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CONTENTS

ORIGINAL RESEARCH

2

Exploring the Effectiveness and Accessibility of Lay Summaries in Four Open-Access Journals

10

Comparison of Progressive and Conservative Representations of Men's Mental Health in Written News Media

16

The Impact and Effectiveness of Science Communication Training in the Honours Life Sciences Program at McMaster University

ACADEMIC REVIEW

30

The Historical Analysis of Prevalence and Public Perception of ADHD in Adults Within International News Coverage

36

Impacts of Air Pollution on the Respiratory System of Adults in Relation to Socioeconomic Status

45

An Interdisciplinary Review of the Qualities of Glioblastoma Multiforme

NEWS & VIEWS

55

Dexamethasone's Connection to COVID-19

DEAR READER,

Welcome to Issue 9 of the *Sciential* Journal! As we slowly start to see things going back to normal after a global pandemic, we're thrilled to publish a new issue with exciting research. *Sciential* gives students an opportunity to publish work that they are passionate and enthralled by. Our aim is to explore the interdisciplinarity of scientific fields through effective science communication. Over the years, especially during the pandemic, we have witnessed the importance of science communication and research. With this journal, we hope to shed light upon the accessibility and interdisciplinary nature of science.

This issue explores a range of scientific topics: the impacts of air pollution, the qualities of glioblastoma multiforme, how the public perceived ADHD in adults, dexamethasone's connection to COVID-19, how effective lay summaries are in journals, the representation of men's mental health in the media, and lastly, the impact of science communication training.

We are extremely grateful to the members of the *Sciential* team for their work and dedication to the journal. We would like to recognize the fantastic work done by our Senior Editors, Samini Hewa and Zani Zartashah, for overlooking the peer-review process. Additionally, we would like to acknowledge the incredible work ethic of our Editors, for their continuous determination to make sure our journal is of high standard. We also appreciate the remarkable work done by the creative board, led by our Creative Director Zachary de Guzman. Lastly, we would like to acknowledge the founders of *Sciential*, Aiman Shahid and Alisa Nykolayeva, along with our Senior Advisor Team Dr. Kimberley Dej, Dr. Veronica Rodriguez Moncalvo, Dr. Katie Moisse, and Science Librarian, Abeer Siddiqui.

On behalf of the *Sciential* team, we strive to provide the best quality of work and hope you enjoy Issue 9 of the *Sciential* journal!



Cynthia Chung
Editor-in-Chief

Mariyam Mohammed
Editor-in-Chief



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Exploring the Effectiveness and Accessibility of Lay Summaries in Four Open-Access Journals

Manvir Kaur Chima¹

1. McMaster University, Honours Life Sciences (Minor in Psychology), Class of 2022

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SUMMARY

Open-access journals are journals without any form of financial or legal barrier to publication. Articles in open-access journals include lay summaries, which intend to summarize research in a manner that is understandable by a general audience. In many open-access journals, lay summaries fall flat when conveying research. This study aimed to characterize the features of lay summaries to better understand areas of weakness. 20 summaries were analyzed from four open-access journals: *PLOS Medicine*, *PNAS*, *Sage Open*, and *Frontiers in Psychology*, using McMaster University's *LIFESCI 2AA3: Introduction to Topics in Life Sciences* rubric. This rubric was created by Dr. Katie Moisse, assistant professor of curriculum and pedagogy at McMaster University, School of Interdisciplinary Science. *PLOS Medicine* ranked highest for all four criteria with an overall average of 14.6 out of 20, while *SAGE Open* typically ranked on the lower end with an overall average of 9.6 out of 20. The differences between journal scores are likely due to varying author guidelines set by each journal. The findings are significant as they imply necessity for cohesiveness in guidelines on lay summary construction between journals, to make better use of taxpayer dollars and better translate scientific findings to society. Limitations include the limited sample size and the lack of inter-rater reliability. Future studies can assess a larger sample size and broader scope of journals to formulate more generalizable conclusions.

ABSTRACT

Lay summaries are an important aspect of research, as they aim to summarize scientific findings in a manner that is accessible to a lay audience. However, lay summaries often incorporate scientific and technical jargon, which makes it difficult for the public to understand research that they are indirectly funding. This study aimed to analyze lay summaries published in four open-access journals to compare differences in effectivity and accessibility when authors summarize the key points of a research study. Four open-access journals, *PLOS Medicine*, *PNAS*, *Sage Open*, and *Frontiers in Psychology* were analyzed using McMaster University's *LIFESCI 2AA3: Introduction to Topics in Life Sciences* rubric. This rubric was created by Dr. Katie Moisse, assistant professor of curriculum and pedagogy at McMaster University, School of Interdisciplinary Science. The rubric judges for an accurate summarization of the study rationale, knowledge gap, methods, results, conclusions, limitations, and next steps, while ensuring accessibility and clarity. Results indicate that total scores are statistically significant between *PLOS Medicine* and *PNAS*, *SAGE Open*, and *Frontiers in Psychology*, but not between *PLOS Medicine* and *Frontiers in Psychology*. A lack of cohesion between journal instructions along with a decreased emphasis on scientific and technical jargon may allude to the disparity seen amongst scores for these four journals. This research depicts specific disparities between open-access journals, which may help revise journal guidelines to ensure cohesiveness and lay audience understanding.

Keywords: Lay summary, open-access, *PLOS Medicine*, *PNAS*, *SAGE Open*, *Frontiers in Psychology*

INTRODUCTION

A key skill in the field of scientific research is effectively conveying complex medical and/or scientific ideas to a lay audience. A lay audience is an audience which does not have expert knowledge on scientific concepts, and as such, require research to be conveyed in an ac-

cessible manner.⁸ For this reason, lay summaries, also referred to as inclusive summaries, are widely used in the press, research journals, funding sources, institutional review boards, and organizations to publicly express scientific research in a manner that is understandable by the lay audience.³

What is a lay summary?

Lay summaries are used widely to convey science to businesses, charitable organizations, and members of the general public.¹⁰ Lay summaries are key tools in conveying research results to clinical participants, and pitching research proposals to funding boards such as the Canadian Tri council.⁴ They include information about the background, aims of the study, significance, methods, results, conclusion, limitations, and next steps.¹⁸ A clear, well-written lay summary aids in the dissemination of science beyond the scope of academics. Lay summaries not only convey the science but add meaning to it by emphasizing its significance to the world of research. Lay summaries are of importance as they bring about awareness surrounding scientific topics to the public. They are also extensively used in securing funding for research projects.¹⁸

An effective lay summary tells the reader enough information to get a grasp of the research and understand the results, significance, and key takeaways. To enhance accessibility, lay summaries should be written in plain English, such that there is no scientific jargon in use, with abbreviations spelt out the first time they are used, and technical terms explained.¹⁸ Authors should answer the question “so what?” in their summaries, which is typically a question of interest for readers to gain an understanding of why the research is important and the impact that it has on society, if any.¹⁸

According to Dubé & Lapane,³ a successful lay summary encompasses a balance between oversimplified information and scientific explanations. To add creativity and maintain interest, analogies are used to express a concept and make it more relatable to everyday life.⁸ It is important to exclude uninteresting and/or hard-to-understand concepts, and instead use visual aids, along with writing in the active voice.¹⁶ Using visual aids makes the scientific concept more relatable, and the use of active voice prevents sentences from being too wordy, thereby improving clarity. Linte⁸ advises using short sentences and brief arguments to ease the digestion of information. A key tactic to uncovering whether a lay summary is written in accordance with a general audience is to ask a family member or friend who does not have knowledge on the topic to read it and provide feedback.⁸ It is important to note the difference between an abstract and lay summary; specifically that an abstract is a summary written in technical terms.

Lay summaries are an important part of publicly-funded research. There is evidence that suggests that the public resorts to published medical research when combating their own health issues.⁷ The general public reacted positively towards open-access research and found it advantageous to research medical conditions

and better understand the phenomena that they experience in their day-to-day.²² Tustin reported that individuals who are dissatisfied with medical professionals resort to open-access journals as a way to obtain medical information.²⁰ The public thus sees this as a positive coping mechanism for managing their illness as it provides them with knowledge, and feelings of involvement and certainty for their conditions.²⁰

The inability to convey the research and results of a study effectively leads to the spread of misinformation, a lack of credibility, and a lack of applicability of that research study to future projects. Although this is detrimental to researchers, the impact it has on the general taxpaying public must not be overlooked. The public is not fully aware of how their tax money is being spent.¹⁰ Simply making research available is not sufficient for its understanding. Issues arise when there is a lack of understanding of open-access journals due to technical jargon in lay summaries. The public instead resorts to lay sources for medical information rather than primary research, which may be deemed unreliable as lay sources are often not peer-reviewed, investigated by scientists, or written by medical professionals.¹⁰

To date, lay summaries are used broadly in various organizations and open-access journals as they continue to expand science and health literacy. Unfortunately, lay summaries are not as accessible to their audience as they originally are set out to be. There is no concrete definition provided to scientists in terms of what constitutes jargon and what is considered “plain English,” which may contribute to the inconsistency in lay summaries among open-access journals.

