18 Delivered live tutorials via Zoom/similar platforms

19 Delivered pre-recorded tutorials

20 Other - please specify:

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25 8. Are these online teaching sessions interactive?
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29 Yes

30 No

31 Majority are

32 Majority are not

33 8b. What makes your teaching sessions interactive? (Please
34 select all which apply)
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38 Opportunity to interact via chat box

39 Opportunity to interact via speech

40 Live quiz
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Other - please specify:

9. Does the online learning follow a pre-set curriculum, or is it based on student requests?

- Pre-set curriculum
- Student requests
- Combination of both

10. During the current Covid-19 pandemic, how many hours per week do you spend on average on online learning?

Student Perceptions of Online Learning

11. Please rank the following statements on your experience of online learning from 1-5 (1=Strongly disagree, 5 = Strongly agree)

0 1 2 3 4 5

The teaching is often stimulating

I find it easy to engage in the lesson

I feel able to ask the questions I want

I enjoy the online teaching

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I would like the online teaching to be more interactive

I feel that online teaching is as effective as face-face teaching

I prefer online teaching to face-face teaching

The teachers are well prepared for the teaching sessions

I feel I am being well prepared for my profession

My internet connection can be problematic

12. What aspects of online learning do you enjoy? (Please select all which apply)

No travel

Ability to ask questions

Cost savings

More comfortable

Interactive

Ability to learn at own pace

Flexibility

Other - please specify:

13. What do you feel are the barriers to online learning? (Please select all which apply)

Internet connection

Lack of space

Timing of tutorials

Lack of devices

Family distractions

Anxiety

Other - please specify:

Role of Online Learning in Clinical Teaching

14a. Do you feel online learning has successfully replaced the clinical teaching you receive from direct patient contact?

Yes
 No
 Yes, to some extent
 N/A

14b. Do you feel able to learn practical clinical skills through online learning?

Yes
 No
 Yes, to some extent
 N/A

15. Have your examinations been affected by Covid-19?

Yes

No

N/A

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4 15b. How have your written examinations been affected?
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- 7 ✓
8 Written exams will take place remotely online
9 Written exams have been postponed
10 Written exams have been cancelled
11 N/A

12 15c. How have your practical examinations been affected?
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- 15 ✓
16 Practical exams will take place with modifications (e.g. virtual patients)
17 Practical exams have been postponed
18 Practical exams have been cancelled
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STROBE Statement—Checklist of items that should be included in reports of *cohort studies*

	Item No	Recommendation	Page No
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up (b) For matched studies, give matching criteria and number of exposed and unexposed	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6
Bias	9	Describe any efforts to address potential sources of bias	6-8, 18
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) If applicable, explain how loss to follow-up was addressed (e) Describe any sensitivity analyses	7
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram	8-9
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest (c) Summarise follow-up time (eg, average and total amount)	8-9
Outcome data	15*	Report numbers of outcome events or summary measures over time	8-12

1	Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8-12
2		(b) Report category boundaries when continuous variables were categorized		
3		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period		
4	Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	8-12
5	Discussion			
6	Key results	18	Summarise key results with reference to study objectives	13-18
7	Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	18-19
8	Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-18
9	Generalisability	21	Discuss the generalisability (external validity) of the study results	13-18
10	Other information			
11	Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	22

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at <http://www.strobe-statement.org>.

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3 **Perceptions of Medical Students Towards Online Teaching During the COVID-19 Pandemic: a**
4 **national cross-sectional survey of 2721 UK medical students**
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3 1 **Abstract**
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8 3 **Objectives** To investigate perceptions of medical students on the role of online teaching in facilitating
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10 4 medical education during the COVID-19 pandemic

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12 5 **Design** Cross-sectional, online national survey

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14 6 **Setting** Responses collected online from 4th May to 11th May 2020 across 40 UK medical schools

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16 7 **Participants** Medical students across all years from UK-registered medical schools

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18 8 **Main outcome measures** The uses, experiences, perceived benefits and barriers of online teaching
19
20 9 during the COVID-19 pandemic.

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22
23 10 **Results** 2721 medical students across 39 medical schools responded. Medical schools adapted to the
24
25 11 pandemic in different ways. The changes included the development of new distance-learning
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27 12 platforms on which content was released, remote delivery of lectures using platforms and the use of
28
29 13 question banks and other online active recall resources. A significant difference was found between
30
31 14 time spent on online platforms before and during COVID-19, with 7.35% students before vs. 23.56%
32
33 15 students during the pandemic spending >15 hours per week ($p<0.05$). The greatest perceived benefits
34
35 16 of online teaching platforms included their flexibility. Whereas the commonly perceived barriers to
36
37 17 utilising online teaching platforms included family distraction (26.76%) and poor internet connection
38
39 18 (21.53%).

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43 19 **Conclusions** Online teaching has enabled the continuation of medical education during these
44
45 20 unprecedented times. Moving forward from this pandemic, in order to maximise the benefits of both
46
47 21 face-to-face and online teaching and to improve the efficacy of medical education in the future, we
48
49 22 suggest medical schools resort to teaching formats such as team-based/problem-based learning. This
50
51 23 utilises online teaching platforms allowing students to digest information in their own time but also
52
53 24 allows students to then constructively discuss this material with peers. It has also been shown to be
54
55 25 effective in terms of achieving learning outcomes. Beyond COVID-19, we anticipate further
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3 26 incorporation of online teaching methods within traditional medical education. This may accompany
4
5 27 the observed shift in medical practice towards virtual consultations.
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10 29 **Article Summary**
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15 **Strengths & Limitations**

- 16 • The COVID-19 pandemic has undoubtedly impacted the delivery of medical education
17 with a sudden shift towards online teaching platforms; to date, this is the first study
18 investigating the perceptions of medical students on these changes.
- 19 • This study is strengthened by its collection of responses from a large national cohort of
20 medical students from 39 out of 40 UK medical schools.
- 21 • The survey extensively explored the benefits of and barriers to online teaching methods
22 with the potential to provide medical schools nationally with a direction for development
23 of resources.
- 24 • Survey responses may have been subject to recall bias, and limited by timing of the study
25 coinciding with the examination season where remote learning platforms may often be
26 resorted to.
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review only

32 INTRODUCTION

33
34 Since the first case of coronavirus disease 2019 (COVID-19) in the United Kingdom (UK)(1), the World
35 Health Organisation (WHO) has declared the COVID-19 outbreak as a global pandemic(2). The
36 nationwide lockdown restrictions to control the spread of disease and “flatten the curve” have
37 impacted all aspects of life(3–5); inevitably, medical education has also been affected, with the halting
38 of lectures, clinical placements, and key examinations(6,7). Such measures have resulted in a sudden
39 shift in teaching methods towards online teaching. Online teaching has played a key role in medical
40 education over recent years(8–10), demonstrated several benefits in enhancing student learning(11).
41 A recent systematic review suggested that offline and online teaching are equivalent in terms of
42 outcomes of examinations(12). Key drawbacks have also been highlighted, including time constraints
43 to implement effective online teaching (8).

