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REVIEW ARTICLE

Post-COVID-19 Pandemic Impact Assessment of Bioinformatics and Women Bioinformaticians: A Realm of Possibilities or Gloom-Ridden

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Abstract:

COVID-19 has greatly influenced the worldwide scientific community to shift its focus towards computational and multidisciplinary approaches to meet the needs around the world. In contrast, a downfall in women computational biologists was significant, attributed to stress in balancing professional and personal household responsibilities due to the preexisting gender gap, especially in India. Additionally, surging cases, deadlines of incomplete projects, and the dilemma about prospects adversely influence productivity, which can be addressed by support and understanding from the family, at the office, and between the mentor and the protégé. A potential focus on life science research, especially computational biology, is anticipated in Post-COVID times.

Keywords: COVID-19, Bioinformatics, Women Researchers, Productivity, Possibility, Stress.

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1. INTRODUCTION

The COVID-19 health crisis has greatly influenced the work culture around the globe. While mandated social distancing efforts are implemented throughout the world, a crisis of this magnitude might encourage scientists to think about their skills and interests in a different way. In this present scenario, the scientific community needs to ensure a position to innovate and meet the needs of the world confronting a pandemic future. Today, the scientific communities are connected globally and scientists work in multidisciplinary approaches through various collaborations and several ways to work from home to the computer in this social distancing period. Due to reduced research hours, scientists are probably devoting more time to analyzing the data, writing manuscripts, and collaborative grant proposals that were unadorned during the everyday chaos of laboratory work. Overall, the scientific system has been changed concerning patterns of collaboration and new ways of scientific communication. Researchers can connect with colleagues all over the world via video conferencing, teleconferencing platforms, or collaborative tools like Slack [1], Microsoft teams [2], Trello [3], etc. The fact that the only way of communication these days is electronic. At all levels, whether a Ph.D. student, a postdoc fellow or an established investigator, all are managing their work through online activities, like webinars or virtual scientific meetings. However, women academics have been inclined towards childcare and family needs. Hence, women scientists are devoting fewer working hours to research activities. The Indian scenario is even more difficult for women to maintain a balanced work-life. During this pandemic period, various national and international academics, as well as research institutes besides, are more associated with organizing online workshops, e-conferences, and online training programs for the benefit of students and researchers.

Global science initiative GISAID provides the primary source of over 92,000 viral genomic sequences of hCoV-19. GISAID is recognized for the rapid exchange of outbreak data during the H1N1 pandemic, H7N9 epidemic, and finally during the COVID-19 pandemic. Over time, new paths of

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collaboration appeared in scientific research during this global social distancing period. In India, the Institute of Genomics and Integrative Biology (IGIB) developed an integrative platform called Genomepedia to report the details of sequenced SARS-nCoV-2 genomes. In addition, global efforts like the European COVID-19 portal are set out to help scientists to coordinate the sharing of the research data related to COVID-19 using the European Open Science Cloud. Another example is ELLIS, which organized a series of regular workshops to connect leading researchers in machine learning and artificial intelligence to combat SARS CoV-2. Furthermore, a new platform called UK Biobank has been created to sequence the SARS CoV-2 viral genomes along with the patient-matched host genome. The field of bioinformatics research is probably playing the most important role these days in SARS COV-2 genome research. Above all, some international efforts such as Crowd fight COVID-19 [4] and COVID-19 Data Portal [5] have been designed to train researchers to work in collaboration to fight against SARS CoV-2, by associating expertise from different fields with data resources [6, 7]. The covid-19 has brought science and technology to the forefront according to public scrutiny. However, in response to the pandemic, abiding by the strict changes in the research institutes and operations, the life of the scientific community has been affected in different manners. While scientists at all stages of their careers and all genders are affected, it is relevant to think about which scientific community has been affected the most.

In this perspective, we have discussed how COVID-19 influenced the trend of global bioinformatics research, how this pandemic affected women researchers, taking into consideration the scenario of COVID-19 in India, where the women biologists are heading, the work-life balance factor for women scientists, the risks to their productivity and finally the future directions in the post-COVID time.