Lay summaries in open-access journals often go by different names, which already shows a form of disparity. This may confuse readers when they read one journal to the next. An open-access journal like *PNAS* calls the lay summary a “significance statement” while *PLOS Biology* refers to it as an “author summary.”²¹ Another disparity arises as there are inconsistencies in the length and inclusion criteria of lay summaries Organizations such as the UK Research Council, The Stroke Association, and the British Heart Foundation each use lay summaries to convey research to the public but have varying guidelines in terms of length.¹⁸ The UK Research Councils permits 600-1000 words, the Stroke Association permits 1,000 words, and the British Heart Foundation permits 100 words.¹⁸

The Current Study

Due to the lack of consensus among journals and the lack of exploration in the field of science communication with regards to lay summaries, this research study will explore the level of accessibility and effectivity of various lay summaries in four open-access journals:

PLOS Medicine, *Proceedings of the National Academy of Sciences (PNAS) of the United States of America*, *SAGE Open*, and *Frontiers in Psychology*.

PLOS Medicine is a peer-reviewed journal which covers a wide scope of medical sciences, and has an impact factor of 11.07 as of 2020.¹² This journal refers to the lay summary as the lay abstract, and instructs to avoid jargon, maintain a word count of 300-500 words, and ensure the summary is concise and accessible. It provides a breakdown of the individual components required for inclusion.¹² *PNAS* is a multidisciplinary, peer-reviewed scientific journal with an impact factor of 11.20 as of 2020.¹⁹ This journal refers to the lay summary as the significance statement and instructs to explain the significance of the research within 120 words.¹² *Sage Open* is a peer-reviewed journal reared around the behavioural and social sciences, and has an impact factor of 1.356 as of 2021-2022.¹⁵ This journal refers to the lay summary as the lay abstract, and instructs for it to be written in 150 words and address the purpose and accuracy of the individual manuscript components.¹⁵ *Frontiers in Psychology* is a peer-reviewed journal that covers a broad scope of psychology aspects, and has an impact factor of 2.99 as of 2020.² This journal refers to the lay summary as the lay abstract, and instructs writers to convey the overall significance in an accessible manner.²

We hypothesized that each of the four journals will differ greatly in the scores they receive due to a lack of consensus among guidelines provided to authors. Investigating this topic of research will grant an understanding of the current guidelines provided by these journals, and whether such plays a role in the efficacy and accessibility of lay summaries at communicating scientific discovery.

METHODS

This study analyzed a total of 20 lay summaries among four different open-access journals. Journals were considered open-access if the journal description mentioned that, and/or if the article was available to view without a pay wall, login credentials, or any sort of subscription. Five lay summaries were analyzed from each of the four journals, *PLOS Medicine*, *Proceedings of the National Academy of Sciences (PNAS) of the United States of America*, *SAGE Open*, and *Frontiers in Psychology*. Articles were chosen from the most recent issue tab/current issue tab on each journal website. The first five articles that appeared were selected and the lay summary (otherwise called significance statement or inclusive summary) were analyzed.

Summaries were graded based on the LIFESCI 2AA3 rubric (Appendix Figure A) that was created by Dr. Katie Moisse, assistant professor of curriculum and

pedagogy at McMaster University, School of Interdisciplinary Science. This rubric was used as it includes key characteristics that an accessible lay summary should have. This rubric entails four sections, each worth five marks, leading to a total score out of 20. The first section of the rubric focuses on the degree at which the study methods, results, and conclusions were accurately summarized. The second section focuses on the degree at which the study rationale, implications, and limitations were summarized. The third section focuses on the level of clarity and organization of the summary overall. The last section focuses on the level of accessibility, particularly whether the writing was tailored towards a general audience.

Raw data was inputted into a Microsoft Excel spreadsheet as seen in Appendix Figure B. Using a statistical software called Prism 9 GraphPad, a one-way ANOVA test was conducted between each journal's lay summary scores to determine whether there was a significant difference in scores between each journal. A one-way ANOVA test was also conducted on the journal scores for each criterion individually. Figures were created on Prism 9 – GraphPad.

RESULTS

To compare the effectiveness and accessibility of each journal, the five lay summary scores for each journal were compared as seen in Figure 1.

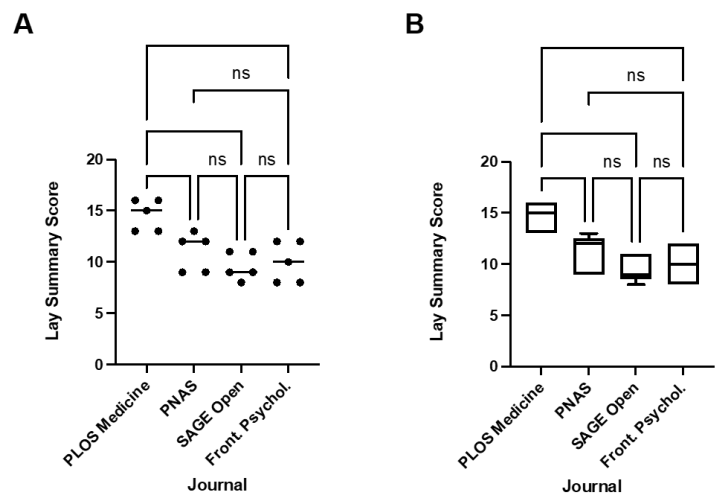


Figure 1. Lay summary scores for five summaries each in four open-access journals based on the LIFESCI 2AA3 rubric. A – Individual scores for five lay summaries are displayed for each journal via scatter plot ($n = 4$). One point on the graph represents the score out of 20 for one lay summary. The horizontal line represents the median score for each journal. Statistical significance is displayed via asterisks, with one asterisk representing lower significance ($p \leq 0.05$) and three asterisks representing greater sig-

nificance ($p \leq 0.001$). No statistical significance is represented by “ns.” B – Lay summary scores for each journal are displayed via box plots ($n = 4$). Error bars represent standard deviation. In both graphs, *Frontiers in Psychology* is abbreviated to *Front. Psychol.* for simplicity.

Figure 1 compares the scores between the four journals. *PLOS Medicine* ranked highest with an average score of 14.6, *PNAS* ranked second with an average score of 11, *Frontiers in Psychology* ranked third with an average score of 10, and *SAGE Open* ranked last with an average score of 9.6. Scores are statistically significant between *PLOS Medicine* and *PNAS*, *SAGE Open*, and *Frontiers in Psychology*, with $p = 0.0194$, $p = 0.0014$, and $p = 0.0030$ respectively. Based on the p -values, greater statistical significance exists between *PLOS Medicine* and *Frontiers in Psychology*, with even greater statistical significance between *PLOS Medicine* and *SAGE Open*. No statistical significance exists between *PNAS* and *SAGE Open*, *PNAS* and *Frontiers in Psychology*, and *SAGE Open* and *Frontiers in Psychology*.

To compare how each journal ranked for the individual criteria from the LIFESCI 2AA3 lay summary rubric, raw data were graphed as depicted in Figures 2 and 3.

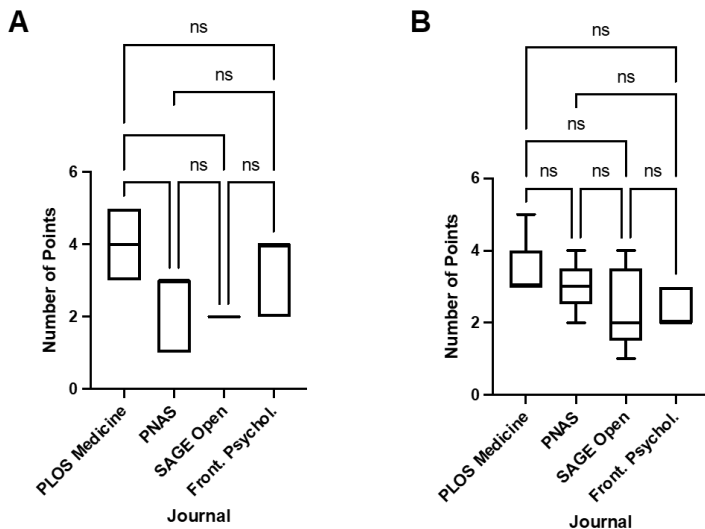


Figure 2. Lay summary scores for each journal based on criteria 1 and 2 from the LIFESCI 2AA3 rubric. A – Lay summary scores for criteria 1 on the rubric ($n = 5$). Standard deviation bars not evident. B – Lay summary scores for criteria 2 on the rubric ($n = 5$). Error bars represent standard deviation. In both graphs, *Frontiers in Psychology* is abbreviated to *Front. Psychol.* for simplicity. All scores are out of five. Statistical significance is displayed via asterisks. No statistical significance is represented by “ns.”