44
45 The unprecedented COVID-19 pandemic has caused a sudden shift towards the exclusive adoption of
46 online teaching, forming the primary source of medical education and enabling students to continue
47 to learn remotely(13). Teaching sessions have covered key clinical conditions, case studies and
48 examination questions via live-streamed tutorials through platforms such as Zoom(6), shown to have
49 high levels of engagement(14). With around 19.6% of the UK medical student demographic consisting
50 of international students(15), many of whom have returned home, this allows individuals to access
51 teaching regardless of location(6). Nevertheless, learning relying on the internet needs to be tailored
52 towards different learning styles to enable it to be impactful and effective(13). However, whilst the
53 benefits to pre-clinical years of blended learning has been shown, for example in anatomical
54 teaching(16) and especially in a generation accustomed to using YouTube(17), there is limited
55 understanding of the impact of exclusive online teaching and its use in clinical years. Concerns have
56 been raised regarding the quality of resources produced during the pandemic due to time constraints,
57 particularly as these resources aim to compensate for lack of exposure(18). Indeed, a recent national

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3 58 Twitter discussion, involving representatives from the General Medical Council (GMC), NHS England
4
5 59 and WHO, found that a key concern amongst students was that remote learning impacted their ability
6
7 60 to develop clinical competence(19). This also highlighted the potential role of the professional use of
8
9 61 social media in facilitating medical education, as shown in surgical training(20).
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14 63 In the coming months, as lockdown restrictions ease, the need for social distancing will continue and
15
16 64 the possibility of medical students acting as vectors of COVID-19(21,22), as seen in the SARS epidemic
17
18 65 in Hong Kong(23), remains. Moreover, PPE shortages may form potential barriers to patient
19
20 66 interaction(24). Therefore, it is likely that e-learning and telemedicine will continue to form vital
21
22 67 sources of medical education. Many authors have suggested that digital health platforms for both
23
24 68 patients and students will remain an integral part of care even after the COVID-19 pandemic(25). Thus,
25
26 69 having a greater understanding of the perceived advantages and drawbacks will allow medical schools
27
28 70 to improve their delivery of online teaching. The COVID-19 pandemic has put us in a unique position
29
30 71 to evaluate the significance of online teaching platforms in medical education. Whilst many students
31
32 72 have acknowledged the impact of COVID-19 on their education(6,21) and explored their role during
33
34 73 the pandemic(26,27), to date no study has investigated the outlook of medical students on the effect
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36 74 of these changes. Therefore, we aimed to investigate their perceptions on the role of online teaching
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38 75 in facilitating their education during the COVID-19 pandemic. Improving our understanding of this
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40 76 could help develop medical school curricula in the future.
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78 **METHODOLOGY**

79 80 **Questionnaire design and distribution**

81 This was a cross-sectional study conducted on a national level via an online survey. A 20-item
82 questionnaire was devised following a literature search on current online teaching methods and the
83 effects of COVID-19 on medical education in the UK (Appendix I). Questions exploring the experiences
84 of online teaching were based on sections I-IV of the Dundee Ready Education Environment Measure
85 (DREEM)(28), a validated questionnaire designed to measure the educational environment of medical
86 schools and healthcare professionals(29). These were 5-point Likert-type questions, ranging from
87 strongly disagree to strongly agree. The remaining items in the questionnaire comprised a mixture of
88 question styles. Certain questions were conditional. Open-ended text responses were also collected
89 and underwent thematic analysis whereby responses were categorised. The question items were
90 initially drafted and informally discussed with a group of medical students before undergoing a careful
91 review and editing process. The final questions explored the following three themes:

- 92 1. General demographics
- 93 2. The use and experience of online teaching during the COVID-19 pandemic
- 94 3. Perceived benefits and barriers of online teaching

95
96 The survey was created using Qualtrics, an online survey software (Version XM, 2019, Provo, UT(30)),
97 and distributed by medical students recruited nationally via social media, with an interest in sharing a
98 national survey, in order to maximise outreach to all 40 registered UK medical schools(31). The survey
99 was accessible via an anonymous link and open for a one-week period (04/05/20–11/05/20).

100

101 **Participants**

102 All 42,190 undergraduate and graduate entry medical students(32) across all years (years 1-5 and
103 intercalated year) from 40 registered UK medical schools(31) were eligible to participate.

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3 **105 Patient and Public Involvement**
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7 107 As this study focused on medical students, patients or the general public were not involved in the
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10 108 study design. However, medical students were involved with the piloting of the survey as well as its
11
12 109 distribution across medical schools.
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16 **111 Participant consent and ethical considerations**
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18
19 112 Participation was voluntary, and participants were informed prior to starting the survey that all data
20
21 113 collected was non-identifiable and would only be used for research purposes. A mandatory selection
22
23 114 box consenting to participation and confirming that that this was the first time completing this survey
24
25 115 was included at the beginning of the survey, ensuring a 100% consent rate and preventing multiple
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27
28 116 responses. Ethical approval was requested from Imperial College London and was deemed not to be
29
30 117 required as all data was anonymised, with informed consent taken from all participants.
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34 **119 Data analysis**
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37 120 Data was exported from Qualtrics to Microsoft Excel (Excel version 16.29, 2019). Qualtrics and
38
39 121 GraphPad Prism (Prism version 8.2.1, 2019) were both used to generate graphs and calculate
40
41 122 descriptive statistics for the survey responses to explore patterns in responses. Multiple responses
42
43 123 were accounted for by identifying unique IP addresses.
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48 125 Wilcoxon test was used to compare hours of online teaching usage before and during COVID-19
49
50 126 overall, whilst Mann-Whitney U test was utilised in a sub-group analysis comparing usage between
51
52 127 pre-clinical and clinical students. These were conducted following the Shapiro-Wilk and Kolmogorov-
53
54 128 Smirnov normality tests which found the data set to be non-gaussian in distribution. *P*-values <0.05
55
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57 129 were considered statistically significant.
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130 **RESULTS**

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132 **Cohort demographics**

133 Of the 2721 responses collected, 68.06% (n=1852) of respondents were female, 31.53% (n=858) were
 134 male, and 0.40% (n=11) identified as other, contrasting against the population of UK medical students,
 135 which comprises of 55% females and 45% males(32). Responses were collected from 39 medical
 136 schools across the UK, from medical students across all years (Table 1). Due to the inability to track
 137 the survey distribution, it was not possible to calculate a response rate. However, non-response bias
 138 was minimised by ensuring the survey was shared by a variety of medical students via a range of
 139 platforms.

Table 1. A table outlining the demographics (gender, university, and year of medical school) of students responding to the survey (n=2721).

Demographic		Proportion of students, % (n)
Gender	Male	31.53 (858)
	Female	68.06 (1852)
	Other	0.40 (11)
University	University of Aberdeen School of Medicine and Dentistry	1.76 (48)
	Anglia Ruskin University School of Medicine	2.21 (60)
	Aston University Medical School	0.07 (2)
	Barts and The London School of Medicine and Dentistry	6.39 (174)
	University of Birmingham College of Medical and Dental Sciences	1.76 (48)
	Brighton and Sussex Medical School	0.44 (12)
	University of Bristol Medical School	3.20 (87)
	University of Buckingham Medical School	0.77 (21)
	University of Cambridge School of Clinical Medicine	1.29 (35)
	Cardiff University School of Medicine	9.22 (251)
	University of Dundee School of Medicine	0.40 (11)
	The University of Edinburgh Medical School	0.44 (12)
	University of Exeter Medical School	2.06 (56)
	University of Glasgow School of Medicine	0.70 (19)
	Hull York Medical School	3.86 (105)
	Imperial College London Faculty of Medicine	3.93 (107)
	Keele University School of Medicine	0.85 (23)
Kent and Medway Medical School	0.04 (1)	
King's College London GKT School of Medical Education	10.11 (275)	
Lancaster University Medical School	0.15 (4)	
University of Leeds School of Medicine	4.96 (135)	