2. HOW COVID-19 HAS INFLUENCED GLOBAL BIOINFORMATICS?

The pandemic that was never witnessed for decades has been a blessing in disguise for many who turned the attention of the world toward healthcare systems [8]. It has opened a new avenue for researchers to work from home through computation-based approaches. Amid the situation of lockdown, the working style of the entire scientific community has shifted towards various computer-based studies, as it is the only medium through which one can carry forward and communicate their research findings safely in the present COVID-19 time [9]. Online classes, meetings, workshops, and conferences are virtually organized all over the world.

In this pandemic, biotechnology and bioinformatics fields have been expanded in various research aspects like disease diagnosis, genomics and proteomics study of viruses, systems biology, computational modeling, drug design, repurposing, vaccine development, and forensic sciences; seeking the attention of scientists and health care professionals [10]. Bioinformatics application has assisted during this pandemic for life science employers, students, and researchers. The world has come up together to fight the battle against coronavirus through computers merged with biology. The literature data on COVID-19 in the National Centre for Biotechnology Information (NCBI) database PubMed has risen tremendously. From 2003 to 2019, only 21 articles were published on Coronavirus. Nevertheless, in just 7 months of 2020, 30655 articles are available in PubMed [11]. Whereas now, around 10,337 genome sequences, 13,274 nucleotides, and 477,330 proteins from all around the world have been submitted to NCBI [12]. These sequences can pave a new way for analyzing and predicting valuable information about the virus [13]. Increasing growth of the data leads to cumulative advances in global bioinformatics. Moreover, sequencing a large number of genomes at such a high rate has become possible only by computational biologists. It has been reported that significant growth was found in the bioinformatics market during this pandemic. Therefore, the job opportunities in the bioinformatics area have increased in the same proportion leading to the progression of this industry. In addition, there is no fear of losing jobs in this area during the lockdown period as they only need an internet connection and a server at home and all they need is to work. In short, knowledge of bioinformatics is acting as a boon from genome sequencing to sequence comparison to drug and vaccine development. It reduces the cost and time of developing drugs and vaccines by several folds by narrowing down the options through simulations.

Handling big biological data is the major key for this area. Artificial intelligence, quantum computing, and new analytical tools have enriched the field of bioinformatics. The genomics and proteomics study of SARS-CoV-2 using a bioinformatics approach developed an integrative database that can be useful for experimental researchers, scientists, and clinicians [14]. The analysis of big data provides information about the genomic sequence of SARS-CoV-2, which is essential to design and evaluate diagnostic tests involved in the development of drugs or vaccines against deadly diseases [15]. From the analysis of the genomic sequence of the virus to the final drug molecule against target protein validation requires several steps to follow, which can be widely divided into five parts. These are retrieval of the viral sequence from the NCBI database, comparative analysis of sequence data, phylogenetic analysis that evaluates the evolutionary origins of traits of interest such as nucleotide and protein sequences, computational modeling of important viral proteins as drug targets, and finally docking several drug candidates against specific target proteins for inhibition of viral activities. Several databases related to COVID-19 have been released in public domain such as NCBI Virus [13], Coronaviridae [16], MicroGMT [17], COVID-Evidence [18], Europe PMC [19], and LITCOVID [20] (Table **1**).

Table 1. List of some important public domain databases related to COVID-19.

Databases	Description	Weblinks
NCBI Virus: SARS-CoV-2 data hub [15]	SARS-CoV-2 content retrieved from the NCBI Virus database. GenBank and RefSeq provide up-to-date nucleotide and protein sequences.	https://www.ncbi.nlm.nih.gov/labs/virus
Coronaviridae [16]	This resource includes access to the SARS-CoV-2 protein sequences and their functions from the UniProt database.	https://viralzone.expasy.org
MicroGMT [17]	Mutation tracker of genome sequences for SARS-CoV-2, developed by Python.	https://github.com/qunfengdong/MicroGMT
COVID-Evidence [18]	A database provides information about worldwide ongoing and completed trials on any intervention to treat or prevent COVID-19 infection.	https://covid-evidence.org/database
EMBL-EBI's COVID-19 Data Portal [19]	COVID-19 Data Portal provides genomic data analysis and sharing through the platform. This portal is part of the European Bioinformatics Institute (EMBL-EBI).	https://www.covid19dataportal.org
LITCOVID [20]	COVID-19 literature compiled by the National Library of Medicine.	https://www.ncbi.nlm.nih.gov/research/coronavirus
Coronavirus3D [59]	The database provides 3D visualization and analysis of SARS-CoV-2 protein structures with CoV-2 mutational patterns.	https://coronavirus3d.org

