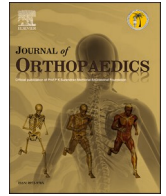




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Challenges to the orthopedic resident workforce during the first wave of COVID-19 pandemic: Lessons learnt from a global cross-sectional survey

Aju Bosco^{a,*}, Hui Wen Tay^b, Ilyas Aleem^c, Mustafa Citak^d, Nalli Ramanathan Uvaraj^e,
Jong-Beom Park^f, Morio Matsumoto^g, Oliver Marin-Penna^h, Janakiraman Buvaneshⁱ,
Moin Khan^j, Hwee Weng Dennis Hey^k

^a Orthopedic Spine Surgery Division, Institute of Orthopedics and Traumatology, Madras Medical College, EVR Road, Park Town, Chennai, 600003, TamilNadu, India

^b Department of Orthopedics, Yong Loo Lin School of Medicine, National University of Singapore, Singapore

^c Department of Orthopedic Surgery, University of Michigan, 1500 East Medical Center Drive, 2912 Taubman Center, SPC 5328, Ann Arbor, MI, 48109, USA

^d Department of Orthopedic Surgery, Helios ENDO-Klinik Hamburg, Holstenstrasse 2, 22767, Hamburg, Germany

^e Orthopedic Spine Surgery Division, Institute of Orthopedics and Traumatology, Madras Medical College, Chennai, 600003, TamilNadu, India

^f Department of Orthopedic Surgery, Uijeongbu St. Mary's Hospital, College of Medicine, The Catholic University of Korea, 271 Cheonbo-ro, Uijeongbu-si, Gyeonggi-do, 11765, South Korea

^g Department of Orthopedic Surgery, Keio University, Keio University Hospital, Shinanomachi 35, Shinjyukuku, Tokyo, 160-8582, Japan

^h Department of Orthopedic Surgery and Traumatology, Hospital Universitario Infanta Leonor, C/ Gran Via del Este, 80, 28031, Madrid, Spain

ⁱ Institute of Orthopedics and Traumatology, Madras Medical College, Chennai, 600003, TamilNadu, India

^j Division of Sports Medicine & Shoulder Surgery, Department of Orthopedic Surgery, McMaster University, 1280 Main Street West, Michael DeGroot Centre for Learning and Discovery (MDCL), 3104 Hamilton, Hamilton, ON, L8S 4K1, Canada

^k University Orthopedics, Hand and Reconstructive Microsurgery Cluster (UOHC), National University Health System, 1E Kent Ridge Road, NUHS Tower Block Level 11, 119228, Singapore

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ABSTRACT

Background: The COVID-19 pandemic has caused unprecedented concerns on the safety, well-being, quality of life (QOL), and training of the orthopedic resident physician workforce worldwide. Although orthopedic residency programs across the globe have attempted to redefine resident roles, educational priorities, and teaching methods, the global orthopedic residents' perspective with regards to their safety, well-being, QOL, and training, taking into account regional variances remains unknown.

Methods: A 56-item-questionnaire-based cross-sectional survey was conducted online during the COVID-19 pandemic involving 1193 orthopedic residents from 29 countries across six geographical regions to investigate the impact of the COVID-19 pandemic on the well-being, safety, and training of orthopedic residents at a global level, as well as to analyze the challenges confronted by orthopedic residency programs around the world to safeguard and train their resident workforce during this period.

Results: The total response rate was 90.3% (1077/1193). Time spent on residency-training activities decreased by 24.7 h/week (95% CI, -26.5 to -22.9, $p < 0.001$), with 50.2% ($n = 541$) residents performing duties outside their residency curriculum. 80.5% ($n = 869$) residents had no prior experience working in infectious outbreaks. A greater percentage of residents from Middle East, Asia and Europe were redeployed to the COVID-19 frontlines, $p < 0.001$. Only 46.5% ($n = 491$) and 58.4% ($n = 600$) of residents underwent training in critical care or PPE (Personal Protective equipment) usage, respectively; 28.5% ($n = 302$) residents (majority from Africa, Middle East, South America) reported lack of institutional guidelines to handle infectious outbreaks; 15.4% ($n = 160$) residents (majority from Africa, Asia, Europe) had concerns regarding availability of PPE and risk of infection. An increase in technology-based virtual teaching modalities was observed. The most significant stressor for residents was the concern for their family's health. Residents' QOL significantly decreased from 80/100 (IQR 70–90) to 65/100 (IQR 50–80) before and during the pandemic, $p < 0.001$.

* Corresponding author. Orthopedic Spine Surgery Division, Institute of Orthopedics and Traumatology, Madras Medical College, EVR Road, Park Town, Chennai, 600003, Tamil Nadu, India.

E-mail addresses: ajubosco@gmail.com (A. Bosco), tayhuiwen@u.nus.edu (H.W. Tay), ialeem@med.umich.edu (I. Aleem), nalliortho@gmail.com (N.R. Uvaraj), spinepjb@catholic.ac.kr (J.-B. Park), orio@a5.keio.jp (M. Matsumoto), olivermarin@yahoo.es (O. Marin-Penna), moinkhanmd@gmail.com (M. Khan), doshhwd@nuhs.edu.sg (H.W.D. Hey).

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Conclusions: The COVID-19 pandemic has significantly impacted the safety, well-being, QOL, and training of the global orthopedic resident physician workforce to different extents across geographical regions. The findings of this study will aid educators, program leaderships, and policy makers globally in formulating flexible, generalizable, and sustainable strategies to ensure resident safety, well-being, and training, while maintaining patient care.

1. Introduction

The COVID-19 pandemic has upended the global public health landscape, overwhelmed healthcare infrastructures worldwide and taxed hospital resources with an uncertain timeline and an unprecedented magnitude.^{1,2} With physicians of frontline medical disciplines working at maximum capacity, physicians of non-frontline medical disciplines including residents-in-training were redeployed to the frontlines of COVID-19 care, and orthopedic resident physicians were of no exception.^{3–8} The orthopedic resident physicians worldwide play an indispensable role in the global healthcare workforce given the essential need for trained healthcare professionals for the management of trauma and disaster victims.

In line with the recommendations of the WHO (World Health Organization) and CDC (The US Centers for Disease Control and Prevention), healthcare systems worldwide had implemented radical changes by adopting system-sustaining measures of isolation, resource conservation and manpower reallocation strategies, considering the uncertain timeline of this crisis.^{3–5,9} A few regional studies have assessed the impact of these changes on the well-being, safety, and training of orthopedic resident physicians at a national/regional level.^{4–8,10–13} However, there is limited quantitative data available from these studies.