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4		University of Leicester Medical School	2.87 (78)
5		University of Liverpool School of Medicine	8.38 (228)
6		University of Manchester Medical School	4.52 (123)
7		Newcastle University School of Medical Education	3.34 (91)
8		Norwich Medical School	7.02 (191)
9		University of Nottingham School of Medicine	3.31 (90)
10		University of Nottingham - Lincoln Medical School	0.07 (2)
11		University of Oxford Medical Sciences Division	2.24 (61)
12		Plymouth University Peninsula Schools of Medicine and Dentistry	0.55 (15)
13		Queen's University Belfast School of Medicine	0.92 (25)
14		University of Sheffield Medical School	0.99 (27)
15		University of Southampton School of Medicine	1.98 (54)
16		University of St Andrews School of Medicine	0.33 (9)
17		St George's, University of London	2.46 (67)
18		University of Sunderland School of Medicine	0.00 (0)
19		Swansea University Medical School	0.11 (3)
20		University of Central Lancashire School of Medicine	1.73 (47)
21		University College London Medical School	2.46 (67)
22		University of Warwick Medical School	2.09 (57)
23			
24	Year	Pre-clinical Year 1	23.19 (631)
25		Pre-clinical Year 2	19.85 (540)
26		Year 3	27.20 (740)
27		Penultimate Clinical Year	20.62 (561)
28		Final Clinical Year	4.52 (123)
29		Intercalating	4.63 (126)

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143 **Student engagement with online teaching platforms**

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145 Prior to the pandemic, students spent an average of 4-6 hours per week using online teaching

146 platforms. Students used a combination of video tutorials (27.71%), online question banks (26.18%),

147 pre-recorded tutorials via their respective medical schools (20.96%) and online flashcards (15.99%).

148 4.46% of students utilised live tutorials via online platforms from their medical school, while 1.79%

149 used live tutorials from other sources (Figure 1). Other resources included the use of Anatomy TV,

150 online notes such as Pulsenotes or TeachMeAnatomy, Acland's Anatomy videos, revision websites e.g.

151 OSCE Stop and Zero To Finals, NICE guidelines, online textbooks and UpToDate, and BMJ Best Practice.

152

153 Students then ranked the effectiveness of online teaching platforms with 1 being most effective and

154 5 being least effective. According to the responses by the students, video tutorials e.g.

155 YouTube/Osmosis appeared to be the most effective, followed by online question banks, and live

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3 156 tutorials, whilst students commented using a variety of other sources. However, following sub-analysis
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5 157 and exclusion of intercalating students, unlike pre-clinical students, clinical students found live
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7 158 tutorials to be the most effective, although rankings for the remaining platforms were similar.
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12 160 During the pandemic, students spent an average of 7-10 hours using online teaching platforms,
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14 161 compared to 4-6 hours prior to the pandemic. The difference in hours prior to and during the COVID-
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16 162 19 pandemic were found to be significant ($p<0.05$). Similar numbers of students spent <1 hour on
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18 163 online teaching platforms before and during the pandemic. However, there was an increase in
19
20 164 numbers of students spending longer periods of time on online teaching platforms, for example 7.35%
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22 165 (n=200) vs. 19.70% (n=641) of students spent >15 hours on online teaching platforms before and
23
24 166 during the pandemic (Figure 2A). Following sub-analysis, before the pandemic, clinical and pre-clinical
25
26 167 students spent similar times on online teaching (Figure 2Bi), whereas during the pandemic differences
27
28 168 in periods were found to be significant ($p<0.001$) (Figure 2Bii), with a greater proportion of pre-clinical
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30 169 students spending >15 hours (28.69% vs. 20.01%). 57.28% of students reported that they were now
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32 170 taking examinations remotely; the remaining reported having postponed or cancelled examinations.
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38 172 **Medical school adaptations to COVID-19**

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43 174 Medical schools adapted to the pandemic in a combination of ways with 28.48% of students reporting
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45 175 their medical school to adapting to remote learning through the delivery of live tutorials via online
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47 176 platforms. Moreover, 42.19% of students reported that their medical school either introduced new
48
49 177 resources to existing learning platforms or created a new online teaching platform with new
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51 178 resources. Other medical schools have either a) not implemented anything as the curriculum had
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53 179 already been covered, or b) delayed teaching with the introduction of a question bank.
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3 181 The online teaching provided as an alternative by the medical schools followed a pre-set curriculum
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5 182 for 66.12% (n=1799) of students, was designed following student requests for 3.38% (n=92) of
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7 183 students, or using a combination of both for 30.50% (n=830) of students. This shows that student
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9 184 opinion was considered in the delivery of online teaching.
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14 186 Furthermore, 59.73% of students found that online teaching sessions have been interactive, with
15
16 187 students finding the opportunity to interact via the chat box or by directly speaking to the lecturer.
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18 188 Some students have also specified that having small group sizes, group discussions, online case
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20 189 simulations and quizzes have been useful in increasing their engagement.
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24 191 **Student perception of online teaching**

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28 193 Students ranked their experience of online teaching using a Likert scale with 1 being strongly disagree
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30 194 and 5 being strongly agree (Table 2). Overall, students did not find online teaching to be engaging or
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32 195 enjoyable, with limited opportunities to ask questions. Furthermore, on average students were
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34 196 neutral when asked whether online teaching should be more interactive, but did not find it as effective
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36 197 as face-to-face teaching.
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43 **Table 2.** A table displaying students' perceptions on their experiences of online teaching,
44 ranked on a Likert scale from 1-5, where 1=strongly disagree and 5=strongly agree. Likert
45 scores have been shown as mean \pm standard deviation (\pm SD)

Statement	Mean	\pm SD
The teaching is often stimulating	2.75	1.18
I find it easy to engage in the lesson	2.55	1.30
I feel able to ask the questions I want	2.70	1.53
I enjoy the online teaching	2.62	1.37
I would like the online teaching to be more interactive	3.04	1.44
I feel that online teaching is as effective as face-to-face teaching	1.92	1.45
I prefer online teaching to face-to-face teaching	1.69	1.48
The teachers are well prepared for the teaching sessions	3.36	1.42
I feel I am being well prepared for my profession	2.28	1.33
My internet connection can be problematic	2.53	1.74

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3 201 The main advantages of online teaching appeared to be that it saves students time on travelling
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5 202 (19.82%), provides flexibility (19.52%), the ability for students to learn at their own pace (18.63%), it
6
7 203 is more comfortable (15.84%), and it cuts costs (14.24%) (Figure 3A). Other medical students (n=82)
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9
10 204 also commented that it provides time efficiency, allows more time for students to focus on
11
12 205 preparing for clinical placements, reduces anxiety, and being able to be in a different country.
13

14 206

16 207 On the other hand, students stated that family distractions (26.76%), internet connection (21.53%),
17
18 208 timing of tutorials (17.31%), anxiety (11.08%), and lack of space (11.03%) as barriers to effective online
19
20 209 teaching (Figure 3B). Students (n=81) commented on experiencing a lack of motivation, difficulty
21
22 210 concentrating and asking questions, and a lack of contact with colleagues as further limitations.
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27 212 **Role of online teaching in clinical teaching**

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30 214 75.99% (n=1842) of medical students felt that online teaching had not successfully replaced the clinical
31
32 215 teaching they received via direct patient contact, with 82.17% (n=1986) feeling they cannot learn
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34 216 practical clinical skills through online teaching. This shows that clinical skills remain a pertinent barrier
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36 217 to online teaching of medical students.
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3 218 **DISCUSSION**
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7 220 **Background**