Criteria 1 and 2 focus on how the different components of the article were summarized. For criteria 1, *PLOS Medicine* scored the highest with an average of 4 points, *Frontiers in Psychology* ranked second with an

average of 3.2 points, *PNAS* ranked third with an average of 2.2 points, and *SAGE Open* ranked the lowest with an average of 2 points. Scores are statistically significant between *PLOS Medicine* and *PNAS*, and between *PLOS Medicine* and *SAGE Open*, with $p = 0.0322$ and $p = 0.0163$ respectively. No statistical significance exists between all other journal pairings. For criteria 2, *PLOS Medicine* scored the highest with an average of 3.4 points, *PNAS* ranked second with an average of 3 points, with *Frontiers in Psychology* and *SAGE Open* scoring the lowest with an average of 2.4 points. Scores are not statistically significant between any of the journals.

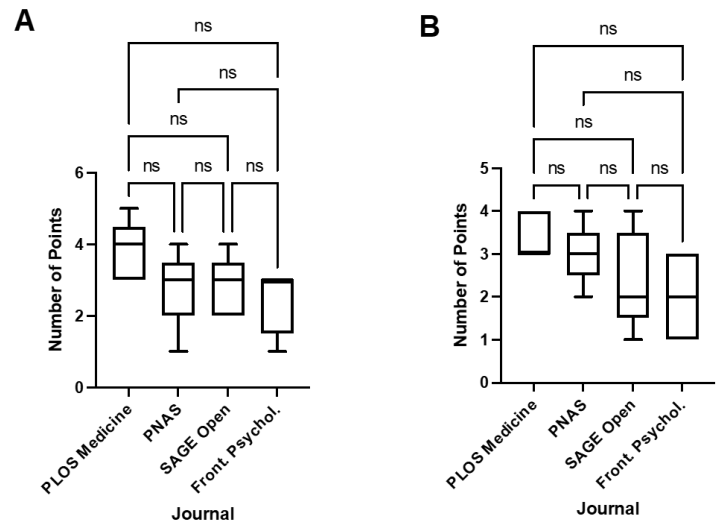


Figure 3. Lay summary scores for each journal based on criteria 3 and 4 from the LIFESCI 2AA3 rubric. A – Lay summary scores for criteria 3 on the rubric ($n = 5$). Error bars represent standard deviation. B – Lay summary scores for criteria 4 on the rubric ($n = 5$). Error bars represent standard deviation. In both graphs, *Frontiers in Psychology* is abbreviated to *Front. Psychol.* for simplicity. All scores are out of five. No statistical significance is represented by “ns.”

Criteria 3 and 4 focus on overall flow and accessibility. For criteria 3, *PLOS Medicine* scored the highest with an average of 3.4 points, *PNAS* and *SAGE Open* tied for second with an average of 2.8 points, and *Frontiers in Psychology* ranked the lowest with an average of 2.4 points. Scores are not statistically significant between any of the journals. For criteria 4, *PLOS Medicine* scored the highest with an average of 3.4 points, *PNAS* ranked second with an average of 3 points, *SAGE Open* ranked third with an average of 2.4 points, and *Frontiers in Psychology* ranked the lowest with an average of 2 points. Scores are not statistically significant between any of the journals.

DISCUSSION

This study analyzed the effectiveness and accessibility of lay summaries across four open-access journals using the LIFESCI 2AA3 rubric. The results conclude that *PLOS Medicine* ranked the highest for all criteria analyzed, while *SAGE Open* typically ranked on the lower end of the scale. This conclusion may be attributed to the varying guidelines proposed by the individual journals. *PLOS Medicine*'s impact factor is 11.07 as of 2020, which is quite high on the spectrum compared to *Frontiers in Psychology* and *SAGE Open* which each have impact factors below 3.^{11,14,15} The author guidelines for this journal mention that any submitted writing should avoid jargon and should be concise and accessible for readers who are not experts in the field, or for those who don't speak English as a first language.¹² The guidelines mention that editors assist with the process to ensure conciseness and accessibility, and that an initial evaluation is conducted for peer review. This requirement may explain *PLOS Medicine*'s significantly higher overall average compared to the other three journals, as seen in Figure 1. In terms of specific lay summary guidelines, the journal mentions a word count (300-500 words), the individual sections that are required (background, methods, and conclusions), and information pertaining to each section. The guidelines mention that background information including rationale and study objects should be mentioned, which may contribute to *PLOS Medicine*'s slightly higher average for criteria 2 in Figure 2, compared to the other journals. The methods and findings guidelines instruct for a description of study participants, design, intervention, analysis, outcomes, and limitations, which are clear guidelines for what is expected, and thus may attribute to *PLOS Medicine*'s significantly higher score for criteria 1, as seen in Figure 2. For criteria 3 and 4, given that clear guidelines were provided and the guidelines instructed to avoid jargon, this may have contributed to the higher average for *PLOS Medicine* as seen in Figure 3.¹²

PNAS has a slightly higher impact factor of 11.20 as of 2020, and claims to publish largely cited research, alongside offering professional editing and exceptional peer review.¹³ This journal refers to the lay summary as a significance statement, and its guidelines are only two sentences. The guidelines mention that the statement should be a maximum of 120 words and explain the significance while being "understandable to an undergraduate-educated scientist."¹⁹ Considering undergraduate scientists are not a lay person and have varying knowledge on scientific topics already, this may attribute to the scientific jargon found in lay summaries. The guidelines are brief and do not make reference to any specific components, such as background information, methods, or results, which may explain why the journal did not score on the higher end (i.e. four or

five points) for criteria 1 and 2. The guidelines do not advise to refrain from using jargon, which may attribute to why *PNAS* scored significantly lower in Figure 1 when comparing to *PLOS Medicine*, a journal whose guidelines mention avoiding jargon. Given that criteria 1 is focused on the methods, results, and conclusions, this tends to be the most jargon-heavy portion of the summary, so without guidelines on jargon, a low score is expected from *PNAS*. *PNAS* also caters to a scientific audience over a lay audience, which may also explain this result. This journal's guidelines mention that manuscripts do not need to be formatted in a specific manner/according to any specific guidelines during the initial submission, which may reason for why *PNAS* scored on the lower end (average of 2.8 points) for criteria 3, a criterion that focuses on the overall organization and clarity of the manuscript. The journal guidelines mention that laboratory jargon should be avoided and that abbreviations should be defined in the main text, but there is no mention of this for the lay summary.¹⁹ This may attribute to why *PNAS* scored an average of 3 points for criteria 4, a criterion focused on accessibility, rather than scoring on the higher end (4 to 5 points).

Frontiers in Psychology has an impact factor of 2.99 as of 2020, which is on the lower end of the spectrum.¹⁴ The journal guidelines refer to the lay summary as the lay abstract and mention very briefly that the general significance of the research should be conveyed, it should be "clearly accessible to a broad readership," and that abbreviations should be limited.¹ Aside from the fact that the journal guidelines as a whole are very vague, "accessible" and "broad readership" are not defined. It is unclear as to whether "accessible" means that it should be easy to access on the Internet based on the article title, or whether it means that it should be easy to understand by a lay audience. Authors submitting their manuscripts may find this guideline unclear, which is reflected in criteria 4, a criterion focused on accessibility, in which *Frontiers in Psychology* ranked lowest on. The guidelines mention a "broad readership" which to some researchers may mean someone who is knowledgeable in many fields, and to others, someone who is not knowledgeable in any field. The level of "lay" is not understood here, which impacts criteria 4. The guidelines do not mention any specifics as to which sections are required in the lay abstract, which may attribute to the fairly low score for criteria 2 (study rationale, implications, and limitations) but higher score for criteria 1 (methods, results, and conclusions). Researchers may believe that the methods, results, and conclusions are the most important part of the abstract, so without specific guidelines, they may neglect the study rationale, limitations, and implications, and focus solely on the methods, results, and conclusions, thus leading to the scores seen in Figure 2. The guidelines also do not mention a word count which may attribute to the fairly low score for criteria 3, a criterion focused on

overall clarity and organization.¹ Without a strict word count, researchers may include too much or too little information, thereby impacting clarity.