Due to the hike in demand for data management tools in life science and medical science research areas, there is a large requirement for the latest technologies for designing drugs and vaccines. Thus, the global bioinformatics market has experienced phenomenal growth during this COVID-19 pandemic. It has been divided into various series based on the applications, *i.e*. preventive medicine, molecular medicine, gene therapy, and drug development along with genome sequencing and data management. Few groups are involved in designing synthetic vaccines with the help of bioinformatics and virology. Using several prediction algorithms identifying the immunogenicity peptides in the T-cell epitope [21]. In addition to this, various initiatives of governments towards the funding of small-scale and start-up companies for the design and development of essentials according to the current situation to combat COVID-19 boost the growth of biotechnology and bioinformatics markets around the globe. In countries like India and China, where outside companies easily access skilled and qualified workforce at very low cost, they are interested to invest in manufacturing units, which also enhance the growth of these sectors. Most researchers these days want to learn bioinformatics tools, software, and machine learning to make these hard times fruitful and contribute to society. The government has launched many opportunities for bioinformaticians using online platforms to work jointly with COVID19. One of them is the Drug Discovery Hackathon 2020 platform launched by the government of India [22]. Among others, National Bioscience Database Center (NBDC) and Database Center for Life Science (DBCLS) have been organizing BIOHACKATHON-EUROPE 2020 for bioinformaticians [23] and Hackseq, an annual hackathon focused on solving problems in genomics organized by the University of British Columbia, Canada [24]. This is in collaboration with other scientific communities for computational biologists all over the world to develop lead drug compounds using an *in-silico* approach [25]. Most scientists are exploring new avenues of research under this unexpected circumstance. Using bioinformatics applications, they are exploring genomics, vaccine design, drug discovery, new analytical methods, mathematical and computational methods, and personalized medicine. Young researchers have acquired new skills to make the best out of this situation and modified their research activities with new strategies involved in bioinformatics.

3. HOW THE PANDEMIC AFFECTS THE WOMEN BIOINFORMATICIANS?

It is an unlikely situation now prevailing in the entire world that all people are confined to their houses because of a pandemic. As there is a prefixed notion that women are the caretakers of the house, the household burden on women has dramatically risen during this pandemic. The pandemic affected the women researchers more adversely as any research requires immense focus and concentration on scientific analysis, which a preoccupied mind cannot justify [26]. It calls the overall negative scientific scenario associated with COVID-19 a “pandemic of bad science” [27].

The proportion of female authors versus male authors in scientific publications as research outcomes has always been low. Moreover, after analyzing various literature databases like PubMed, arXiv, and Biorxiv, the proportion of female authors in publications is less in computational biology compared to other areas of biological sciences [28]. However, computational biology or bioinformatics might provide a more conducive environment for the participation of women authors compared to other sciences as this can even be performed at home. Paulin Hogeweg was a woman scientist who coined the term bioinformatics in the early 1970s when the technology was not even developed as much as now [29]. However, the status of women in computational biology is not at all good. While bioinformatics is an ally between biology and computer science, women are contributing more in the area of basic biology and men in computer science. The role of women is in the intermediate. Most of the research papers published in this field are probably male scientists; women have very little part [28]. Megan Frederickson, an ecologist from the University of Toronto, Canada, has analyzed the data from arXiv and bioRxiv preprint servers to know the contribution of women in submitting preprints during the lockdown during the pandemic