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10 221 With the rise of COVID-19, it is unsurprising that many medical institutions have resorted to online
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12 222 education platforms. However, online education has been used preceding this pandemic. Here, we
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14 223 discuss how this pandemic has shaped the use of online teaching currently as well as its application in
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16 224 the future of medical education.
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21 226 **The impact of COVID-19 on uptake of online teaching**

23
24 227 Our study found a significant increase in the time spent on online teaching platforms before and
25
26 228 during the pandemic ($p<0.05$), particularly amongst pre-clinical students. This was expected, as the
27
28 229 primary source of education and engagement of students with their medical school was online, in
29
30 230 addition to the pre-existing use of online teaching resources. This is despite the reported cancellation
31
32 231 of clinical examinations and conversion of written examinations into open book, which would arguably
33
34 232 reduce student engagement. Hence, the cancellation of clinical examinations may have accounted for
35
36 233 the greater proportion of pre-clinical students engaging with online teaching for more than 15 hours,
37
38 234 which is greater than that of clinical students.
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40 236 The development of innovative educational projects has been initiated to enhance remote medical
41
42 237 education(19). A rise in external resources and teaching programmes such as Osmosis, BiteMedicine,
43
44 238 Becoming A Doctor and Sustaining Medical education in a Lockdown Environment (SMILE) has allowed
45
46 239 many teaching sessions to be available to medical students across the country. Hence, students may
47
48 240 learn from a wider community of professionals. However, the high flow of resources causes a
49
50 241 proliferation of choice which may increase burnout rates. Schwartz claimed that this choice overload
51
52 242 is due to the failure of universities on fulfilling their education role to their students(33,34). Yet,
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54 243 although some platforms were created to facilitate learning during lockdown (e.g. SMILE), many
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3 244 diverse medical education platforms available existed prior to the pandemic with increasing usage,
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5 245 which may suggest that students desire this flexible curriculum.
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10 247 Our results suggest that students would like online teaching sessions to be more interactive. This could
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12 248 be achieved via student response systems incorporating methods such as polls, quizzes or breakout
13
14 249 rooms(35)(36), which have been shown to encourage student participation(37). Indeed, previous
15
16 250 literature suggests the incorporation of online Q&A sessions to improve student engagement(13),
17
18 251 based on a previous model advising the use of synchronous learning(38). Synchronous learning is
19
20 252 defined as a social learning environment alongside answering questions live(39). This active
21
22 253 communication between lecturers and students allows ambiguous concepts to be addressed
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24 254 immediately to increase student involvement, creating a more active learning environment. Indeed,
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29 30 256 **Student perception of online teaching**

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32 257 Students scored their experiences of online compared to face-to-face teaching to be lower, with an
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34 258 average of 1.69 scored for preference for online teaching, and 2.55 for engagement in lessons (Table
35
36 259 2), suggesting most students prefer face-to-face teaching. Furthermore, previous studies utilizing the
37
38 260 DREEM survey found higher average scores for educational environments(40–42). The discrepancies
39
40 261 found may have been due to students comparing their current experiences to previous face-to-face
41
42 262 teaching. However, given that students are currently solely limited to online teaching, responses may
43
44 263 not truly reflect the efficacy of online teaching. Nevertheless, as online teaching has become
45
46 264 mainstream, it is paramount to analyse its efficacy compared to previous methods for further
47
48 265 development.
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54 267 Furthermore, unlike teaching evaluated by DREEM previously, the current pandemic caused a sudden
55
56 268 shift towards the use of online teaching on a large scale, allowing for inconsistencies with
57
58 269 underdeveloped medical curricula, many teachers being inadequately prepared and technical
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3 270 difficulties(8). Therefore, the low scores of student experiences may be due to the unexpected,
4
5 271 sudden introduction of online teaching. Despite the relatively high score of 3.36 for teacher
6
7 272 preparation(40–47), the quality of the sessions delivered may have been impacted by several factors
8
9
10 273 such as poor internet connection, family distractions and the timing of the tutorials, as demonstrated
11
12 274 by our results. In the future, medical schools must carefully build an infrastructure comprising of
13
14 275 technologically versatile lecturers to deliver well-organised, succinct tutorials, games and resources,
15
16 276 especially given the lack of awareness of “conscientious online lecture design” amongst medical
17
18 277 educators(48).
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22
23 279 The low score of 2.28 for being “well prepared for my profession” (Table 2), compared to previous
24
25 280 studies reporting up to 3.18(41,43,46,47,49), is striking, mirroring concerns that remote or online
26
27 281 teaching may compromise the clinical competence and confidence of students(19). The loss of
28
29 282 immediate feedback may have contributed to this, as generally students and doctors prefer face-to-
30
31 283 face sessions for communication(50) and feedback purposes(51). Nonetheless, it is important to note
32
33 284 that students often do not feel completely prepared for their profession(52).
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39 286 Moreover, overall video tutorials (e.g. YouTube or Osmosis), were ranked as the most effective online
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41 287 resources, compared to live tutorials, particularly for pre-clinical students. Reasons for this may
42
43 288 include the short, organized and aesthetic nature of pre-recorded videos(53). In comparison, live
44
45 289 tutorials tend to be longer, face technical difficulties and are less engaging. Despite these challenges,
46
47
48 290 live tutorials were perceived to be the most effective by clinical students. This may be due to the
49
50 291 sessions’ synchronous nature, allowing for real time discussions to occur, reflecting clinical practice.
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54 293 Notably, in this study, distinctions between the different forms of online teaching were not made
55
56 294 when investigating students’ perceptions. Rather, it was an evaluation of online teaching as a whole,
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58 295 which may have impacted the results, as teaching modalities are often specific to the topic being
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2
3 296 taught(48). Furthermore, student preferences may depend on the purpose of engaging with
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5 297 resources, for example for learning new content versus revision(54), or for short-term versus long-
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7 298 term knowledge retention(55).
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11 300 **Benefits and barriers of online teaching**

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16 302 To students, the main advantages of online teaching are the time and money saved from the lack of
17
18 303 travel, its flexibility and the ability for students to learn at their own pace (Figure 3A). Further benefits
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20 304 of live online lectures(14) include opportunities for students to anonymously ask and answer
21
22 305 questions, potentially encouraging further engagement from those who would not otherwise
23
24 306 participate in a live lecture, due to the less intimidating environment online(56). However, these
25
26 307 benefits may not be applicable to all forms of online teaching. For example, the limited synchronous
27
28 308 aspects of pre-recorded content may deter students due to the lack of opportunities to interact with
29
30 309 lecturers(57). Also, watching pre-recorded lectures, alongside the possibility of attending face-to-face
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32 310 lecture, has been shown to negatively correlate with learning success(58).
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39 312 The main barriers to online teaching appear to be family distractions, internet connection and the
40
41 313 timing of tutorials (Figure 3B). This may disadvantage students with large families or with limited
42
43 314 internet access. Moreover, the mental health of students, recently shown to be impacted by the
44
45 315 COVID-19 pandemic(59), may be adversely affected as indicated by the free text responses. This may
46
47 316 be, in part, attributed to the lack of interaction with friends and colleagues leading to a rise in anxiety.
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49 317 Alternatively, with exams being open book and with an unrestricted setting, students may be less
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51 318 prone to exam anxiety(60). Although, this does not address the family and noise disturbances which
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53 319 may still affect exam performance.
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58 321 **Medical student role during the COVID-19 pandemic**