The challenges confronted by the orthopedic resident physicians redeployed to the COVID-19 frontlines are unique, considering their unfamiliarity in handling critical medical illness, coupled with the loss of valuable on the ground learning activities due to the decrease in clinical and surgical case volumes. The varying intensity of the pandemic across countries and the capacity of each nation's health infrastructure to handle the pandemic could likely have a direct influence on their resident workforce.^{14–17} This study aims to comprehensively investigate the impact of the COVID-19 pandemic on the well-being, safety, and training of orthopedic residents at a global level, as well as to analyze the challenges confronted by orthopedic residency programs across the world to safeguard and train their residents during this period. It also aims to provide an insight into possible regional variations.

2. Materials and methods

2.1. Study design and participants

The representative sample consisted of orthopedic resident physicians from universities or teaching hospitals in each participating country (as per WHO's situation report), in their corresponding geographical regions (Africa, Asia, Europe, Middle East, North America and South America). [Table 1s](#) (Supplemental Digital Content).^{14,16,17} A cross-sectional, self-administered, questionnaire-based survey was conducted using an online survey platform between 10 May and 5 June, 2020. Approval from the Institutional Review Board was obtained. Consent to participate was implied in a voluntary response to the survey. Participants were assured of the anonymity of their identity and their responses. Periodic reminders were sent through e-mails every fifth day during the survey period.

2.2. Questionnaire development

The survey questionnaire was pretested on an independent group of 25 orthopedic residents representing all years of residency to ensure face

and content validity. The final 56-item questionnaire comprised mainly close-ended questions to allow for comparisons to be made, with limited open-ended questions to allow for collection of qualitative data. The wide breadth of questions were aimed to analyze the role and preparedness of orthopedic residents for COVID-19 patient care as well as to provide a comprehensive insight on the global impact of COVID-19 pandemic on orthopedic residents' training, occupational safety, resident well-being [in terms of the residents' worries and stressors, rated on a 5-point Likert scale (with 1 being the least significant worry and 5 the most)] and overall QOL.

2.3. Statistical analysis

Questionnaire responses were collated on an electronic database. Statistical analysis was conducted using IBM SPSS Statistics version 22.0 (IBM Corp., Armonk, N.Y., USA). Continuous, nominal, and ordinal variables measured on a 5-point Likert scale were expressed as means \pm standard deviations (SD), frequencies with percentages, and medians with interquartile ranges (IQR), respectively. The number of cases per 100,000 population as of 14 May 2020 was calculated for each country, and the median rate out of all the countries, at 30 cases per 100,000 population, was used to stratify countries into more ($>30/100,000$) versus less ($\leq 30/100,000$) affected by COVID-19, [Table 1s](#) (Supplemental Digital Content).^{14,16,17} Comparison between the two groups was conducted using unpaired t-tests with difference of means and 95% confidence intervals (95% CI) for normally-distributed continuous variables, Mann-Whitney U tests for ordinal and skewed continuous variables, and chi-squared tests for nominal data. In addition, comparisons were also made across the six geographical regions, using ANOVA with post-hoc Tukey tests for normally-distributed continuous variables, Kruskal Wallis with post hoc Dunn's tests (with Bonferroni adjustment) for ordinal and skewed continuous variables, and chi-square tests with post hoc analysis of residuals for nominal variables. Statistical significance was set at p -value < 0.05 throughout. Multiple imputation was conducted for variables with $>5\%$ missing data, although any missing data was likely to be random, and no difference in statistical significance was observed after multiple imputation.

3. Results

Of the 1193 participants, 1077 (960 males, 117 females) responded (response rate of 90.3%). Mean respondent age was 30.3 ± 3.6 years (range, 24–50 years). Other demographic data are shown in [Table 1](#).

3.1. Resident work schedule

Significant changes were observed in the structure of the orthopedic residency curriculum globally during the COVID-19 pandemic, [Table 2](#), [Fig. 1](#) (Supplemental Digital Content). The total hours per week spent on residency program-related activities decreased by an average of 24.7 h (95% CI, -26.5 to -22.9 ; $p < 0.001$), with the reduction in residency work hours being significantly greater in the more affected as compared to less-affected countries (28.9 h versus 22.8 h, respectively). Further breakdown found a significant decrease in time spent on emergency trauma care services, outpatient clinics, faculty lectures, and clinical demonstrations/case discussions (p -values < 0.001), with the impact being more significant in the more affected countries, [Table 2s](#) (Supplemental Digital Content).

3.2. Impact on resident training

A significant decrease in faculty-delivered lectures (70.3%–34.5%, $p < 0.001$), clinical case demonstrations/discussions (65.7%–26.2%, $p < 0.001$), journal clubs (58.7%–25.4%, $p < 0.001$) and symposia (29.8%–10.3%, $p < 0.001$), with a corresponding increase in the use of webinars/online symposia (17.8%–57.3%, $p < 0.001$), telecasting of recorded lecture (5.3%–20.5%, $p < 0.001$), and surgical videos moderated by faculty (5.2%–10.0%, $p < 0.001$) were observed, **Table 2**. This change in the landscape of orthopedic residency education was radical in the more affected than less-affected countries, evidenced by a two-fold increase in the adoption of modern teaching tools (webinars, online symposia, telecasting of lectures and surgical videos), **Table 2s** (Supplemental Digital Content). A regional analysis showed that the use of virtual educational methods was lesser in Africa (11.3%), Asia (16.1%) and the Middle East (18.5%) as compared to North America (36.1%), South America (29.3%), and Europe (24.4%), **Fig. 2A** (Supplemental Digital Content). However, the average satisfaction level for online teaching methods (3 out of 5 [IQR 2–4]) was lower than that for traditional teaching methods (4 out of 5 [IQR 3–5]), **Table 2**.

3.3. Impact on residency timeline and specialist certification

A third of the surveyed residents ($n = 327$, 30.4%) were in the final year of their residency. A large proportion had their residency duration extended ($n = 162$, 49.5%) and certification examinations postponed ($n = 231$, 70.6%), **Table 2**. Significant differences were observed between regions, with a greater percentage of final year residents from Africa ($n = 16$, 72.7%), Middle East ($n = 10$, 62.5%), and Asia ($n = 124$, 51.5%),

having their residency timelines extended, as compared to North America ($n = 0$, 0.0%), South America ($n = 7$, 29.2%) and Europe ($n = 4$, 23.5%), $p < 0.001$, **Table 4s** and **Fig. 2B** (Supplemental Digital Content).