time. The data were analyzed from 15 March 2020 to 15 April 2020 and compared with the same period during 2019. It has been interestingly observed that while the contribution by males increased by 6.4% but only 2.7% in women's contribution. Nevertheless, the long-term analyses are quite shocking as there is a tremendous decline in women's contribution to submitting preprints [26]. The pandemic has worsened the state of women in the field of bioinformatics. Now in the lockdown, women scientists have to handle both the family as well as work simultaneously. It has become an additional hurdle for a woman to grow in this field, yet many of them make the best of it and the rest of them quit. Only the strongest ones will survive in this state. Having said this, it is believed that what matters is the arrival of the fittest, not survival of the fittest anymore.

COVID-19 pandemic affected the health and socio-economic status of humankind posing a great challenge to the scientific community. There was a tremendous amount of data generated from SARS-CoV-2 research and this led to the need for the development of tools for analysis. The European Virus Bioinformatics Center, Germany reviewed existing bioinformatics resources, applied them to accelerate the research on SARS-CoV-2, and curated a list of bioinformatics tools specifically for coronaviruses [30]. For the development of preventive strategies and therapeutic interventions to combat SARS-CoV-2, it is vital to understand the epidemiology and pathogenic characteristics of the virus. In this aspect, advanced bioinformatic tools played a crucial role. The next-generation sequencing (NGS) technologies were employed to accurately analyze and quantify extreme variability within viral- quasi-species. The high throughput sequencing technologies have significantly contributed to the identification of the SARS-CoV-2 virus. For instance, metagenomics was initially applied for the rapid identification and characterization of COVID-19 cases. They also identified co-infections in nasopharyngeal swabs from patients, intermediate hosts in the transmission of infection, screening of homologous sequences in other organisms, effect of the virus on the human fecal microbiome, etc. Then whole genome sequencing addressed the limitation of obtaining viral genome from clinical samples owing to low viral load. It helped in the sequencing of the viral genome from samples belonging to different countries all over the world. In addition, genome-wide association studies (GWAS) established an evolutionary relationship between coronaviruses and also helped in the accurate detection of rare viral variants.

Using the information obtained from all these techniques primers were designed for conserved segments of the viral genome to prevent false-positive results from real-time polymerase chain reaction (RT-PCR). This further helps in vaccine and drug development using computer-aided drug design (CADD) to validate potential drug targets. All these bioinformatics algorithm-based tools and databases help clinicians better diagnose COVID-19 infection in patients with different symptoms. These computational tools aided the scientific community in achieving potential vaccine candidates in a shorter period [31]. The tools developed for detection and annotation are PriSeT, CoVPipe, poreCov, VADR, V-Pipe, Haplof low, VIRify, and Genome analysis tools by VBRC, VIRULIGN, Rfam COVID-19 resources, UniProt COVID-19 protein portal, Pfam protein families database. For epidemiology, evolution, and tracking, Covidex, Pangolin, BEAST 2, Phylogeographic reconstruction using air transportation data, COPASI, COVIDSIM, CoV-GLUE, and PoSeiDon were developed. For drug designing, the resources such as VirHostNet SARS-CoV-2 release, CORDITE, P-HIPSTer, and CoVex were developed. Therefore, it is noteworthy that bioinformaticians around the world responded quickly to the COVID-19 pandemic and developed tools specific to SARS-CoV-2 for early and accurate detection and treatment [32]. Therefore, COVID-19 brought a great transformation in the field of bioinformatics, especially genomics and proteomics. Since the time immemorial there is a gender gap existing and unfortunately continuing in science. However, the COVID-19 pandemic further deepened this gap and led to gender inequalities in scientific careers [33]. Reflections on motherhood and the negative impact of the COVID-19 pandemic on women's scientific careers are already well explained earlier by Guatimosim (2020) [33]. Across the world, women scientists especially those in their early careers are at high risk of losing their jobs. A significant rise in submissions of preprints was witnessed during the pandemic and women scientists contributed only one-third of them. This is mainly due to the closure of schools, and nurseries and the unavailability of childcare helpers increased household responsibilities and reduced the productivity of scientist mothers working from home [34]. On a positive note, women bioinformaticians have a new wave of opportunity opening to them, owing to the COVID-19 research and its impact on global health. With the advent of COVID-19, there is a surge observed in the usage of online tools to collaborate with other scientists all over the world. The power of collaboration is understood, many women researchers turned to their work mode with extreme focus, some women researchers came back to their work, and virtual laboratories are made with an alliance [35]. For women bioinformaticians, they may expect more opportunities with ample learning curves. Just from the comfort of the home and being connected to a server, they can access large data and build solutions to address the problem. While this pandemic has brought hope for women bioinformaticians in one way, there are downfalls to it too. First, working from home is not easy as it may sound to women with the preexisting gender gap. Women are more inclined towards childcare and paying attention to family needs and hence, devoting less time to work. The line becomes blurred with women researchers as to when to stop working and when to look after family [36]. Second, working with big data from home requires a large infrastructure, proper network service, along with a good internet connection. Deficiency in any of these can cost time and effort resulting in restarting the work from the beginning. Third and final is the lack of ergonomic tools such as chairs, desks, and balanced posture while working from home. This may sound trivial, but this is equally important to work efficiently. The setup for work ideally should mimic the workplace for increased productivity that is often less for a woman in a household compared to the men members of the family.