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5 323 On the other hand, medical students are being asked to 'step-up' and join the front-line of doctors
6
7 324 tackling COVID-19(61). As well as the early graduation of UK medical students(62), many universities
8
9 325 have given their students the opportunity to volunteer. For example, the University of Birmingham
10
11 326 has facilitated for over 700 medical students to volunteer in the NHS(27). Although medical schools
12
13 327 have halted clinical placements, this opportunity could provide more exposure, undoubtedly
14
15 328 impacting the development of medical students. However, for those who are not volunteering due to
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17 329 living with vulnerable family members or having health conditions themselves, this would then put
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19 330 them at a disadvantage as their peers continue to gain clinical exposure.
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25 332 As lockdown restrictions ease and students slowly return to medical school, clinical placements may
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27 333 incorporate more virtual aspects as healthcare evolves(22). Indeed, new platforms have been
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29 334 developed by the NHS (e.g. NHS NearMe) which have shown that video consultations are better than
30
31 335 telephone consultations in reducing medical error and improving patient outcomes(31). However,
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33 336 Professor Martin Marshall, chairman of the RCGP, has highlighted that most consultations are still
34
35 337 taking place over the phone as opposed to video calls(63). This may be subject to change with a
36
37 338 demographic who are increasingly familiar with the use of the internet. Additionally, in Germany,
38
39 339 online platforms as observed in Dermatology may "provide a safe and efficient alternative for face-to-
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41 340 face outpatient care"(25), abiding by social distancing rules.
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47 342 **Future direction of online teaching**

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51 344 Furthermore, the digitalisation of medical teaching could play a significant role in the future of medical
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53 345 schools. Allowing users to tailor their learning and acquire new skills through the chaotic nature of an
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55 346 amplitude of resources could halt the development of medical students. Having discussed benefits of
56
57 347 both face-to-face and remote teaching as well as the future of healthcare online, we suggest that in
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1
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3 348 order to maximise the benefits of these learning methods, a mixture of online and in-person teaching
4
5 349 should be utilised moving forward. This can be incorporated into an effective learning method such
6
7 350 as problem-based learning (PBL) or team-based learning (TBL) which have been shown to improve
8
9 351 learning outcomes(64,65), student motivation and understanding(66). Students are set online
10
11 352 materials to study and are then are expected to discuss content in person in a group tutorial(67). This
12
13
14 353 allows students to study at their own pace, in a manner suitable to them, while also holding them
15
16 354 accountable for their own learning. While students find PBL sessions to be interactive and to improve
17
18 355 self-directed learning(68,69), TBL has been found to be more engaging and “conducive to learning” in
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21 356 pre-clinical settings, due to smaller groups, ensuring timely tutor feedback(70).
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25 358 Compared to face-to-face teaching, students in this study felt less satisfied with online teaching and
26
27 359 ill-prepared for their profession. With many of these students due to graduate as doctors in the next
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29 360 few years, this is concerning, highlighting the need for medical schools to improve their delivery of
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31 361 medical education given that online teaching is here to stay. Hence, we suggest that until innovative
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33 362 solutions are generated, medical schools adopt TBL or PBL learning styles for efficiently delivering
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35 363 high-yielded teaching.
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40 41 365 **Limitations and Future work**

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45 367 This is the first study to look at the impact of COVID-19 on online teaching across the UK, with
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47 368 responses from 39/40 medical schools. One of the strengths of this study is its large sample size of
48
49 369 2792 medical student across all pre-clinical and clinical years. Furthermore, the recruitment of a range
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51 370 of medical students for survey distribution via a range of methods minimised potential response bias.
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53 371 However, this study also had some limitations. Some medical schools may have been
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55 372 disproportionately represented with larger numbers of responses from some schools e.g. Kings
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57 373 College London, compared to newer medical schools such as Aston or Kent, potentially skewing results
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1
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3 374 due to sample bias. Additionally, 68.06% of participants were female, in comparison to 55% of UK
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5 375 medical students who are female(32); thus, the results may not be generalisable to the medical
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7 376 student population. Further, some aspects of this survey depended on participants' memory perhaps
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9 377 influencing their reporting, introducing elements of recall bias. The survey did not evaluate the various
10
11 378 ways different content may have been taught e.g. online lectures, games, or question banks;
12
13 379 perceptions of game-based online anatomy teaching would have differed from online didactic lectures
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15 380 on immunology. Thus, we cannot truly evaluate the types of online teaching provided. Also, it is
16
17 381 important to note that the period covered is usually when students have examinations, hence
18
19 382 students may have been spending more time on online teaching platforms regardless. In addition,
20
21 383 since this survey, medical schools may have updated their online resources. Lastly, student receptivity
22
23 384 to PBL/TBL methods should have been evaluated. To truly measure the impact of COVID-19 on student
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25 385 utilisation of online teaching, a more in-depth, qualitative analysis such as focus groups conducted in
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27 386 collaboration with medical schools is required to gather more accurate results, such as the effects on
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29 387 examination performance.
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389 **Author Contributions**

390 SD contributed to the study concept and design, and developed the questionnaire. SD recruited
391 collaborators for survey distribution and data collection. SD supervised the project, had full access to
392 the data, controlled the decision to publish, and accepts full responsibility for the conduct of this
393 study, as the guarantor. AH and SD contributed equally to this study as joint first authors. AH
394 developed and designed the questionnaire, contributed to data acquisition and interpretation, writing
395 and critical revision of the manuscript. AH is the corresponding author and managed project
396 administration. MS developed the questionnaire, contributed to data acquisition and interpretation,
397 and writing and critical revision of the manuscript. AA developed the questionnaire, and contributed
398 to data visualisation and presentation, and writing and critical revision of the manuscript. LA
399 performed data analysis, interpretation, visualisation and presentation, and contributed to writing
400 and critical revision of the manuscript. All authors approved the final version to be published and are
401 accountable for all aspects of the work. Sixteen students were involved with survey distribution and
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403

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41 432 **Competing Interests**

42
43 433 All authors have completed the ICMJE Unified Competing Interest form (available on request from the
44
45 434 corresponding author) and declare: no support from any organisation for the submitted work; no
46
47 435 financial relationships with any organisations that might have an interest in the submitted work in the
48
49 436 previous three years, no other relationships or activities that could appear to have influenced the
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51 437 submitted work.
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56 438

57 439 **Data sharing**

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3 440 Raw data are available upon request from the corresponding author (ah2716@ic.ac.uk). Due to the
4
5 441 anonymous nature of the survey, it was not possible to disseminate the results of this study to the
6
7 442 participants.
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10 443

11
12 444 **Transparency statement**

13
14 445 The lead author confirms that the manuscript is an honest, accurate, and transparent account of the
15
16 446 study; no important aspects of the study have been omitted; and any discrepancies from the study as
17
18 447 originally planned have been explained.
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22
23 449 **Ethical approval**

24
25 450 Ethical approval was requested from Imperial College London and was deemed not to be required as
26
27 451 all data was anonymised, with informed consent taken from all participants. The work was carried out
28
29 452 in accordance with the Declaration of Helsinki, including, but not limited to the anonymity of
30
31 453 participants being guaranteed and the informed consent of participants being obtained.
32
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3 678 **Figure Legends**
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7 680 **Figure 1.** Students were asked about the different types of online teaching platforms they used before
8 the COVID-19 pandemic as represented by this bar chart (n=2721). Options included live tutorial by
9 the medical school, live tutorial by other sources, online question banks, online/digital flashcards, pre-
10 681 recorded lectures/tutorials, video tutorials e.g. YouTube, none, or other).
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18 685 **Figure 2.** Students were asked the approximate number of hours spent on online teaching platforms
19 before and during the COVID-19 pandemic (n=2721). A – A bar graph comparing the number of hours
20 686 spent on online platforms before and during the COVID-19 pandemic by students overall. A Wilcoxon
21 687 test was then conducted which found the difference to be significant ($p < 0.05$). B i - A bar graph
22 comparing the number of hours spent on online platforms by pre-clinical and clinical students before
23 688 the COVID-19 pandemic. B ii - A bar graph comparing the number of hours spent on online platforms
24 by pre-clinical and clinical students during the COVID-19 pandemic. A Mann-Whitney U test found the
25 689 difference in time spent between the students during the COVID-19 pandemic to be significant
26 690 ($p < 0.001$).
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695 **Figure 3.** A bar chart outlining the advantages of and barriers to online teaching. A – Students were
696 provided with a list of potential ways in which online teaching was advantageous and they were asked
697 to select all which applied to them. They were also given the option to input their own statements
698 (n=2721). B – Students were provided with a list of potential barriers to the benefits they may receive
699 from online teaching and they were asked to select all which applied to them. They were also given
700 the option to input their own statements (n=2721).