3.4. Redefined roles and responsibilities of orthopedic residents

Half of the surveyed residents ($n = 541$, 50.2%), had been redeployed to perform duties outside their residency curriculum, which was significantly greater in the more affected ($n = 215$, 63.2%) as compared to the less-affected countries ($n = 326$, 44.2%), $p < 0.001$, **Table 3**. A regional analysis showed that a majority of residents from Middle East ($n = 39$, 78%), Asia ($n = 495$, 69.9%) and Europe ($n = 67$, 54%) were involved in COVID-19 duties as opposed to relatively fewer residents from North America ($n = 18$, 37.5%), South America ($n = 21$, 27.6%), and Africa ($n = 19$, 32.8%), $p < 0.001$, **Table 4s** and **Fig. 2C** (Supplemental Digital Content).

These residents were mostly involved in the care of stable COVID-19 patients in wards ($n = 385$, 36.0%) and in screening for COVID-19 illness at fever clinics/emergency departments ($n = 302$, 28.3%).

3.5. Risk of COVID-19 infection

The major sources of exposure to SARS-CoV-2 were in the COVID-19 wards ($n = 385$, 36.0%) and fever clinics/emergency departments ($n = 302$, 28.3%), similarly, observed across the six geographical regions. In addition, nearly half of the residents ($n = 521$, 48.8%) were in self-isolation or quarantine, with no significant difference between the more affected ($n = 166$, 49.4%) and less-affected ($n = 355$, 48.5%) countries, $p = 0.78$, **Table 3**.

Table 1
Comparison of demographic profile of the survey participants.

Demographic Parameters	All countries	Less affected countries	More affected countries	p-value	Mean difference (95% CI)
	Frequency (%)	Frequency (%)	Frequency (%)		
*Q1. Age (mean ± SD)	30.3 ± 3.6	30.3 ± 3.5	30.4 ± 3.8	0.86265	0.0 (–0.5 to 0.4)
Q2. Gender (n = 1077)				<0.001	
Male	960 (89.1)	679 (92.1)	281 (82.6)		
Female	117 (10.8)	58 (7.9)	59 (17.4)		
Q4. Place of stay				<0.001	
In University resident quarters	219 (20.4)	208 (28.4)	11 (3.2)		
Alone in own residence/apartment	322 (30.0)	212 (28.9)	110 (32.4)		
With friends/colleagues in own residence/rented apartment	87 (8.1)	54 (7.4)	33 (9.7)		
With family (spouse & children)	340 (31.7)	190 (25.9)	150 (44.1)		
With family (extended family)	105 (9.8)	69 (9.4)	36 (10.6)		
Q5. Hospital type				<0.001	
Public, university affiliated	632 (59.0)	380 (52.0)	252 (74.1)		
Public, non-university affiliated	146 (13.6)	92 (12.6)	54 (15.9)		
Private, university affiliated	244 (22.8)	226 (30.9)	18 (5.3)		
Private, non-university affiliated	49 (4.6)	33 (4.5)	16 (4.7)		
Q6. Duration of residency program (number of years)				<0.001	
2	22 (2.0)	17 (2.3)	5 (1.5)		
3	288 (26.8)	241 (32.7)	47 (13.9)		
4	432 (40.2)	403 (54.8)	29 (8.6)		
5	176 (16.4)	41 (5.6)	135 (39.8)		
6	141 (13.1)	20 (2.7)	121 (35.7)		
7	14 (1.3)	13 (1.8)	1 (0.3)		
8	2 (0.2)	1 (0.1)	1 (0.3)		
Q7. Current year of residency				<0.001	
1	220 (20.8)	166 (23.1)	54 (15.9)		
2	260 (24.5)	194 (26.9)	66 (19.4)		
3	274 (25.8)	197 (27.4)	77 (22.6)		
4	194 (18.3)	130 (18.1)	64 (18.8)		
5	73 (6.9)	17 (2.4)	56 (16.5)		
6	34 (3.2)	12 (1.7)	22 (6.5)		
7	4 (0.4)	2 (0.3)	0 (0.0)		
8	1 (0.1)	2 (0.3)	1 (0.3)		
Q6,7. Number of final year of residents	327 (30.4)	253 (34.3)	74 (21.8)	<0.001	

SD – Standard deviation.

Values in bold in the p-value column indicate statistical significance taken as $p < 0.05$.

^a “Q” denotes the question number in the survey questionnaire. Data are expressed as n (%) or mean ± SD.

Table 2
Comparison of orthopedic residency training before and during the COVID-19 pandemic.

	Before COVID-19	During COVID-19	p-value
	Frequency (%)	Frequency (%)	
^a Q8 vs Q19. Hours per week spent in orthopedic residency program (mean ± SD)	63.6 ± 28.0	38.8 ± 30.7	<0.001 mean difference = -24.7 (95% CI, -26.5 to -22.9)
Q9 vs Q20. Hours per week spent on emergency trauma care services/duty			<0.001
None	4 (0.4)	0	
≤6 h	166 (15.5)	44 (31.3)	
7–12 h	200 (18.7)	333 (22.7)	
13–24 h	275 (25.7)	241 (20.0)	
25–48 h	266 (24.8)	213 (15.1)	
49–72 h	99 (9.2)	34 (3.2)	
>72 h	62 (5.8)	37 (3.5)	
Q10 vs Q21. Hours per week spent in orthopedic outpatient clinic			<0.001
Orthopedic clinics closed	11 (1.0)	171 (16.0)	
≤2 h	93 (8.6)	237 (22.2)	
3–5 h	165 (15.3)	280 (26.2)	
6–10 h	381 (35.4)	223 (20.9)	
11–15 h	239 (22.2)	91 (8.5)	
>15 h	188 (17.5)	65 (6.1)	
Q11 vs Q22, Q23. Hours per week spent in Operation Theatre (OT)		Emergency (n = 1051)	
None	1 (0.1)	307 (28.7)	4 (0.4)
≤2 h	25 (2.3)	161 (15.1)	350 (33.3)
3–5 h	48 (4.5)	222 (20.8)	282 (26.8)
6–10 h	189 (17.6)	154 (14.4)	215 (20.5)
11–15 h	256 (23.8)	83 (7.8)	79 (7.5)
16–20 h	236 (22.0)	42 (3.9)	43 (4.1)
>20 h	319 (29.7)	100 (9.4)	78 (7.4)
Q12 vs Q24. Hours per week spent attending faculty lectures			<0.001
None	51 (4.8)	272 (25.7)	
≤2 h	36 (3.4)	284 (26.8)	
3–5 h	303 (28.4)	276 (26.0)	
6–10 h	465 (43.5)	151 (14.2)	
>10 h	213 (19.9)	77 (7.3)	
Q13 vs Q25. Hours per week spent attending clinical demonstration			<0.001
None	174 (16.3)	422 (39.6)	
≤2 h	11 (1.0)	374 (35.1)	
3–5 h	425 (39.8)	192 (18.0)	
6–10 h	459 (42.9)	77 (7.2)	
Q14 vs Q26. Teaching methods used			
Lectures by faculty	750 (70.3)	355 (34.5)	<0.001
Clinical demonstration	701 (65.7)	269 (26.2)	<0.001
	626 (58.7)	261 (25.4)	<0.001