As of 2020-2021, *SAGE Open* has an impact factor of 1.356, the lowest amongst the four journals.¹⁵ The manuscripts published to this journal are peer-reviewed by two experts, but the process differs from the traditional approach such that *SAGE Open* places more emphasis on the accuracy of the research methodology, results, and conclusion.⁹ This takes focus off of summarization and accessibility, which may attribute to why *SAGE Open* scored significantly lower on criteria 1 and 2 compared to *PLOS Medicine*, and on the lower end for criteria 4. The guidelines place a heavy focus on making articles discoverable and advises for discoverable titles and abstracts. This emphasizes gaining publicity, and as such, manuscripts published in this journal may not be targeted towards a lay audience, explaining the low score for criteria 4, a criterion focused on accessibility. The specific abstract guidelines do provide a word count, which may attribute to why *SAGE Open* tied for second for criteria 3, a criterion focused on organization and clarity. A strict word count may make the research more concise and only focus on important details, thus enhancing the clarity of the summary. The journal guidelines mention which sections to include (purpose, methods, results, and conclusions), but does not provide any specifics on what each section entails, like *PLOS Medicine* does.⁸ This is reflected in Figure 2, as *SAGE Open* scored lowest for criteria 1 and 2, both of which are criteria reared around the individual components of the lay summary.

Overall, it is evident that *PLOS Medicine* scored highest on all criteria. When comparing *PLOS Medicine* to the three other journals, there is a substantial difference in the amount of information provided on the author guidelines page. A key reason for this may be because *PLOS Medicine* is the only journal that explicitly states to avoid jargon, while the three other journals do not explicitly mention such. Another reason for this may be because *PLOS Medicine* is the only journal that breaks down the individual components of the summary (background information, methods, results, conclusions) while also providing further instructions for each individual section. A third reason for *PLOS Medicine*'s significantly higher ranking may be because this journal is the only journal whose guidelines mention limitations and future implications, which is one of the criteria on the rubric. Many researchers may find this information irrelevant to mention in the lay summary, and without any guidelines on it, will likely disregard including it at all.

Although the results in this study are promising, there were some limitations. A limitation of this study is that there was an insufficient sample size due to time con-

straints. Given that only 20 lay summaries were analyzed, there is not enough data to generalize the results and conclusions of this study to each individual journal, and a smaller sample size decreases statistical power. Another limitation is that there was only one grader for the summaries, so the study lacks interrater reliability. This may bias the study as all of the data and results are based solely on one individuals' interpretation. The rater's status, as an undergraduate student in science, differs widely from a lay person, and may influence what is considered jargon and what is not. A third limitation of this study may come from the selection of articles from each journal. There was no way to control for the type of subject area that was of focus for each article. For example, one journal may have five, very heavy, biology-based articles in their recent issue, while another journal may have articles focusing on climate change in their recent issue. The climate change articles are likely more accessible and easier to understand by a lay audience, simply because of the subject at hand. This may bias the results as there was no control measure for the type of subject, but rather articles were picked at random, providing an unfair advantage to some journals over the other. Another limitation is that only the first five articles from each journal were analyzed, which disregards older lay summaries that could have been better/worse, and skewed the results accordingly.

The LIFESCI 2AA3 rubric may also have some limitations within it. The rubric does not provide specific instructions on specific components to look for and what is considered "accurately summarize." Some raters may assume this means to concisely describe the study, some may assume it means to correctly describe the study, and some may assume both. There is also ambiguity in terms of how the comments for 2 points and 3 points differ on the rubric for criteria 1 and 2 as they both sound quite similar and revolve around the same idea of confusion. As such, different raters may assign points differently. Lastly, the rubric does not explicitly state to look for jargon, although this is where a lot of the issues with inaccessible lay summaries stems from.

Next steps include reproducing this study with more journals and more lay summaries from each journal. This will make the conclusions of the study more generalizable to the journal and provide guidance to the journal in terms of how the author guidelines should be changed to enhance effectiveness and accessibility of lay summaries. Another next step is to impose a cohesive set of guidelines for constructing these lay summaries universally between all journals. This will assist in sustaining the level of open-accessibility that a journal displays, while also making it easier for readers to follow and understand. Lastly, all researchers who plan to publish a manuscript in any open-access journal should be required to attend a set number of sci-

ence communication workshops, in order to fully demonstrate their understanding of accessibility and effectivity with regard to lay summaries. The LIFESCI 2AA3 rubric used in the study could also be tweaked slightly to add some clarity. For instance, there could be more specifics on each individual section such as the methods, which could be further broken down into study participant criteria, the type of study, and the intervention. There should also be a section on the rubric that explicitly states that jargon is avoided in the summary, as this is the root cause of inaccessible lay summaries.

CONCLUSION

The main findings of this study suggest that there are differences in the effectiveness and accessibility of lay summaries between different open-access journals. This disparity may be attributed to varying guidelines provided by each journal to authors creating these lay summaries for public dissemination. Consistency between journal guidelines as well as the incorporation of specific guidelines against scientific jargon may help improve the cohesiveness, quality, and accessibility of lay summaries amongst open-access journals.

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APPENDIX

Content	Level 5 5 points	Level 4 4 points	Level 3 3 points	Level 2 2 points	Level 1 1 point	Criterion Score
Did you accurately summarize the study methods, results and conclusions?	You excelled at this task, providing information that was consistently on-point.	Your summary is mostly accurate but sometimes ambiguous.	Your summary is mostly accurate but incomplete, introducing the potential for confusion.	Your summary raises multiple questions or lacks focus and was difficult to unpack.	Your summary contains multiple inaccuracies.	/ 5
Did you accurately summarize the study rationale, implications and limitations?	You excelled at this task, providing information that was consistently on-point.	Your summary is mostly accurate but sometimes ambiguous.	Your summary is mostly accurate but incomplete, introducing the potential for confusion.	Your summary raises multiple questions or lacks focus and was difficult to unpack.	Your summary is off-point.	/ 5
Style	Level 5 5 points	Level 4 4 points	Level 3 3 points	Level 2 2 points	Level 1 1 point	Criterion Score
Is your writing clear, clear and logically organized?	Your writing is free of typos and grammatical errors and easy to follow, with smooth transitions that carry your reader from one thought to the next.	Your writing is clean and your sentences are strong, but the overall organization could be improved.	Your writing contains one typo, grammatical error, confusing sentence or awkward transition or it lacks some clarity in terms of sentence structure and organization.	Your writing contains more than one typo, grammatical error, confusing sentence or awkward transition.	Your writing has multiple mistakes or minimal flow.	/ 5
Is your writing tailored to its audience and purpose?	Your writing is a joy to read, you make complex concepts relatable and consider your audience from start to finish, in terms of the language you use and the organization of your thoughts.	Your writing is accessible and contains elements that will engage your audience.	Your writing is generally accessible and contains at least one element aimed at engaging your audience, but some parts fall flat.	Your writing is generally accessible but it lacks elements that will engage your audience and keep them reading from start to finish.	Your writing contains words or descriptions that are inaccessible to your audience or may bore them.	/ 5
Total						/ 20

Figure A. LIFESCI 2AA3 rubric for lay summaries.

Journal Name	Lay Summary #	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Total /20	Average
PLOS Medicine	Lay 1	3	5	5	3	16	14.6
	Lay 2	5	3	4	4	16	
	Lay 3	5	3	3	4	15	
	Lay 4	4	3	3	3	13	
	Lay 5	3	3	4	3	13	
PNAS	Lay 6	3	3	3	3	12	11
	Lay 7	3	2	1	3	9	
	Lay 8	1	3	3	2	9	
	Lay 9	3	4	3	3	13	
	Lay 10	1	3	4	4	12	
SAGE Open	Lay 11	2	2	3	4	11	9.6
	Lay 12	2	4	2	3	11	
	Lay 13	2	2	3	2	9	
	Lay 14	2	1	4	1	8	
	Lay 15	2	3	2	2	9	
Frontiers in Psychology	Lay 16	4	2	3	3	12	10
	Lay 17	2	3	2	1	8	
	Lay 18	2	3	1	2	8	
	Lay 19	4	2	3	1	10	
	Lay 20	4	2	3	3	12	
	Total	57	56	59	54	226	
	% out of 100 points	0.57	0.56	0.59	0.54		

Figure B. Raw lay summary scores for each journal based on the criteria listed on the LIFESCI 2AA3 rubric

Comparison of Progressive and Conservative Representations of Men's Mental Health in Written News Media

Manvir Kaur Chima¹, Sashini Buddima Kosgoda¹,
Julia Solina Angelyca Pagotto¹

1. McMaster University, Life Sciences, Class of 2022

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SUMMARY

During most recent years, mental health has come to the forefront in the media. However, men's mental health is still often stigmatized. This is concerning as men are less likely to receive treatment for mental health conditions.¹ Throughout this paper, we will be investigating the representation of men's mental health in progressive versus conservative news media, as society is often reliant on media.

Based on our criteria, progressive news media scored higher than conservative news media on their support of men's mental health. However, both political landscapes had few articles covering the topic between the years 2010 and 2020. Less than half the total number of articles provided external resources for men struggling with their mental health.