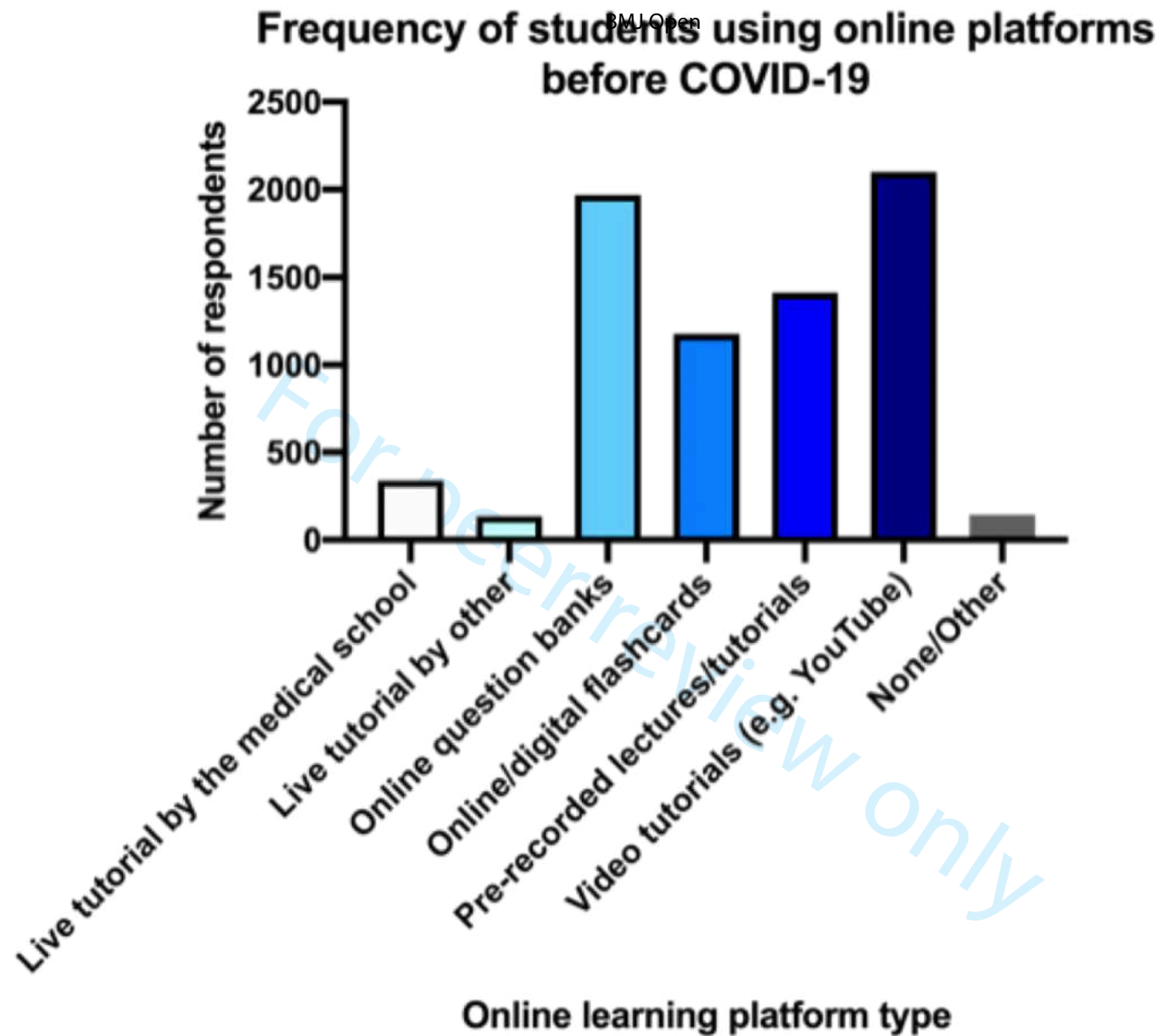
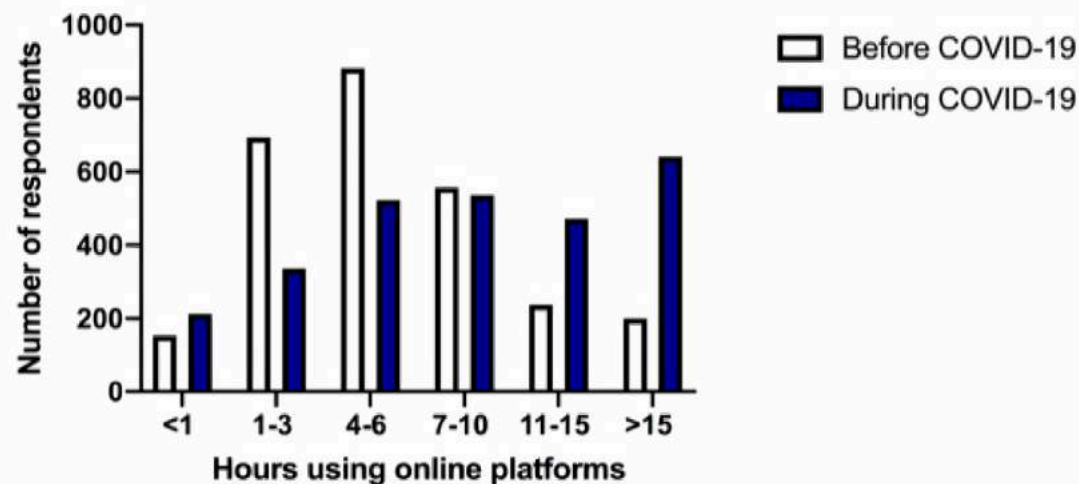


Figure 1. Students were asked about the different types of online teaching platforms they used before the COVID-19 pandemic as represented by this bar chart (n=2721). Options included live tutorials by the medical school, live tutorials by other sources, online question banks, online/digital flashcards, pre-recorded lectures/tutorials, video tutorials e.g. Youtube, none, or other).