Table 2 (continued)

	Before COVID-19	During COVID-19	p-value
	Frequency (%)	Frequency (%)	
Journal club, interactive discussion			
Symposia	318 (29.8)	106 (10.3)	<0.001
Webinars, online symposia	190 (17.8)	589 (57.3)	<0.001
Telecasting recorded lectures	57 (5.3)	211 (20.5)	<0.001
Telecasting recorded video of orthopedic surgery with discussion by faculty	55 (5.2)	103 (10.0)	<0.001
Q27. Usefulness of teaching methods as rated by residents ^c , median [IQR]			
Lectures by faculty	4 (3–5)	..	
Clinical demonstration	4 (3–5)	..	
Journal club, interactive discussion	3 (2–4)	..	
Symposia	3 (2–4)	..	
Webinars, online symposia	3 (2–4)	..	
Telecasting recorded lectures	3 (2–4)	..	
Telecasting recorded video of orthopedic surgery with discussion by faculty	3 (3–4)	..	
Changes in final year residency curriculum (bN=327)	Frequency (%)		
Q37. Residency duration extended	162 (49.5)	..	
Q38. Postponement of certification examination	231 (70.6)	..	
Q39. Preponement of certification examination	77 (23.5)	..	

Data are expressed as n (%) or mean ± SD or median [IQR]. Values in bold in the p-value column indicate statistical significance taken as p < 0.05.

SD – Standard deviation; IQR – Interquartile range.

^a “Q” denotes the question number in the survey questionnaire.

^b “N” denotes the number of final year residents who participated in the survey (calculated from questions 6 and 7). The analysis for questions 37,38,39 considered only responses from the final year residents.

^c Scored on a 5-point Likert scale (1- least useful and 5- most useful).

3.6. Preparedness of orthopedic residents for the COVID-19 pandemic

Only 19.3% (n = 208) of surveyed residents had previous experience working in a public health outbreak, with significant difference between the more (n = 50, 14.8%) and less affected (n = 158, 21.6%) countries, p = 0.00855, [Tables 4 and 3s](#)(Supplemental Digital Content). Regional analysis showed that a greater percentage of residents from Middle East (n = 18, 34.6%), Asia (n = 157, 22.2%) and Africa (n = 10, 17.2%) had previously worked in a public health outbreak as compared to those from Europe (n = 16, 12.9%), South America (n = 5, 6.7%) and North America (n = 2, 4.2%), p < 0.001, [Table 4s](#) and [Fig. 2E](#) (Supplemental



Fig. 1. Impact of COVID-19 pandemic on residency curriculum, resident education, and resident well-being.

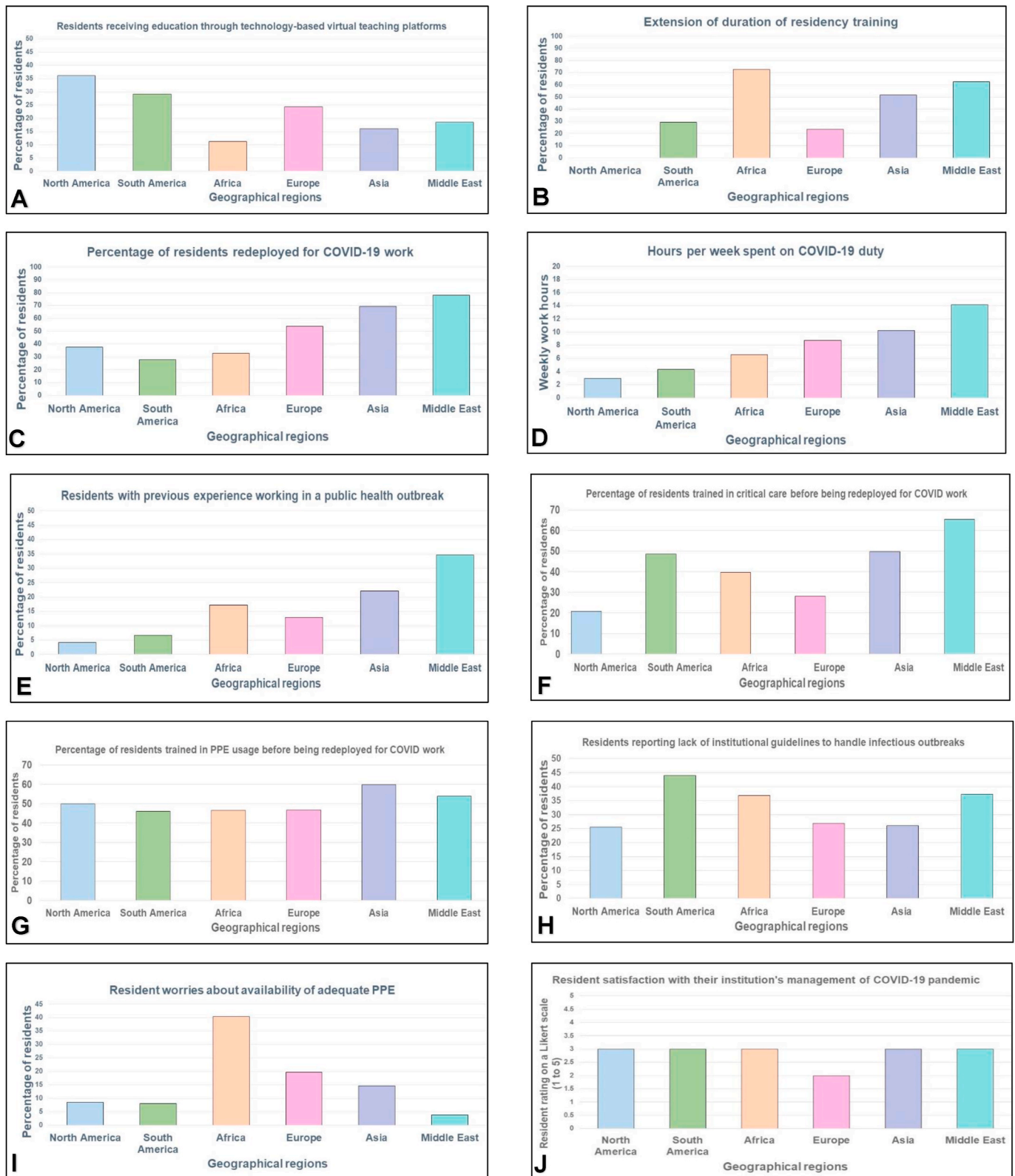


Fig. 2. Regional variations in the challenges confronting the global orthopedic resident workforce during the COVID-19 pandemic.