Although our findings suggest a better representation of men's mental health in progressive news media, there is still a limited overall representation. Men's mental health should be further discussed in written news media and the appropriate resources should be provided within each article. It is crucial that further research be conducted with larger sample sizes to determine whether these differences are widespread, and what the consequences of these differences are.

ABSTRACT

Men's mental health has long been stigmatized in Western society. The media plays a substantial role in emphasizing the importance of mental health; however, a gender disparity exists as men are often less highlighted than women in regard to this subject. This study investigated whether a difference in men's mental health portrayal exists between progressive and conservative news media in the United Kingdom. Using Factiva, eight news articles were analysed; these included: The Guardian, The Daily Mirror, The Daily Telegraph, and The Times, yielding a sample size of 32. Five criteria were established to score the articles on a Yes (1) or No (0) scale. An ANOVA and a t-test were used to determine the statistical significance of the results. The analyses showed significantly higher scores for progressive news media than conservative news media, whereby The Guardian had the highest percentage of articles that included criteria 1 through 4. The findings revealed a significant difference between how men's mental health is portrayed in progressive versus conservative news media. Specifically, there was a better representation of men's mental health in progressive news outlets. Since a limited number of papers were analysed, further research should be conducted to better understand the portrayal of men's mental health in the media.

Keywords: Male, mental health, progressive media, conservative media, written news media, stigma

INTRODUCTION

According to the National Institute of Mental Health,¹ the prevalence of mental illnesses is lower among men compared to women. However, men are also less likely to receive treatment for their mental health conditions. This poses an interesting question as to whether men actually experience fewer incidences of mental illness, or if they are more likely to dismiss and conceal their mental health conditions due to internalized stigmas.

Gendered ascriptions of stoicism to men and emotional vulnerability to women have long been the convention in Western society. However, enforcing certain attitudes and behaviours as primarily male or female can have damaging mental health effects on people of all gender identities. An example of this, which is specific to American men is demonstrated by their suicide rate, which was 3.73 times higher than that of American women in 2019.² Coleman et al.³ suggest that this disparity may be linked to high traditional masculinity (HTM), which is a set of attitudes and behaviours normally associated with men. These include emotional

restriction, physical fitness, and aggression. The researchers found that HTM men were 2.4 times more likely to commit suicide, but 1.45 times less likely to report suicidal ideation compared to non-HTM men.³ Societal representations of masculinity can therefore affect mental health outcomes for men, as many men internalize these stereotypes and strive to act in accordance with them. It is important to analyse how the news media portrays men's mental health issues. The media has, the potential to shape the public's perception of these topics in a way that can either empower men to openly discuss their struggles and seek therapy or, alternatively, to suffer in silence.

Research on news coverage of mental health disorders (MHDs) in men is limited.⁴ Currently, our proposed study on how politically progressive versus conservative news outlets portray men's mental health issues is a novel avenue of research. Previous studies have focused on the general news coverage of MHDs in men and found that, as a whole, these types of articles tend to convey a negative tone and link MHDs with violence.⁵⁻⁷ With political polarization being a deep-seated issue in the United Kingdom,⁸ it would be interesting to decipher whether progressive or conservative news outlets in this region are perpetuating this stigmatization of men's mental health issues. Current literature has illustrated that individuals who hold conservative political beliefs are more likely to stigmatize mentally-ill individuals.^{9,10} The present study expands upon this body of research by uniquely examining the role of political biases within news media and how that has influenced their portrayal of mental health issues, specifically in men. The purpose of the study was to elucidate whether certain types of news outlets promote harmful portrayals of MHDs in men, thus highlighting an area of news coverage in need of reform.

We specifically examined how supportive progressive news media outlets in the United Kingdom were compared to conservative news media outlets when reporting on the topic of men's mental health within a 10-year time period between the years 2010 to 2020. The four outlets we chose to focus on were: The Guardian (TG), The Daily Mirror (TDM), The Daily Telegraph (TDT), and The Times (TT). The first two are progressive and the latter two are conservative. Since previous research indicates that people with conservative political beliefs carry more negative views about men's mental health issues, we hypothesized that conservative news media outlets would be more likely to cast the topic of men's mental health in a negative light compared to progressive news media outlets.

METHODS

Data Collection

Factiva was used to search for news articles for our research study. Factiva is a database, which allows one to search for current and archived publications from news media outlets. Eight news articles about men's mental health, which were published between the years 2010 and 2020, were selected from each of the following popular U.K. news outlets: The Guardian (TG), The Daily Mirror (TDM), The Daily Telegraph (TDT), and The Times (TT).

Search Criteria

To search for articles in Factiva, we inputted "men's mental health" into the search bar entitled "this exact phrase," followed by "man, men, male, males" into the search bar entitled "at least one of these words", so that our search results would also encompass these synonyms. We searched for articles published by the four news outlets mentioned earlier; we then further refined our search by only including articles that were written in English within the timeframe of January 1, 2010 to December 31, 2020. We excluded duplicate articles as well as blog posts and focused solely on news articles for this study. The total sample size was 32 articles, with eight articles from each news outlet.

Scoring System

First, we briefly read through all of the retrieved news articles to determine if the theme of the articles was about mental health in general or specifically men's mental health. All articles that discussed mental health in a general setting, were deemed inappropriate for the analysis and were excluded. The remaining articles were further analyzed, and scores were given to the articles based on the criteria mentioned below.

Approach

Two individuals assessed each article. The content of each article was analyzed in light of five criteria. For each article, we went through each criterion and stated "yes" if the article met the criterion and "no" if the article did not. For each "yes" given, one point was awarded, and for each "no" given, a score of zero was awarded. A total score out of five was given to each article. After analyzing the articles from each news outlet, we totalled the scores of all the articles from the progressive and conservative outlets separately. We then subsequently divided them by their respective number of articles in order to obtain an average article score for each side. The side with the higher score was determined to have greater support for men's mental health.

The criteria used to analyse the articles and constitute a “yes” designation (i.e. 1 point) were as follows:

1. Claims made about male mental health are supported with quotes from mental health experts or institutions
2. Personal experiences from men with mental health conditions are included
3. Themes of recovery, rehabilitation, and systemic issues regarding the shortage of institutional resources and poor quality of mental health care are conveyed
 - Possible key phrases to look for include: “in need of support,” “not alone,” “destigmatize,” “empathize,” “lack of services,” “more funding required”
4. Themes of violence, criminality, and personal failings are **NOT** conveyed
 - Possible key phrases to look for include: “crazy,” “shocking behaviour”, “needs to be locked up”, “danger to society”, “acting selfishly”, and “personal responsibility”
 - Note: Since these phrases are indicators of violence, criminality, and personal failings, we ensured their absence in order to determine that a given article did not convey the aforementioned themes, and was therefore supportive of men’s mental health
5. Links to mental health resources are included

Statistical Analyses

Using the Prism GraphPad software, an analysis of variance (ANOVA) was performed to determine statistically significant differences between the average article scores, as well as the percentage of news articles containing each criterion across all four news outlets. A t-test was then conducted using the same software, in order to determine statistically significant differences between the average article score of the progressive news outlets compared to the conservative ones.

RESULTS

Comparing average article scores for each news outlet provides an understanding of men’s mental health portrayal in progressive versus conservative news media. ANOVA was utilized to explore between-group differences for each news outlet, while an unpaired t-test was used to determine the differences between progressive and conservative news outlets.

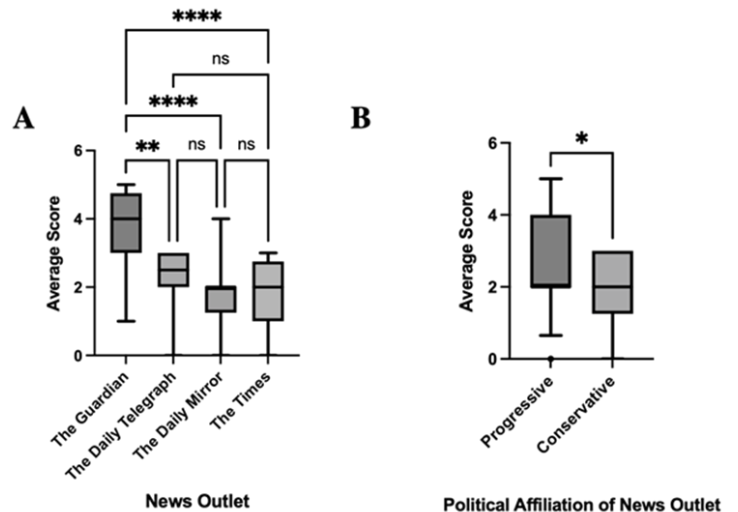


Figure 1. Average article scores for news media based on five criteria. (A) Box plot representing average scores for individual news outlets (n = 8). **(B)** Box plot representing average scores based on political affiliation of news outlets (n = 16). The scores for TG and TDM are grouped as progressive, whereas the scores for TDT and TT are grouped as conservative. In both graphs, scores are out of five and averaged among two raters. Error bars represent standard deviation. Statistical significance is denoted by asterisks, and no significance is denoted by “ns”.