4. WOMEN BIOLOGISTS IN INDIA: WHERE ARE WE HEADING?

Although women are getting comparatively flexible hours to work on their research during the period of the pandemic, it is difficult to allot dedicated hours to them. Hence, women biologists are unable to meet the deadlines of their projects and are inept to submit preprints during this time [7, 37]. In the Indian scenario, it has become even more difficult for women to handle home and work pressure. The pressure of household work has increased during this lockdown, especially on women resulting in several health issues including change in sleep patterns, building up of frustration, pressure, guilt, fear, and anxiety. Considering the societal pattern of India, the major contribution to handling household tasks is led by women and men do not have much to do with household stuff irrespective of their occupations, exceptions excluded [38]. Recent studies on Indian women found differences based on discipline. There are significantly about 28% of females with 1st authored papers and has increased in a decade from 0.35 to 0.43 in the decade between 2008-2017. In India, women involved in research are comparatively lesser than men. Several barriers exist for female researchers that need designed strategies so that they can be of interest to young women researchers [39]. On a positive note, Indian women in bioinformatics research have made the Women in Biology (WiB) a forum at Bioclues where students, young researchers, and established scientists all share a common interest in bioinformatics research [40].

Taking into consideration the earlier data of women biologists in India, during the early years of the Indian Agricultural Research Service, women scientists were comparatively less represented. There were only 167 women scientists during the 1980s with a higher proportion of 40% scientists in crop science and the majority of them placed in plant pathology followed by genetics. Only a few of them are known to the scientific world for their contributions. Representations of animal biotechnologists are less even now when compared to plant scientists with specializations in bioinformatics. Most of the experts working in agricultural bioinformatics are either biotechnologists or genetics experts. However, their representation as a first author or corresponding author is less than 10%. Manuscripts are being accepted in journals with an impact factor of 0.5 to 2.5 provided they do have enough experience in communicating manuscripts. Nevertheless, the number of articles published by women bioinformaticians in journals impact factor of 3.0 is statistically insignificant. Fellow selection in the National Academy of Agricultural Science (NAAS) in India is limited to up to 5.8% every year. Representation of women in key scientific positions ranges from 0% to 40% depending on their placement and impact on the institute. Even before the onset of the pandemic, women scientists throughout the world shared authorship. Moreover, they are less likely to be the first or most communicating authors than men are. The gap between senior authorships for women and men has grown only in recent years [41]. Depending upon the present situation of COVID-19 where the productivity of women scientists significantly altered throughout the world, the state of women biologists in India will be unaltered during the post-COVID-19 time too. This is alarming until the women biologists in India will prioritize their work and keep a good work-life balance. Amidst COVID-19, academia needs new solutions to ensure gender equality in science [42].