Digital Content). Prior to COVID-19, most residents (n = 918, 85.7%) had undergone certified life support training, with only 44.6% (n = 409) receiving periodic renewal of their certifications, Table 4. In view of COVID-19, 46.5% (n = 491) of residents had received further training on the management of critical medical illness, with 68.5% (n = 336)

receiving training for monitoring and provision of initial life support, and 19.6% (n = 96) receiving training for intensive care. A regional analysis showed that a significantly lesser percentage of residents from North America (n = 10, 20.8%), Europe (n = 35, 28.2%), and Africa (n = 23, 39.7%) had received critical care training as compared to Middle

Table 3
Redefined roles and responsibilities of orthopedic residents during COVID-19 pandemic.

	All countries	Less affected countries,	More affected countries,	p-value	Mean difference (95%CI)
	Frequency (%)	Frequency (%)	Frequency (%)		
*Q28. Redeployed to perform duties outside orthopedic residency curriculum for performing work related to COVID-19	541 (50.2)	326 (44.2)	215 (63.2)	<0.001	
Q29. Number of orthopedic residents in self-isolation/quarantine	521 (48.8)	355 (48.5)	166 (49.4)	0.78292	
Q30. Nature of COVID-19 work					
Care of stable COVID-19 patients in ward	385 (36.0)	279 (38.1)	106 (31.5)	0.03793	
Care for patients in ICU and not on ventilatory support	100 (9.4)	69 (9.4)	31 (9.2)	0.91701	
Care for patients in ICU on ventilatory support	36 (3.4)	24 (3.3)	12 (3.6)	0.80557	
Screening at fever clinics/ED	302 (28.3)	232 (31.7)	70 (20.8)	<0.001	
Community screening	53 (5.0)	30 (4.1)	23 (6.8)	0.05493	
Performing orthopedic procedures for COVID-19 patients	15 (1.4)	1 (0.1)	14 (4.2)	<0.001	
None	410 (38.4)	263 (35.9)	147 (43.8)	<0.001	

Data are expressed as n (%). Values in bold in the p-value column indicate statistical significance taken as $p < 0.05$.

SD – Standard deviation; ICU – Intensive Care Unit; ED – Emergency Department.

^a “Q” denotes the question number in the survey questionnaire.

East ($n = 34$, 65.4%), Asia ($n = 352$, 49.2%), and South America ($n = 37$, 48.7%), Fig. 2F (Supplemental Digital Content). Overall, only 58.4% ($n = 600$) of residents had received training on the appropriate use of personal protective equipment (PPE), with significant differences observed across geographical regions, Table 4 and Fig. 2G (Supplemental Digital Content). A majority of residents believed that life support skills training ($n = 815$, 78.1%) and critical care training ($n = 718$, 68.1%) must be an integral part of orthopedic residency curriculum, Table 5.

3.7. Preparedness of institution and nation for the COVID-19 pandemic

Majority of surveyed residents ($n = 756$, 71.5%) reported that their institutions had formal guidelines to tackle infectious outbreaks, with no significant difference between the more affected ($n = 252$, 75%) and less-affected ($n = 504$, 69.8%) countries, $p = 0.082$, Tables 4 and 3s (Supplemental Digital Content). A greater number of residents from North America ($n = 35$, 74.5%), Europe ($n = 90$, 73.2%), and Asia ($n = 521$, 73.9%) reported that their institutions had formal guidelines as compared to those from Africa ($n = 36$, 63.2%), Middle East ($n = 32$, 62.7%) and South America ($n = 42$, 56.0%), Fig. 2H (Supplemental Digital Content). Residents received institutional updates at least once a day ($n = 450$, 42.7%) or once to twice a week ($n = 362$, 34.3%), with 23.0% ($n = 242$) reporting lack of institutional updates on COVID-19 scenarios, Table 4. Residents were only moderately satisfied with the quality of PPE provided by their institutions (score of 3 out of 5 [IQR 2–4]) and with their institutions' management of COVID-19, rating a median score of 3 out of 5 (IQR 2–4). 17.6% ($n = 183$) residents expressed concerns on their institution's ability to tackle COVID-19 crisis, with 83.6% ($n = 883$) believing in the need for formal protocols and mock drills to ensure better preparedness, Table 5.

3.8. Residents' quality of life, stressors, and coping mechanisms

Residents' self-rated QOL showed a significant decrease from 80/100 (IQR 70–90) before COVID-19 to 65/100 (IQR 50–80) during COVID-19, $p < 0.001$, Table 6. The most common stressors were that of family health ($n = 771$, 74.0%), personal health ($n = 506$, 48.6%), uncertainty of residency timeline ($n = 488$, 46.8%) and insufficient residency training/education/research ($n = 483$, 46.4%). A greater percentage of residents from Africa ($n = 23$, 40.4%), Europe ($n = 24$, 19.7%) and Asia ($n = 101$, 14.6%) were worried about the adequate availability of PPE as compared to other regions, Fig. 2I (Supplemental Digital Content). The commonly used coping methods by residents were entertainment from television/internet ($n = 592$, 55.9%), listening to music and reading ($n = 522$, 49.3%), and regular exercise ($n = 499$, 47.1%), Table 6.

4. Discussion

Residency training constitutes a limited timeframe during which a resident must acquire the core competencies of medical knowledge, patient care, practice-based learning, kinesthetic skills (for surgical specialties), leadership, interpersonal and communication skills, and professionalism to meet the accepted standards of graduation.¹⁸ Achieving a balance between clinical work, surgical training, academic endeavors and research in ideal circumstances, is in itself a challenging task. The COVID-19 pandemic has profoundly disrupted this balance.