The mean average scores were 3.625, 2.250, 1.875, and 1.813 for TG, TDT, TDM, and TT, respectively. TG was statistically significant compared to the other three outlets (TG vs TDT: $p = 0.0023$, TG vs TDM: $p < 0.0001$, TG vs TT: $p < 0.0001$). All other between-group comparisons were not significant (TDT vs TDM: $p = 0.7387$, TDT vs TT: $p = 0.6358$, TDM vs TT: $p = 0.9982$). TG had the highest mean score, while TT had the lowest. Based on Figure 1B, there was statistical significance between progressive and conservative news media ($p = 0.0207$). The progressive news media mean score (2.750) was significantly higher than conservative news media (2.031).

Comparing the percentage of articles with each criterion across the four outlets provides an understanding of what each news outlet prioritizes when reporting men’s mental health. ANOVA aided in exploring the differences between groups for each outlet based on individual criterion.

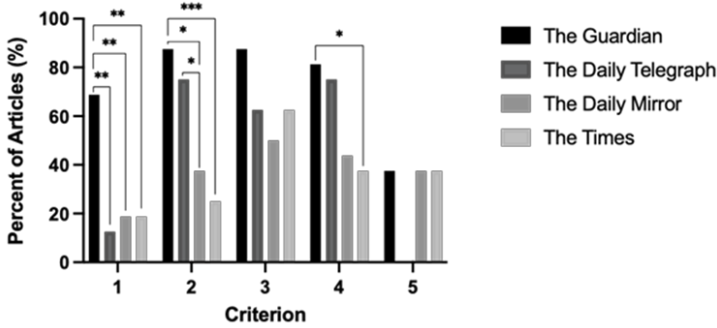


Figure 2. Percent of news articles that portray criterion 1 to 5 (n = 8). Statistical significance is denoted using asterisks.

Based on Figure 2, TG had the highest percentage of articles that included criterion 1 through 4. For criterion 1, only TG was statistically significant compared to the other three outlets (TG vs TDT: $p = 0.0014$; TG vs TDM: $p = 0.0055$; TG vs TT: $p = 0.0055$). For criterion 2, TG was statistically significant compared to TDM ($p = 0.0105$) and TT ($p = 0.0009$), and TDT was statistically significant compared to TT ($p = 0.0105$). For criterion 4, TG was statistically significant compared to TT ($p = 0.0496$). All other between-group comparisons were not significant.

Comparing the percentage of articles with each criterion across the two political groups provides an understanding of what progressive versus conservative news media prioritize when reporting on men’s mental health. ANOVA was utilized to explore between-group differences for the two types of outlets based on individual criterion.

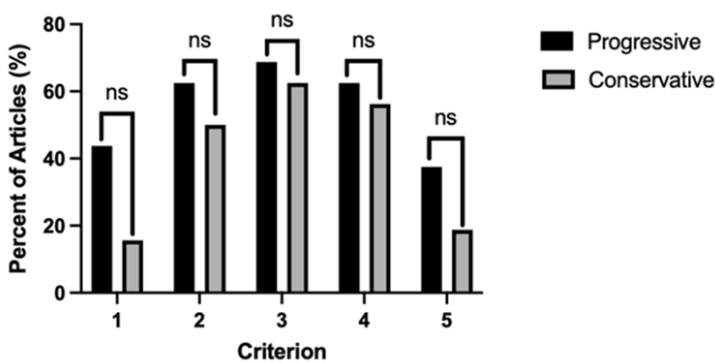


Figure 3. Percent of news articles that portray criterion 1 to 5 based on political affiliation of news outlet (n = 16). Statistical significance is denoted using asterisks.

According to Figure 3, a larger percentage of progressive outlets scored higher on all criteria. No statistical significance exists ($p = 0.2094$) between progressive and conservative news media for each criterion.

DISCUSSION

Analysis of Results

Our hypothesis that conservative news media outlets are more likely to negatively portray men’s mental health compared to progressive news media outlets was supported by the significant score differences in the t-test between these two types of outlets (Figure 1B). Another notable finding was that The Guardian scored significantly higher than the other outlets- even compared to The Daily Mirror, which is also progressive. As shown in Figure 2, articles from The Guardian were significantly more likely to satisfy the first two criteria, meaning they contained information supported by mental health experts and incorporated more personal experiences from men who have mental health issues. This could be due to the fact that The Guardian is only owned by The Scott Trust, a trust established solely for ensuring the quality and the journalistic freedom of The Guardian.¹¹ Therefore, The Guardian can publish articles that focus on quality of content rather than the views of shareholders or organizations.

Moreover, The Guardian scored higher than the other outlets for criteria 3 (Figure 2), meaning that its articles were more likely to discuss the shortage of institutional resources offered to men and the poor quality of men’s mental health care. Although the differences in the scores were not significant, these findings align with previous studies which reveal that conservative parties have a greater negative outlook on mental health.¹² Current literature also reveals that people with conservative beliefs are more likely to stigmatize mentally-ill individuals.^{9,10} This aligns with our findings from Figure 1B, as progressive news media outlets scored significantly higher than conservative news media outlets resulting in a more supportive portrayal of the mental health issues discussed within their articles.

Furthermore, previous research has found that conservative news outlets tend to portray mentally ill individuals as a danger.¹³ In our study, Figure 2 shows that there was a significant difference between The Guardian’s (progressive) score for criteria 4 compared to that of The Times (conservative), indicating that The Times’ articles were more likely to include themes of violence, criminality, and personal failings when discussing men’s mental health. However, there was no significant difference when comparing this criterion among progressive versus conservative outlets as a whole (Figure 3).

Interestingly, future plans of the Labour (progressive) and Conservative parties in England have indicated that although the Labour Party claims to support mental health on their platforms, they have not followed

through with their intentions. During the 2010 election in England, the Labour Party's platform mentioned the need to increase mental illness support. However, the Conservative Party only followed through with their plans by investing money in mental health support and reforming the Mental Health Act.¹⁴ This suggests that although progressive political beliefs may lead to supportive discussion around mental health topics, it may not translate to taking action to help the cause. A similar finding was noted in our study when looking at the scores for criteria 5 in Figures 2 and 3. The four news outlets scored similarly with low scores across the board, indicating that few articles provided links to mental health resources.

Limitations and Next Steps

Within this paper, there are some limitations that should be addressed. There were only eight articles used for each of the four news outlets for a total sample size of 32 articles. This is a relatively small sample size, resulting in a low statistical power. Additionally, the ANOVA test assumes that the data collected is normally distributed. However, since our variables are discrete, they cannot be normally distributed. Thus, the p-value may not be exact. In future research, more news articles should be used from various different news outlets. This will provide a larger sample size to allow for stronger statistical power and the ability to generalize results. Furthermore, by looking at more news outlets, trends can be better understood.

Another limitation is human bias regarding the collection of data. Although each article was reviewed by two individuals in order to reduce bias, this bias is still present. Moreover, although the articles were scored by two individuals, it was a different pair of individuals for each article. To eliminate this bias, future research can utilize programming software to sift through and score written news articles. This will also allow more articles to be covered and therefore provide a larger sample size.

The final limitation involves the type of media that was used. In this paper, only written news articles were used to represent the coverage of men's mental health in the media, but there are other forms of media that cover men's mental health and including them would allow for the findings of this research to be more generalizable. As a next step, research should look at different media outlets, such as Instagram, Twitter, YouTube, and other social platforms. Looking at other platforms will allow for a more rounded understanding of how men's mental health is portrayed and communicated in media.

CONCLUSION

In conclusion, our findings suggest that there is a statistically significant difference between the way men's mental health is portrayed in progressive versus conservative written news media, with progressive outlets being more supportive in their reporting overall (Figure 1B). Progressive news outlets also scored higher than conservative news outlets when compared using individual scoring criteria; however, these differences were not significant. Although our findings suggest that there is a better representation of men's mental health in progressive news outlets, further research with larger samples of news articles and more types of media would be needed to determine whether this difference in reporting is widespread and what its consequences are.