5. IS WORK-LIFE BALANCE IMPOSED MORE DURING COVID-19 LOCKDOWN TIME?

Mental health is a global problem. While before the pandemic, maintaining a good work-life balance was relatively more possible along with special self-attention, a variety of different stressful circumstances during the pandemic significantly broke this balance and increased the stress to an unprecedented level [43]. Pandemic makes it more difficult to manage all things at home from academic work to household work to managing family. Additional pressure is on women academic's shoulders to tackle all this. Men can focus on work for home comfort, while women manage both. Pre-existing gender gaps have further increased during the pandemic and a lot of family burden is on the shoulders of the women. They are struggling to maintain the family's physical as well as mental health throughout this social isolation phase along with the wedge of maintaining a job. Socio-historical surveys have thrown light on a gendered "duty to care", the spirit that fell exactly on the women's shoulders even throughout the 1918 Spanish flu pandemic. Interestingly, even after 100 years, women still bear a substantial burden of domestic liabilities and receive notably more household demand disturbances in their already restricted working hours. Malleable work has gone well for many during COVID-19, but it has adversely affected many women's career plans and efficiency levels, making the COVID-19 situation an unpaid care work for women [44]. A survey related to this revealed that submissions to scientific journals have increased around 25% in comparison to non-pandemic conditions, while the majority of the articles are capitulated by men academics. There are additional indications that, there is a gendered effect regarding who gains from pliable work, and it is not women. On the other hand, men are motivated to raise productivity with flexible working time and gain the required reorganization for such. However, women are expected to acquire flexible working conditions to enhance their unpaid labor role – more into family and home responsibilities. This indicates putting the rewards of the paid job on the subsidiary to take care of other members of the family and possibly putting high risk on their professions [45]. During the pandemic, some people started suffering from economic crises leading to increased trauma in their lives. While some have become so busy and adapted themselves to the new normal, others are still battling. The ones who are not adopted yet are facing more mental problems. The rate of suicide significantly increased during the COVID-19 period. There is evidence that shows the pandemic influences heavily the socio-psychological state of mind [46]. Social isolation and economic hitches exacerbated different psychiatric disorders including suicidal behavior in vulnerable populations. COVID-19 survivors may also be at elevated suicide risk. Women are more prone to this risk [46].

Even in today's world, women leaders represent less than 7% of world leaders, but countries like New Zealand, Taiwan, Germany, and Finland where women are administering various leadership positions have emerged as models for the whole

world in this emergency. Their vision and understanding of various perspectives, as well as their democratic leadership practices, have assisted them to direct public health and the public frame of mind toward social isolation. Institutes, organizations, and companies alone cannot resolve the never-ending tug of war between the professional and personal lives of women. To accomplish this goal of gender equity and work-life balance, we have to throw back the acceptance of gender in families and communities first. Women's conservative character needs to be challenged, remodeled, and updated according to the needs of this modern world. It is possible with men's assistance and understanding of their appreciable hold on the consequences that women can focus more on their professional life and can be more productive while less occupied in household work [45]. Mutual understanding among the family members, employees, and the boss, mentor, and mentee may serve as the key to tackling work-life balance in this pandemic. We may say that better work-life balance is needed during or post-pandemic times as the systematic work style of women researchers is significantly disturbed during this period. The employment number of children and their age are the two factors on which productivity depends at home. Working women experienced great difficulty at home, as they shared a larger household leading to an impact on productivity. The unequal share of households is to be equalized to increase the impact of productivity during lockdown [47]. Prioritization of work and allotting dedicated hours to perform quality work at flexible timings can bring out some solutions to restore the much-needed balance.