Our finding that orthopedic residents were redeployed to perform duties outside their residency curriculum was similarly observed in other studies although the percentage of redeployed residents varied between countries.^{4–8,11,12,19} Recent studies show that more orthopedic residents from Europe (18%–20.9%) were redeployed to the COVID-19 frontlines as compared to USA (7%), which aligns with our observations that a greater percentage of residents from the Middle East, Asia and Europe were redeployed to the COVID-19 frontlines.^{4,7} This could likely be attributed to the increased demand to manage the relatively greater number of COVID-19 cases in these regions, at the time of survey, coupled with a lower physician:population ratio in Asia and the Middle East.^{14,15,17} Our observation that most residents were involved in the care of stable COVID-19 patients in wards and in screening for COVID-19 illness at fever clinics/emergency departments aligns with the findings of Chang D et al.⁶

From our data, only 46.5% and 58.4% of residents underwent training in critical care or PPE usage, respectively. A significantly lesser percentage of residents from North America, Europe, and Africa had received critical care training as compared to other regions. A recent study from USA reported that 79.2% of their residents had received training on PPE usage.⁴ Another study from Europe reported that 60.3% of redeployed orthopedic residents had not received any specific training for COVID-19 care.⁷ A survey of orthopedic residents from South Korea reported that 42.4% of residents had not received PPE training.⁶ Redeploying resident physicians of surgical specialties to work outside the zone of their expertise without adequate training can increase the likelihood of errors due to lack of competency and can impose a great psychological burden on them.^{20,21} Residents of non-frontline medical specialties should be trained in life support skills and critical care before being redeployed for the care of seriously ill COVID-19 patients. Restructuring residency programs globally to integrate life support skills and critical care training, will ensure better preparedness of the resident workforce for possible future public health crisis.

A recent survey on orthopedic residents from South Korea reported that the major zones of exposure to SARS-CoV-2 were in the COVID-19 wards and fever clinics/emergency departments, which aligns with our

Table 4
Preparedness of residents and their institution for the COVID-19 pandemic.

	Frequency (%)
Resident preparedness	
Before COVID-19	
^a Q15. Previous experience working in a public health outbreak	208 (19.5)
Q16 Level of expertise in offering medical care to patients with critical medical illness	
No previous training in critical care	306 (28.6)
Can monitor and alert medical team if intervention is needed	272 (25.4)
Can monitor and provide initial life support	420 (39.2)
Can monitor and provide advanced life support including intubation and placing on ventilatory support	73 (6.8)
Q17. Has undergone certified life support training	918 (85.7)
Q17. Type of certified training acquired:	
BLS (Basic Life Support)	679 (63.4)
ALS (Advanced Life Support)	430 (40.1)
BTLS (Basic Trauma Life Support)	222 (20.7)
ATLS (Advanced Trauma Life Support)	287 (26.8)
Intensive Care training	122 (11.4)
NELS (National Emergency Life Support)	30 (2.8)
None	153 (14.3)
Q18. Periodic renewal of certification (^b N = 918)	409 (44.6)
During COVID-19	
Q32. Mandatory training to handle critical medical illness before treating COVID-19 patients	491 (46.5)
Q33. Training undergone to handle COVID-19 patients (^c N = 491)	
Informal training without certification	294 (60.5)
Imparted by the institution with certification	88 (18.1)
National training programme for COVID-19 without certification	73 (15.0)
National training programme for COVID-19 with certification	31 (6.4)
Q34. Nature of training imparted to handle COVID-19 patients (^c N = 491)	
BLS (Basic Life Support) skills	213 (44.3)
ALS (Advanced Life Support) skills	123 (25.6)
Intensive Care training	96 (20.0)
None of the above	160 (33.3)
Q35. Confidence in managing critically ill in ED or CCU after undergoing training (^c N = 491)	
Not confident	140 (29.8)
Can monitor and alert medical team if intervention needed	157 (33.4)
Can monitor and provide initial life support	140 (29.8)
Can monitor and provide advanced life support and put on ventilator	33 (7.0)
Q36. Training in donning and doffing of PPE	600 (58.4)
Institution preparedness	
Q47. Frequency of COVID-19 updates by institution	
Several times a day	186 (17.6)
Once a day	264 (25.0)
More than twice per week	238 (22.6)
Once per week	124 (11.8)
None	242 (23.0)
Q48. Platforms used by institution to convey COVID-19 updates	
Physical meetings of institution head with department heads	241 (23.5)
Teleconference	193 (18.8)
Email	441 (43.1)
Text message	355 (34.7)
Circulation of notice	286 (27.9)
Automated voice message by phone	37 (3.6)
Official institution messenger groups	233 (22.8)
Q49. Presence of formal institutional guidelines to tackle infectious disease outbreaks	756 (71.5)

Data are expressed as n (%).

PPE- Personal Protective Equipment; ED – Emergency Department; CCU – Critical Care Unit.

^a “Q” denotes the question number in the survey questionnaire.

^b “N” denotes the number of residents who had undergone certified life support training prior to COVID-19 (based on responses to question 17). The analysis for question 18 was done including only that subgroup of residents who had undergone certified life support training, considering the missing responses as well.

^c “N” denotes the number of residents who underwent mandatory training to handle critical medical illness during COVID-19 (based on responses to question 32). The analysis for questions 33, 34, 35 was performed including only that

subgroup of residents who had undergone mandatory training to handle critical medical illness, considering the missing responses as well.

Table 5
Resident opinions on the need for life support and critical care training, institutions’ preparedness, and countries’ preparedness for COVID-19.

	All countries, Frequency (%)	Less affected countries, Frequency (%)	More affected countries, Frequency (%)	p-value
Resident preparedness				
^a Q50- Belief that BLS and ALS training should be an inherent part of orthopedic residency training	815 (78.1)	572 (80.6)	243 (72.8)	0.00445
Q51. Belief that endotracheal intubation & ventilatory support training should be imparted to orthopedic residents	718 (68.1)	524 (72.9)	194 (57.9)	<0.001
Q52. Satisfaction with the quality of PPE (1 least - 5 most) (median [IQR])	3 (2–4)	3 (2–4)	3 (2–4)	0.01343
Institution preparedness				
Q53. Belief that formal protocols for tackling public health outbreaks need to be developed and practiced	883 (83.6)	627 (86.8)	256 (76.6)	<0.001
Q55. Satisfaction with the institution’s management of the COVID-19 pandemic (1-least satisfied to 5-most satisfied) (median [IQR])	3 (2–4)	3 (3–4)	3 (2–4)	0.32146
Nation preparedness				
Q54. Preparedness of nation’s health system in handling the COVID-19 pandemic (1-least satisfied to 5-most satisfied) (median [IQR])	3 (3–4)	3 (3–4)	4 (3–4)	0.25700
Q56. Satisfaction with nation’s handling of the COVID-19 pandemic (1-least satisfied to 5-most satisfied) (median [IQR])	3 (3–4)	3 (3–4)	3 (2–4)	0.01122

Data are expressed as n (%) or median [IQR]. Values in bold in the p-value column indicate statistical significance taken as p < 0.05.