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The Impact and Effectiveness of Science Communication Training in the Honours Life Sciences Program at McMaster University

David Rodrigues^{1,2}, Katie Moisse³

1. McMaster University, Life Sciences, Class of 2022

2. Queens University, Msc Aging and Health

3. McMaster University, Assistant Professor, School of Interdisciplinary Science

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SUMMARY

Science communication (scicomm) is the practise of using a variety of techniques to explain scientific knowledge to diverse audiences (i.e, general public, other scientists, children). This is fulfilled in order to spread awareness, create enjoyment, form an opinion, and enhance ones understanding. The ineffective communication, which the public receives is often due to scientists failing to acquire formal scicomm training in their undergraduate programs. This is needed in order to accurately communicate their research to a lay audience. This study investigates scicomm training, practises, and teaching at a whole degree across various types of courses within the undergraduate Life Sciences program at McMaster university. Based on the results, there were four skills that illustrated an increase in comfort (effectively practising/performing a skill), and four skills that showed an increase in discomfort (difficulty practising/performing a skill). Upon completing a scicomm course, there were four skill sets, which indicated that students showed an increase in comfort, regarding their ability to practise them. The results of this study contribute to curriculum development by identifying overlap; furthermore, they expose gaps of knowledge within the science program. These results influence and suggest appropriate changes to the existing curriculum, course activities and assessments, promote the development of these fundamental skills for science students as they progress through their undergraduate degrees, which is required in both academia and the workplace.

ABSTRACT

Proper training in science communication (scicomm) skills are consistently falling short of requirements in higher education. This highlights the need to examine a curriculum as a whole as opposed to a course level view. This study investigates whether or not students in their current undergraduate level are comfortable with performing various scicomm skills, in addition to exploring if the dedicated scicomm courses are effectively teaching students the necessary skills. We administered a survey to students on topics regarding scicomm, and asked them to rate their level of comfort, agreement, ranking of importance, and open-ended questions. Four scicomm skills that had the greatest increase in comfort; Argumentative Writing (12%), Literature Review (15%), Public Lecture-Style Presentation (19%), and Oral Presentation (30%). Alternatively, four scicomm skills had the greatest increase in discomfort; Debate (15%), Audio (18%), Policy Communication (19%), and Public Debate (22%). Upon completion of the scicomm courses, there was an increase in comfort for; oral science communication (22%); selecting and using the appropriate written, oral, and multimedia tools (24%); communicating science in written forms (26%); and personal knowledge of written, oral, and multimedia tools (50%). A small sample size, missing data (voluntary questions), omittance of Life Sciences research seminar courses, and uncertainty if academic level implied one took the course(s) in the same year, were limitations. These findings can inform changes to the existing curriculum in order to facilitate the development of scicomm skills for science students as they progress through their undergraduate degrees.

Keywords: Science, communication, training, student, skill, program

INTRODUCTION

The field of science communication (scicomm) is a developing discipline of research and practice that is continuously evolving.¹ Science communication entails using a variety of skills to discuss scientific philosophies, knowledge, research, and critiques to a non-science audience in an accessible, engaging, and useful manner. The goals of science communication are to spread awareness, create enjoyment, develop an interest, form an opinion, and create a better understanding when one is reading.¹ It is important to describe what science communication is and its purpose, due to the interdisciplinary nature of the field and the varying definitions and opinions on it.² This area of academia is not meant to encourage scientists to discuss more about their work, but to make sense of their science and inform the intended audience.¹

Communication skills are one of the largest recognized learning outcomes across multiple undergraduate programs in higher education.³ Learning outcomes are developed to aid in course design, teaching of material, learning opportunities, and course difficulty.⁴ Learning outcomes describe the knowledge, skill, and fundamentals that one should acquire upon completion of an evaluation, course, or program.⁴ Informing the public on matters related to science has become increasingly difficult for graduates of science programs due to scicomm training not being explicitly mentioned as a learning outcome. The responsibility of communicating science research, breakthroughs, and discoveries to a variety of individuals with different levels of education, has been linked to science practitioners.³ Today, there is a global push to improve scientists' abilities to communicate research, in order to avoid the spread of misinformation and poorly communicated knowledge.^{3,5} Science communication has transformed how research is prioritized, practised, and governed, this includes changing policies to accurately convey scientific findings.⁶

When trying to develop a skill, training is at the core of achieving it. Communicating about any topic, especially science, is no different. Today, scientists are expected to communicate with the public to encourage informed decision making and increase science literacy.⁷ The "lay public" is everyone in society, including scientists in different disciplines (non-experts).^{4,7} It is a group encompassing individuals of different professions, ages, cultures, socio-economic circumstances, and levels of knowledge.^{4,7} The current rise of "media science" is growing and diverse.⁸ Access to traditional forms, such as the news and various social media platforms aids in the immediate spread of information. This has influenced the push for scientists to actively connect with the public and build trust.⁸ It is important to understand that not all science communicators are scientists and not all scientists are meant to be

science communicators. Individuals, such as reporters, bloggers, and social media content creators are able to engage in science communication.⁸ But scientists will always be regarded by news reporters, government officials, and governing bodies when making bylaws and policies.⁸

The ineffectiveness of communication that the public receives is not entirely due to a lack of science literacy, but failure in scientists acquiring formal training in science communication during their undergraduate programs.² Scientists are trained in analytical skills, research methodologies, problem-solving, critical thinking, and scientific literature between other scientists. These skills create the foundation for an effective scientist in order to conduct and carryout exceptional research. However, these same scientists do not learn the fundamentals required in order to communicate their research to a lay audience, as their oral, interpersonal, and written communication skills are not challenged during their undergraduate years.⁵ The most obvious answer to address this gap is to increase the inclusion of communication training as a mandatory or 'generic' learning outcome for science programs, Bachelor of Science (BSc), and ensuring that graduates possess the relevant skills required.⁵ Currently, scientific training seems to continuously lack the inclusion of communicating information effectively among various audiences outside the academic discipline.⁹ Today, the amount of literature in this discipline is scarce and the impacts of such training are not well documented. Previous studies have examined the impact of training, solely on communication practice. This presents a call for examination into current science programs, to assess the impact and effectiveness of science communication training at an undergraduate level.

The Honours Life Sciences program at McMaster University requires students to take 1 mandatory science communication course. As a student progresses through their studies, they are given the option to enrol in additional science communication courses. These higher-level courses are designed to build on the previous knowledge, which is taught to practise and gain advanced skills. Students are taught to write different forms of work, such as lay summaries, explainers, translations, commentaries, media critiques, essays, opinion editorials, manuscripts, reflections, oral presentation of thesis', and utilizing various modes of media to communicate science, such as: blogs, websites, social media, and podcasts. They further teach students to use clear language, storytelling techniques, tailoring a message, how to elicit emotion, and deciding which medium is best to reach their audience.

The focus of our thesis work is to examine the impact and effectiveness of science communication training by mapping it throughout the undergraduate Life Sciences program. Specifically, the area of interest being investigated is the comfort level of students enrolled in

their current undergraduate level (level II to V), in regards to performing various science communication skills. In addition, we explored whether or not the dedicated science communication courses are effectively teaching students the skills that are necessary for success.

LITERATURE REVIEW

1. Science Communication as an Academic Discipline

In general, academic disciplines vary, and emerge due to a variety of reasons.¹⁰ In higher education, scicomm is a new field of study and has been incorporated as a reaction to the external demand for improved communication skills.¹⁰ A continuous topic of conversation surrounds whether scicomm's prominent emergence demands the same merit in academia as other fields, while it progresses away from just a learning component of a course, to being recognized as its own discipline.⁶ The idea of engaging non-scientific individuals with science has continued to gain momentum since the 1990s, as funding bodies in science increased as they needed to understand what their investments were contributing towards.⁶ Although scicomm as a discipline is new, the practise of this skill dates back to when science emerged.⁶ The interdisciplinary field of scicomm incorporates a broad range of areas; science, communication, education, pedagogy, psychology, philosophy, and sociology.¹ Literature on this topic has made it apparent that recognizing scicomm as its own academic discipline has been debated since 2010.⁶ The author Gascoigne and colleagues discuss that in 2010, the phrase "books on science communication" generated over 115000³ impressions on Google.¹¹ The further rise in the search for scholarly articles and journals, showed that science communication was emerging and generating questions across professionals and the public about its field.¹¹ The rapid rise in science communication importance can be linked to the establishment of science communication courses, certificates, degrees, and programs in universities across the globe.¹² Researcher Trench and colleagues examined the publication of papers in the field of science communication.¹³ The researchers found that 37 papers were published before 1995, while 42 papers were published from 1995 to 2015 alone.¹³ Borchelt's analyse of publications in the field of science communication, showed that more than twice as many articles were published between 2005 and 2009, compared to 2004 and prior.¹⁴ The journal, *Public Understanding of Science*, increased the number of issues per year from 4 to 6 in 2009.¹⁵ In 2012, this same journal continued to increase their issues released to 8, to reflect the growth in the research being done in science and the importance of communicating its findings.¹⁵ Popular journals, such as *Science Communication* in-

creased their issues published each year from 4 to 6 in 2012 and the *Journal of Science Communication* reached a new high, publishing 6 issues per year in 2016.¹⁶ This growth in issues published is attributed to the increase in the number of submissions to journals, as well as the development and prominence of the evolving field.¹⁷

Arguments presented suggest that scicomm in higher education is a 'skill' that you acquire through practise in courses, as opposed to an individual field of study. However, it has further been argued that the practise of formal training at a post-secondary level aids in the development of science communication as its own academic discipline.⁶ Often times the interdisciplinary nature of a field of study is viewed as a strength.⁶ Higher education may see this as an instability when deciding to deem it as an academic discipline due to unclear outcomes, unstable funding for the program, and the ambiguous opinions regarding who "own's" science communication.⁶

Regardless of the continued debate surrounding its status, science communication has established itself in universities as a desired skill. Upon recognizing this demand, the need for science communicators and scientists who are trained to communicate to the lay public has drastically increased.