6. IS PRODUCTIVITY AT RISK?

Productivity is at risk to a certain extent. As some researchers are experiencing more stress either due to the increasing cases of COVID-19 or approaching deadlines of their uncompleted projects or dilemma about their future job prospects, overall they are deviating their focus from the work to some other things. On the other hand, others with the extra burden of household work are unable to dedicate quality time to research. All these factors may reduce productivity to a certain extent. COVID-19 overturned normal daily life all of a sudden, including the area of scientific research. Unfortunately, as we discussed earlier, scientists have not experienced these new odds equally [44]. Women scientists seem to be submitting fewer papers for publication (including preprints), whereas men are submitting more. This inequity may result in fewer women being granted tenure and promotions, an unequal gender pay gap, and even some women researchers being pushed out of science for less productivity [48].

Keeping the global pandemic in the scenario, as employed researchers are working from home when the schools and day-care centers are closed, researchers with young children are struggling. Women scientists with young kids and family responsibilities are scaling back their research time more than men do. The service work duties are consuming more of women's time as universities coordinate pandemic responses. This gender discrimination matters in academia where "publish or perish" still exist. Women are already underrepresented in science, and their representation declines at every career stage [48]. In an earlier study, it has been shown that although female scientists have made steady gains in recent decades, they face persistent career challenges. Universities and colleges in the USA employ much more male scientists than females and men earn significantly more in science [49]. This disparity is pronounced for women of color. A tenure track position that requires a lot of time and devotion often coincides with early family responsibilities and parenthood. For parents in science, especially mothers, this timing does not go well. A report showed that after having children, 43% of mothers and 23% of fathers leave full-time employment in science, technology, engineering, and mathematics fields in the USA [48]. As the pandemic grinds on and uncertainty prevails about reopening schools and childcare centers, the effects on research productivity, especially for women, will only get worse. Gender equity in scientific publishing will elude us until we address gender equity at home.

An important work by Korbel and Stegle, 2020 was also reported to have caused adverse effects on the scientific community, triggering stress and work interruptions. They reported new patterns of national and international cooperation, idea exchange, and electronic learning. This 'a new normal' *i.e*., the ability to work efficiently from home, and to collaborate with scientists and clinicians nationally and internationally, without extensive travel, might ultimately, even result in benefits for scientific communities and society as a whole. Jan Korbel and Oliver Stegle, both group leaders at EMBL Heidelberg, have surveyed fellow scientists in Germany, Spain, the UK, Italy, France, Canada, Turkey, and the USA to know how this COVID-19 scenario, with partial or complete institutional lockdowns, is affecting their work and health conditions. They particularly witnessed the stress level among the participants and recognized two different potential risk groups; one of those was young trainees, especially trainees working abroad in institutes located on a different continent. They identified that a big number of these participants lived alone and were likely to feel more isolated at the time of lockdown. The second group was female scientists. A large proportion of the female participants were working in wet laboratories that have been more affected by the lockdown period than the dry laboratories, and they were also more often bound by childcare duties than male participants were. The study came up with some interesting statistics, which are as follows: 77% of the life science institutes in the study set were facing shutdown, 57% of the participants had lost around 6 months of their work, 66% of the participants used the extra time for their career development during this pandemic period, 26% of the participants fear of additional loss of work, 30% attended any virtual conferences, while only 18% of the study group have participated in COVID-19 related research [50]. The data reveals the severity of work-life balance during the pandemic with significantly declining overall productivity that may prolong the effect even in the post-pandemic period. In neuroscience, medical science, and more, all the cross-country analyses have shown that women scientists are less the first authors, less productive showing clear gender inequality, and negative career cost [33, 51 - 54]. Considering the present situation in India, the anxiety-based stress and depression rates in the Indian population during the COVID-19 lockdown were reported with high prevalence due to socio-economic

conditions [55]. In another recent survey, it was reported that there has been a 20% increase in mental illness in the Indian community during the COVID-19 period [55, 56]. In India, it has been reported that 136 million jobs are at risk with reduced pay, with no appraisal leading to uncertainty and insecurity in post-COVID-19 [57]. Surprisingly, it was reported in an earlier survey that males are found to be more anxious than females in India [58]. This can be related to the socio-cultural norms that predominate in many Indian communities wherein females are responsible for household chores and males are barely involved in these activities. Nevertheless, the unavailability of domestic helpers in lockdown has induced household responsibilities leading to productivity being at risk in general.