IQR – Interquartile range; PPE – Personal Protective Equipment; BLS – Basic Life Support; ALS – Advanced Life Support.

^a “Q” denotes the question number in the survey questionnaire.

findings.⁶ With our data showing that, only 58.4% of the surveyed residents had been trained on the appropriate use of PPE, and 15.4% of residents (a greater percentage of them from Africa, Europe, and Asia) concerned about the adequate availability of PPE, they are at a substantial risk of being infected with SARS-CoV-2. In a recent study from USA, 35% of residents expressed concerns on the adequate availability of PPE which aligns with our findings.⁴ High-exposure risks, insufficient

Table 6
Impact of COVID-19 on residents' well-being and quality of life.

	All countries	Less affected countries	More affected countries	p-value
	Frequency (%)	Frequency (%)	Frequency (%)	
^a Q40. Overall QOL before COVID-19 (1 worst – 100 best) (median [IQR])	80 (70–90)	80 (70–85)	80 (70–90)	<0.001 ^b
Q42. Overall QOL during COVID-19 (1 worst – 100 best) (median [IQR])	65 (50–80)	60 (50–80)	70 (60–80)	<0.001 ^b
Q41. Extent of worry of the effect of COVID-19 on the following: (1 least - 5 most) (median [IQR])				
Own health	3 (2–4)	2 (2–4)	3 (2–4)	<0.001
Family's/relatives' health	4 (3–5)	4 (3–5)	4 (4–5)	<0.001
Residency program (Quality of training and timeline of residency)	3 (3–4)	3 (3–4)	4 (3–4.5)	0.00475
Q43. Extent of worry about acceptance of doctors in the society, if infected	3 (2–4)	4 (3–5)	3 (2–4)	<0.001
Q44. Self or family treated indifferently by the society for fear of spreading COVID-19 infection	270 (25.8)	189 (26.4)	82 (24.7)	0.56757
Q45. Stressors from COVID-19				
Personal health	506 (48.6)	379 (53.5)	127 (38.0)	<0.001
Family health	771 (74.0)	499 (70.5)	272 (81.4)	<0.001
Insufficient residency training/education/research	483 (46.4)	299 (42.2)	184 (55.1)	<0.001
Uncertainty of timeline of residency	488 (46.8)	292 (41.2)	196 (58.7)	<0.001
Delay in residency due to postponement of certification examinations	264 (25.3)	170 (24.0)	94 (28.1)	0.15234
Concerns of ability of institution to tackle COVID-19 patients	183 (17.6)	135 (19.1)	48 (14.4)	0.06297
Fear of being deployed to care for COVID-19 patients	152 (14.6)	102 (14.4)	50 (15.0)	0.81002
Fear of adequate availability of PPE	160 (15.4)	118 (16.7)	42 (12.6)	0.08730
None	24 (2.3)	20 (2.8)	4 (1.2)	0.10222
Q46. Coping methods				
Music/reading	522 (49.3)	373 (51.4)	149 (44.6)	0.03863
Regular exercise	499 (47.1)	290 (40.0)	209 (62.6)	<0.001
Yoga/meditation	93 (8.8)	64 (8.8)	29 (8.7)	0.93827
Avoiding listening to news frequently	227 (21.4)	124 (17.1)	103 (30.8)	<0.001
Self-isolate/spend time with family	302 (28.5)	188 (25.9)	114 (34.1)	0.00602
Entertainment from Television/internet	592 (55.9)	390 (53.8)	202 (60.5)	0.04172
Research/academia	275 (26.0)	152 (21.0)	123 (36.8)	<0.001
None	5 (0.5)	3 (0.4)	2 (0.6)	0.68319

Data are expressed as n (%) or median [IQR]. Values in bold in the p-value column indicate statistical significance taken as $p < 0.05$.

QOL- Quality of life; IQR – Interquartile range; PPE – Personal Protective Equipment.

^b Wilcoxon signed-rank test was used to calculate the p-value for Q40 versus Q42 as the data obtained had a skewed distribution. The values are expressed as median (IQR) because of skewed data.

^a “Q” denotes the question number in the survey questionnaire.

protective measures, and health system unpreparedness are important factors responsible for the increased risk of infection in healthcare workers (HCWs).²² With healthcare systems dependent on an adequate resident physician workforce, it is vital to safeguard them by ensuring adequate availability of high-quality PPE, implementing context-dependent appropriate PPE usage, minimizing exposure by adopting a rotating team strategy with “active-duty” and “self-isolated remotely-working” resident teams, conducting regular health assessments and self-isolating residents with comorbid illness.^{23,24}

From our data, 28.5% of the surveyed residents (greater percentage of them from Africa, Middle East, and South America), reported that their institutions lacked formal guidelines to tackle infectious outbreaks and 23% residents reported lack of institutional updates on current COVID-19 scenarios and guidelines, with residents expressing only moderate satisfaction with their institution's management of COVID-19 crisis. Our finding that residents expressed lack of confidence in their institution's ability to handle the COVID-19 crisis was similarly observed in another study from the USA.⁴ Governments should ensure that their healthcare systems formulate guidelines and contingency plans to tackle the ongoing and possible future public health crisis. Healthcare structures should maintain active communication channels with their resident physician workforce, providing constant updates about current scenarios, updated guidelines and their implications for residents. This will help mitigate residents' uncertainty on the ability of their institution and nation to manage the crisis, while boosting their morale to work confidently.⁴

Our finding of a decrease in time spent on key resident training activities (outpatient clinics, orthopedic surgeries) was similarly observed in studies from Europe, Italy, USA, Pakistan, Iran, and Singapore.^{4,5,7,8,10,11,13,19,21} However, no quantitative data is available from these countries. A more recent study from South Korea, quantitatively assessed the significant decrease in time spent in outpatient clinics, elective and emergency orthopedic surgeries which aligned with our observations.⁶ In a recent study from Europe, 58.6% of orthopedic residents reported that their surgical training was significantly impaired.⁷ This is likely attributed to the direct effects of measures taken for minimizing the transmission of infection, resource conservation and reallocation, thereby resulting in cancellation of outpatient clinics and elective surgeries, with redeployment of residents to COVID-19 work, and self-isolation or quarantine.^{3,4,9,20,25} Our data shows that 48.8% of residents were kept in self-isolation to minimize exposure to infection, which was similarly observed by Chang D et al.⁶ Recent studies show that most hospitals adopted a rotating-team policy with active-in-duty and remotely working self-isolated teams.^{3,4,6,7,19,23,26} A significant decrease in in-person teaching activities like faculty-led didactics and clinical case discussions was observed in our study with similar observations reported from Europe, USA, South Korea and Singapore.^{4–7,10,11,21}