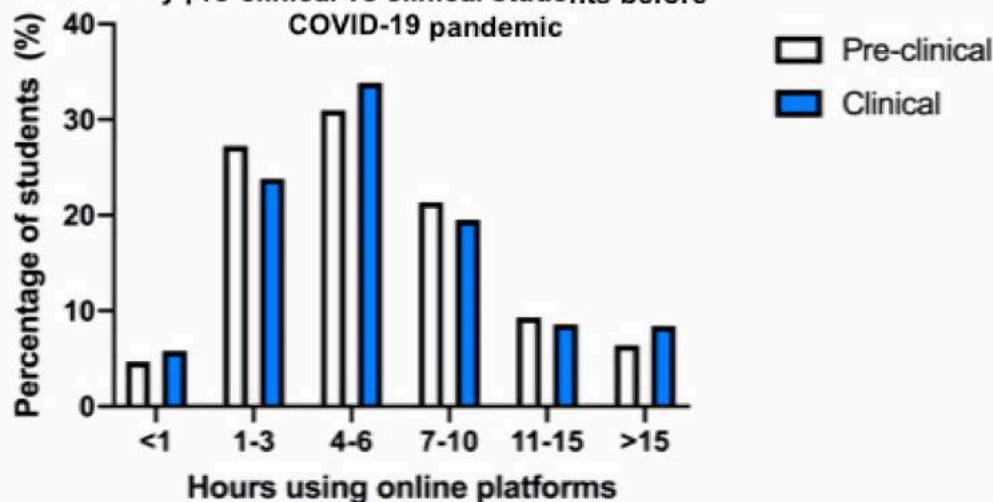
A

Number of hours spent on online platforms before and during COVID-19 pandemic



B i

Number of hours spent on online platforms by pre-clinical vs clinical students before COVID-19 pandemic



B ii

Number of hours spent on online platforms by pre-clinical vs clinical students during COVID-19 pandemic

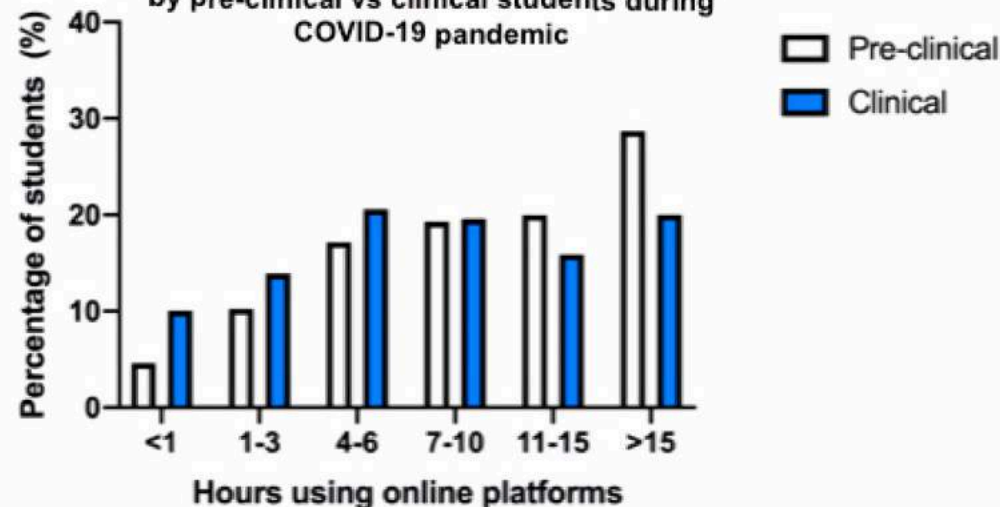
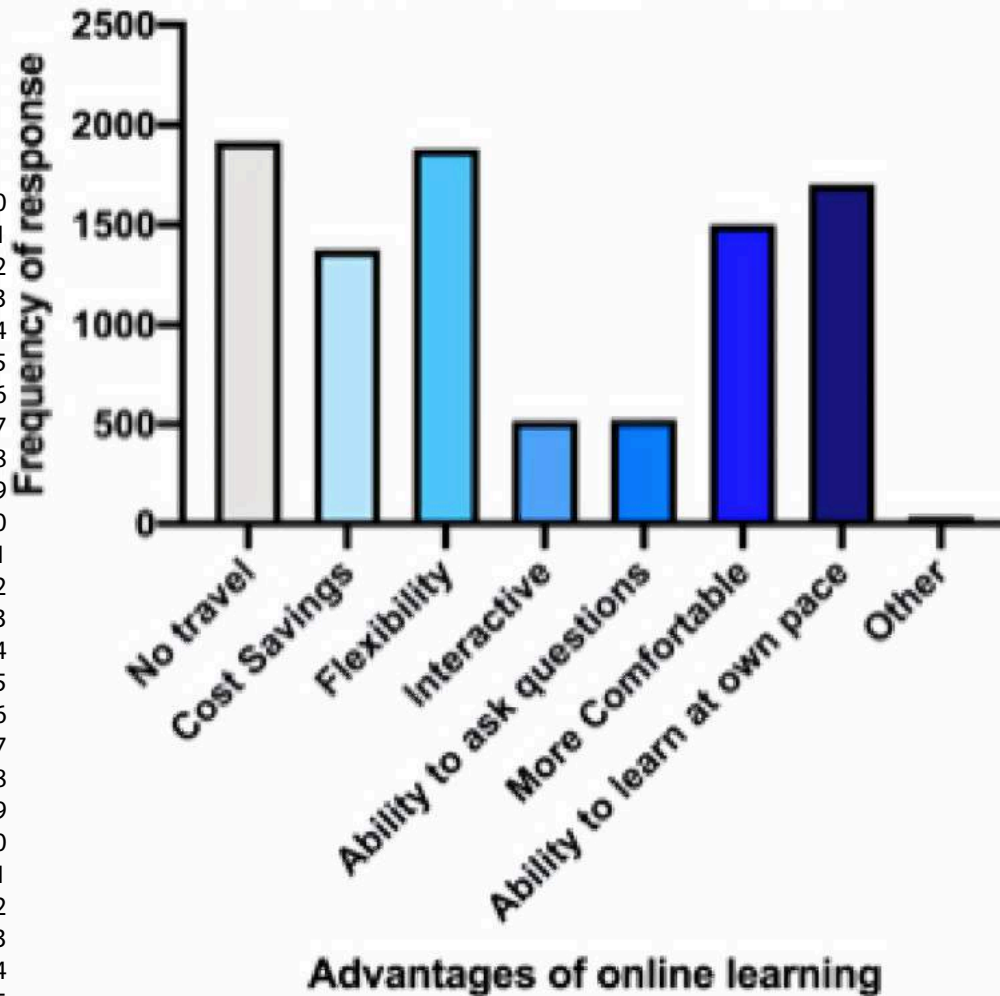


Figure 2. Students were asked the approximate number of hours spent on online teaching platforms before and during the COVID-19 pandemic (n=2721). A – A bar graph comparing the number of hours spent on online platforms before and during the COVID-19 pandemic by students overall. A Wilcoxon test was then conducted which found the difference to be significant ($p<0.05$). B i - A bar graph comparing the number of hours spent on online platforms by pre-clinical and clinical students before the COVID-19 pandemic. B ii - A bar graph comparing the number of hours spent on online platforms by pre-clinical and clinical students during the COVID-19 pandemic. A Mann-Whitney U test found the difference in time spent between the students during the COVID-19 pandemic to be significant ($p<0.001$).