In another point of view, Prof. Correll of Stanford's School of Humanities and Sciences, who works on gender bias, workplace-changing conditions, and organizational traditions, thinks that women are continuing to perform significantly more housework and childcare, leaving men more time to focus on work during this COVID-19 time. In her conversation with the employees of VMware Women's Leadership Innovation Lab, they have heard from executive members that younger employees, who were less able to contribute to the team before, have now come up and are teaching organizational leaders best practices in teleconferences and digital communication tools. Finally, employees now have more conversations with their colleagues. According to them, they are now concentrating on studying how they can freeze these new and overall practices as organizations create the "new normal". For them, it is a test for all of us for healthier times.

CONCLUSION

Post-COVID times fetch attention and more work for life sciences, especially computational biology. Some of the areas of work with healthcare systems are studies to improve the understanding of disease mechanisms, health problems, disease emergence, and re-emergence. This will help in detecting, preventing, and combating future pandemics based on our experience. The current circumstance has constrained all of us into unrest in the education sector affecting women's academics too. The widespread adoption of digital technology during the current pandemic is additionally significant when it means giving quality education to a nation like India of ~1.35 billion individuals. Even though we were not prepared to do so a few months ago, this is the only start. There is a new horizon waiting for us if this open door of the digital revolution is appropriately utilized. The future will be a period of innovation-driven advanced education in India. With nearly 1000 universities, over 51,000 higher education establishments, and around 40 million students, India is one of the biggest higher education frameworks prepared to overwhelm China and the US. Now is the opportunity to think about the challenges that we face and how frontier technologies can help to solve those challenges. South American countries like Chile or Argentina might be a model where several project calls are made aimed to fight COVID-19, where women researchers can take part. This pandemic has taught us the things that we have consistently known and may be overlooked. There will be many changes in academia as the post-COVID time arrives. We need to balance quality and quantity. We need a definite wet laboratory. Industry collaborations. The research funding needs to be evaluated. Overall, science communication will change.

The productivity of women depends on children and elderly family needs that have a lot of negative impact on the overall current situation. Several reforms may be adopted in work culture by reducing worked hours and wages related to gender gaps [48]. Post -COVID may be a bliss to several, for two reasons: less workspace requirement to finish the task efficiently will be a benefit for firms, and reallocation of household tasks within the family may strengthen to revive the traditional gender practice. There may be an impact on the imbalance in labor but will give women to come back to careers for future research. The ones who are clear with their goals will remain productive during that time and the ones who do not want to do anything productive will end up following trends without creating new ideas. Pandemic has no or very little role to play in this because ideas come from within irrespective of the environment where we are. The pandemic may have a little negative impact on productivity due to mental stress. Many people who do not use social media applications and other online platforms to communicate with one another and to work from home through meeting applications, respectively, are learning these things. This is one of the most productive things happening during these unprecedented times in one's lifetime. There are two extremities: either the person goes negative and destroys mental health or the person goes positive and starts to work on oneself from maintaining health to staying calm and fresh leading to increased productivity [48]. The COVID-19 outbreak changed how scientists communicate and share the data, bringing a completely new culture of research; more preprint submissions, more publications, and more productivity [59]. A recent report by Witteman *et al*. (2021) also reports that the new COVID-19 gender policy changes are supporting female scientists and are improving the research quality [60]. On a positive note, research collaborations during the pandemic time are reported to enhance the performance and visibility of women scientists. In conclusion, these new experiences of science and technology gained during the COVID-19 pandemic may help us to better cope with any global crisis period in the future, and this lockdown period has taught us many ways to spend time, to learn new things by devoting yourself to science and to keep the science going in a better way.

LIST OF ABBREVIATIONS

IGIB	=	Integrative Biology
NBDC	=	National Bioscience Database Center
DBCLS	=	Database Center for Life Science
RT-PCR	=	Real-ime Polymerase Chain Reaction
CADD	=	Computer-aided Drug Design

CONSENT FOR PUBLICATION

Not applicable.

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CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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