The significant decrease in time spent in outpatient clinics and faculty-supervised elective surgeries deprives residents of opportunities to hone their clinical and surgical skillsets through repeated practice and real-case experiences, resulting in inability to meet their board eligibility and graduation requirements. Institutions across the world should embrace technology-based virtual teaching methods to maximize learning amidst in-person restrictions.^{18,27–29} Educational institutions, national/international academic bodies and professional societies around the world should collaborate to restructure residency programs to integrate technology-based training, develop structured e-learning resources and virtual didactic curriculums with free access and make education globally accessible, through online centralized/regionalized teaching sessions and virtual academic conferences. With the use of virtual teaching platforms and video-conferencing technologies, learning can be made accessible to residents across geographical

boundaries. Resident participation in telehealth clinics will be useful to maintain their clinical learning experience.^{12,23,28} Video-based coaching,^{29,30} and surgical simulation tools^{31,32} will be a valuable aid for residents to sharpen their kinesthetic skills in addition to the limited hands on surgical experience available from participation in essential and emergency surgeries.

Our observation of an increase in the use of technology-based virtual teaching modalities, aligns with findings from other studies.^{4–8,10,11,13,20} However, we observed that this transition to a technology-based virtual education was significantly marked in the Americas and Europe as compared to Africa, Middle East, and Asia. While previous studies have reported the usefulness of these techniques,^{18,29,30} we observed that residents' satisfaction level for these techniques was lower than for the traditional methods of learning. Similar observations were made by Chang D et al.,⁶ and Funke K et al.²⁷

Our observation that residents had their residency duration extended and certification examinations postponed aligned with the findings of recent studies from USA and Europe.^{3,4,7,11,12} Program leaderships and academic bodies must come up with innovative and objective methods to assess resident competencies together along with restructuring of the minimum graduation requirements and EPA(Entrustable Professional Activity) targets to accommodate the new technology-based training methods.^{18,23,27,28}

With 80.5% (n = 860) of our surveyed residents having no previous experience working in infectious outbreaks, they are prone to psychosocial stress and burnout. Despite adopting a variety of coping methods to overcome their stress, residents' self-rated QOL dramatically decreased during the pandemic, with similar findings from Chang D et al.⁶ Our data showed that the most significant stressors for residents was the concern for their family's health, followed by personal health, uncertainty surrounding the timeline of residency and inadequate training. A recent study from South Korea, recorded similar observations.⁶ In a study involving general surgery residents from Boston, 100% residents reported that their most significant concern related to COVID-19 outbreak was the health of their family.⁴ Other studies have shown that residents were concerned about fulfillment of graduation requirements, inadequate training and residency timeline.^{4,5,7,11,12,31} Healthcare institutions should ensure the availability of professional psychological support and resident wellness programs, establish crisis hotlines, maintain active communication channels to address residents' concerns, and host routine virtual social hours to foster camaraderie between faculty and residents.^{4,11,31} Though redeployment has forced residents of non-frontline medical specialties to work beyond the scope of their training, it is a valuable opportunity for them to work in concert with colleagues from other medical disciplines, foster camaraderie, and broaden their professional network, that will enable them to provide holistic patient care through a multidisciplinary team approach in future. By working in crisis situations like this, residents gain valuable lessons in systems-based practice, resource optimization, teamwork, and also acquire attributes like courage, empathy, resilience, grit in the face of adversity, adaptability and leadership, which will prepare them to face future crisis.

4.1. Strengths and limitations of this study

The authors acknowledge the limitations of non-uniformity and selection-bias present in our study, while recognizing the generalizability, internal and external validity of the survey approach. This study is also limited by the rapidly evolving pandemic scenarios and changing policies. In addition, there may be some recall bias for resident responses to scenarios before the onset of this pandemic, and this limitation could not be mitigated as it would not have been possible to pre-empt the onset and severity of COVID-19.

This is the first study to comprehensively assess the global impact of COVID-19 pandemic on a large group of orthopedic residents(n = 1077) from 29 countries across six geographical regions. The high response

rate (1077/1193, 90.3%), and selection of countries to be most representative of the prevailing scenario in each region are strengths of this study. The large sample size and its diverse representation make the findings of this study generalizable. The diversity of countries included in this study has allowed for comparisons to be made to gain a better understanding of how the COVID-19 pandemic has impacted residents to varying extents across geographical regions. Though the surveyed residents belong to a specific specialty, the authors believe that many observations made in this study can be extended to residents of other surgical specialties as well.

Given the rapidly evolving and unpredictable nature of the current pandemic, these challenges will continue to exist for the foreseeable future. The results of this study will aid clinicians, educators, and policy makers around the world in formulating adaptable, flexible, generalizable, and sustainable strategies at a global level to ensure resident safety, well-being, and education, while maintaining patient care.

Author contributions

AB and HWDH conceptualized the research question. AB, HWDH and NRU designed the study methodology. All the authors were involved in investigation and data curation. AB, HWDH, NRU, HWT, and JB were involved in formal analysis and interpretation of the data. HWDH and HWT did the statistical analysis of the acquired data. AB, HWDH, HWT wrote the original draft. AB, HWDH, IA, NRU, MC supervised the work. All the authors critically reviewed the manuscript, provided critical feedbacks, and gave approval for the final version to be published. All the authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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CRediT authorship contribution statement

Aju Bosco: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing – original draft, Writing – review & editing, Supervision, Project administration. **Hui Wen Tay:** Investigation, Data curation, Formal analysis, Writing – original draft, Writing – review & editing, Software. **Ilyas Aleem:** Investigation, Data curation, Writing – review & editing, Supervision. **Mustafa Citak:** Investigation, Data curation, Writing – review & editing, Supervision. **Nalli Ramanathan Uvaraj:** Methodology, Investigation, Data curation, Formal analysis, Writing – review & editing, Supervision, Project administration. **Jong-Beom Park:** Investigation, Data curation, Writing – review & editing. **Morio Matsumoto:** Investigation, Data curation, Writing – review & editing. **Oliver Marin-Penna:** Investigation, Data curation, Writing – review & editing. **Janakiraman Buvanesh:** Investigation, Data curation, Writing – review & editing, Formal analysis, Software. **Moin Khan:** Investigation, Data curation, Writing – review & editing. **Hwee Weng Dennis Hey:** Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing – original draft, Writing –

review & editing, Supervision, Project administration.

Declaration of competing interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jor.2021.09.001>.

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