A

B

Frequency of responses to the different advantages of online teaching



Frequency of responses to the different advantages of online teaching

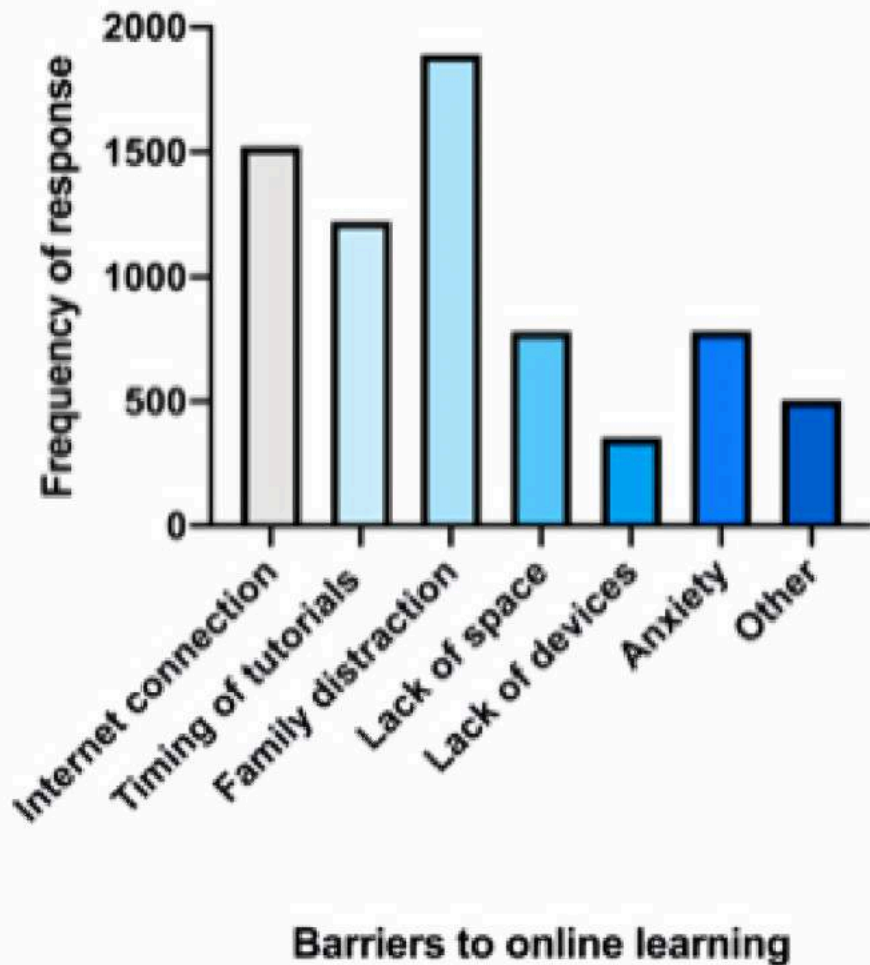


Figure 3. A bar chart outlining the advantages of and barriers to online teaching. **A-** Students were provided with a list of potential ways in which online teaching was advantageous and they were asked to select all which applied to them. They were also given the option to input their own statements (n=2721). **B-** Students were provided with a list of potential barriers to the benefits they may receive from online teaching and they were asked to select all which applied to them. They were also given the option to input their own statements (n=2721).

Appendix

Appendix I – Online Questionnaire

Covid-19, Online Learning & Medical Education

Thank you for your interest in completing our short survey investigating the role of online learning in facilitating medical education during the Covid-19 pandemic in the UK. The data collected is **non-identifiable** and will be used for research purposes.

This survey will close on Monday 11th May at 10pm.

Please tick the box to proceed:

I consent to my information being used for research purposes and this is my first time completing this survey.

Survey Code:

Background

1. Which UK Medical School do you attend?

2. What year are you in?

3. What is your gender?

Online Learning & Medical Education

4. Prior to the Covid-19 pandemic, which online learning platforms/resources did you engage with? (Please select all which apply)

Video tutorials e.g. Youtube/Osmosis

Live tutorials via Zoom/similar platforms by **Medical School**

Live tutorials via Zoom/similar platforms by **other sources**

Online question banks

Online/Digital Flashcards e.g. Brainscape, Anki

Pre-recorded tutorials via Medical School specific online learning platform

None

Other - please specify

5. Which method of online learning do you find the most effective? Please rank the following methods from 1-5 (1=most effective, 5=least effective)

Video tutorials e.g. Youtube/Osmosis

Live tutorials via Zoom/similar platforms

Online question banks

Online/Digital Flashcards e.g. Brainscape, Anki

Other - please specify:

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4 6. Prior to the Covid-19 pandemic, how many hours per week did
5 you spend on average on online learning?
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11 7. During the current Covid-19 pandemic, how has your medical
12 school adapted teaching for your year? (Please select all which
13 apply)
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16 Introduced a new online learning platform with new resources

17 Introduced new resources to an existing online learning platform

18 Delivered live tutorials via Zoom/similar platforms

19 Delivered pre-recorded tutorials

20 Other - please specify:

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33 8. Are these online teaching sessions interactive?
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36 Yes

37 No

38 Majority are

39 Majority are not

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47 8b. What makes your teaching sessions interactive? (Please
48 select all which apply)
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51 Opportunity to interact via chat box

52 Opportunity to interact via speech

53 Live quiz
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Other - please specify:

9. Does the online learning follow a pre-set curriculum, or is it based on student requests?

- Pre-set curriculum
- Student requests
- Combination of both

10. During the current Covid-19 pandemic, how many hours per week do you spend on average on online learning?

Student Perceptions of Online Learning

11. Please rank the following statements on your experience of online learning from 1-5 (1=Strongly disagree, 5 = Strongly agree)

0 1 2 3 4 5

The teaching is often stimulating

I find it easy to engage in the lesson

I feel able to ask the questions I want

I enjoy the online teaching

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I would like the online teaching to be more interactive

I feel that online teaching is as effective as face-face teaching

I prefer online teaching to face-face teaching

The teachers are well prepared for the teaching sessions

I feel I am being well prepared for my profession

My internet connection can be problematic

12. What aspects of online learning do you enjoy? (Please select all which apply)

<input type="checkbox"/> No travel	<input type="checkbox"/> Ability to ask questions
<input type="checkbox"/> Cost savings	<input type="checkbox"/> More comfortable
<input type="checkbox"/> Interactive	<input type="checkbox"/> Ability to learn at own pace

Flexibility

Other - please specify:

13. What do you feel are the barriers to online learning? (Please select all which apply)

Internet connection

Lack of space

Timing of tutorials

Lack of devices

Family distractions

Anxiety

Other - please specify:

Role of Online Learning in Clinical Teaching

14a. Do you feel online learning has successfully replaced the clinical teaching you receive from direct patient contact?

Yes
 No
 Yes, to some extent
 N/A

14b. Do you feel able to learn practical clinical skills through online learning?

Yes
 No
 Yes, to some extent
 N/A

15. Have your examinations been affected by Covid-19?

Yes

No

N/A

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4 15b. How have your written examinations been affected?
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- 7 ✓
8 Written exams will take place remotely online
9 Written exams have been postponed
10 Written exams have been cancelled
11 N/A

12 15c. How have your practical examinations been affected?
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- 15 ✓
16 Practical exams will take place with modifications (e.g. virtual patients)
17 Practical exams have been postponed
18 Practical exams have been cancelled
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STROBE Statement—Checklist of items that should be included in reports of *cohort studies*

	Item No	Recommendation	Page No
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up (b) For matched studies, give matching criteria and number of exposed and unexposed	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6
Bias	9	Describe any efforts to address potential sources of bias	6-8, 18
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) If applicable, explain how loss to follow-up was addressed (e) Describe any sensitivity analyses	7
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram	8-9
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest (c) Summarise follow-up time (eg, average and total amount)	8-9
Outcome data	15*	Report numbers of outcome events or summary measures over time	8-12

1	Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8-12
2			(b) Report category boundaries when continuous variables were categorized	
3			(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
4				
5	Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	8-12
6	Discussion			
7	Key results	18	Summarise key results with reference to study objectives	13-18
8	Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	18-19
9	Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-18
10	Generalisability	21	Discuss the generalisability (external validity) of the study results	13-18
11	Other information			
12	Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	22

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at <http://www.strobe-statement.org>.