2. Science Communication Training: The Current State

The skill 'communication' has been introduced as a learning outcome for science degrees in many countries, including Canada.² Recognizing that the communication of science needs to be better taught, has resulted in an increased number of courses designed to teach and train students about effective communication techniques.² Although this acknowledgement is a positive step in better educating early scientists, their efforts are hindered as there is little evidence to support what the core elements taught in these courses should include.² The absence of a student's possession of 'generic' communication skills is the result of many factors; limited opportunities in the science curriculum due to the lack of courses offered, access to available course(s), the push/encouragement for students to enrol in scicomm directed courses, a student's perception of scicomm, and the level of importance of scicomm. Science communication courses tend to be offered as elective classes and attract individuals who actively seek learning communication opportunities or have strong interests in scicomm careers.² The inclusion of science communication content in other science courses (non-scicomm based) is dictated and is at the discretion of the professor in charge of lecturing.² This typically involves traditional writing with individuals in the same field.² Professors encounter challenges in communicating science effectively due to their

academic discipline-specific content.² As scientists progress through undergraduate studies to post-graduate and then doctrine, they inevitably become more specialized in their field of study. This poses a challenge as they are unable to also become experts in science communication. This calls into question a scientist's/professor's level and ability to teach a desired skill like, 'communication' to their students, as they may also find it challenging to perform science communication practises. The lack of professors possessing a proper background and knowledge in scicomm suggests a deficiency of future students obtaining these skills. Education plays an integral part in training and preparation. This provides reason to properly map the effectiveness of scicomm training throughout undergraduate BSc programs.

One key research paper has presented results giving reason to assess the effectiveness of current scicomm training across respected universities. Mercer-Mapstone and Kuchel examined which communication skills were being taught and assessed directly, indirectly or absent in undergraduate science courses across 4 research intensive universities.³ The researchers found that 10 of the 12 core science communication skills were absent in more than 50% of assignments.³ In these courses, 77% of all assessments administered taught less than 5 core communication skills and 22% taught 5 or more directly.³ There was a significance difference in how openly communication skills were taught across different majors/disciplines (i.e. Physics, Chemistry, Biology, Geography, Mathematics).³ This is a critical finding as there is a lack of explicitness and diversity in the way communication skills are being taught based on the field of science that one is enrolled in. An encouraging trend identified was that communication assignments geared towards non-scientific audiences were taught more directly than assessments targeted at scientific audiences.³ However, the failure to develop the necessary core science communication skills challenges the ability of early scientists to be able to communicate to a non-scientific audience. For example, the critical skill of determining whether a word is considered jargon is one that was once overlooked.

Upon the examination of learning outcomes in undergraduate science programs at research intensive universities across Canada, only 2 schools highlighted and mentioned 'communication'. Specifically, McMaster and Queens University included critical analysis of literature and refined communication skills as a pillar of learning. Institutions, such as the University of Toronto, Western, Guelph, McGill, Ryerson, and Brock, do not explicitly mention the word or discuss 'communication' as a learning outcome of their science programs, the specializations offered, and highlights of the courses. These post-secondary schools emphasized their range of courses focusing on core science skills, major fields in science, and resolving key controversies

or gaps of knowledge in life sciences and healthcare.

The results presented by Mercer-Mapstone and Kuchel and the lack of acknowledgement of communication skills in Canadian universities presents reason to encourage similar studies across all universities worldwide, which are known for their respected science programs.³

3. Scientists as Communicators: Communicating to the Public

It is no secret that science journalism is the gateway for spreading scientific material and news to the public. Until recently, scientists have failed to prioritize the communication of their research and recognizing it as a requirement of their job.⁸ This has resulted in a drastic separation between the science community and the general public.⁸ Leaders of the scientific community are actively pushing their colleagues to engage more frequently with the public, in order to bring awareness to modern science that can guide personal and societal decisions.¹⁸

Science journalists that obtained the skills necessary for sharing science information are able to make complex topics accessible to a lay audience. A challenge in science journalism is communicating research effectively, since material can become oversimplified and generalized.⁷ This can result in basic information being obscured or wrongly portrayed, initiating the spread of misinformation.⁷ Scientists are solely trained to publish papers and discuss findings with their peers, making it challenging for them to understand how lay audiences think and interpret.⁷ Scientific findings and analyses of results often become complicated, making it challenging to communicate these facts due to discipline-specific jargon.⁷ This problem often arises as scientists fear being misunderstood and presenting inaccurate information, leading to the use of specialized language.⁷ A lack of scicomm training makes it difficult for a practising scientist to determine whether a common scientific word is jargon or not. A simple word, such as 'significant' can be considered jargon, as not every individual accurately understands its meaning.⁷ Phrasing in writing, like 'positive correlation' may be inferred as something positive when it can actually represent a negative link between two variables.⁷ The gap between what scientists believe and what the public knows and truly understands can be bridged by incorporating formal communication skills when training aspiring scientists. This will provide the quality of discourse needed between scientists and the general public.

Although some practising scientists may not acknowledge the importance of writing to a lay audience, the ability to write for a wide range of individuals becomes increasingly important with regards to con-

tinuing their research. For example, in order to obtain funding, scientists must be able to clearly communicate to peers, reviewers, and other public bodies about how their ideas are valuable and relevant to society. Scientists are an essential link between policy makers, taxpayers, stakeholders, and governments, ensuring evidence-based decision making occurs by these individuals.^{9,19}

These arguments presented prove there is a shortcoming in the science communication training at universities. Although scientists are recognizing the need to engage with the public, their goals are not comparable to the knowledge needed to effectively connect and communicate with them.¹⁸ However, this does not mean that scientists are 'bad' at communicating, rather, it implies that effective communication skills develop from practise and it is rarely natural to anyone, especially science experts.¹⁸ Ensuring students are partaking in these practises early on in their academic careers is vital in promoting a scientifically literate society.²⁰

4. Science Communication Training and the Workplace

Today, the science community has been identified as the least trained group of professionals in public communication.²¹ A survey completed by various professionals, including educators, employers, and government officials, showed that communication skills were identified as an essential requirement for the workplace by STEM graduates (**S**cience, **T**echnology, **E**ngineering, and **M**athematics).^{3,6} Employers in the United Kingdom, United States, and Canada found that the training received by graduates does not reflect the reality of the modern-day workplace requirements needed to be successful.³ Every year, a set of learning outcomes are established that act as a baseline for acquiring knowledge, helping to guide curriculum development, and promote graduate employability.³ The reservations expressed by workplace professionals calls into question the science communication training in undergraduate programs. This demonstrates that there is a discrepancy between what universities say science graduates should be able to do and what they actually learned throughout their program.³ There are various complaints from journalists, industries, laboratory researchers, government officials, and the public stating that scientists are not equipped with the proper communication skills needed to convey information effectively to non-experts.³ According to McKinnon and Bryant, graduates of STEM programs who have completed science communication training and demonstrate the skills, are perceived as more valuable to future employers.⁶ This illustrates that it is imperative to improve communication training in higher education to ensure graduates of a science program have a

solid foundation of relevant skills for employability.

5. The Consequences of Inadequate Scicomm Training and Practise

Today, the COVID-19 pandemic has proven the importance of science communication in an age of misinformation, as new knowledge is abundant, evolving, and controversial.²² For example, the misinformation of science and the lack of proper public communication surrounding the pandemic can hinder population health and protocol by leading to negative outcomes.²² A lesson that has become clear during this pandemic is the improper announcing of information to the public, which makes it a challenge to counter misinformation, leading to confusion.²² This results in public hesitation stemming from their inability to distinguish and understand the information presented to them.²² The continued outbreaks, the uncertainty in receiving the vaccine, and the controversy over wearing a face mask, are unfortunate examples of how disorganized science communication can confuse non-scientific audiences.²² This leads to distrust of scientists and scientific evidence, and casts doubt about the justification for health protocols and alterations in personal behaviour as new information surfaces.²² During such major events, scientists are responsible for communicating newly emerging science with the public to ease their fears, help them make informed decisions, and encourage engagement.²⁰

Policy-makers reference scientific research heavily when designing laws, as well as prior to passing legislation. When science is communicated ineffectively, flawed or biased bills and policies can be passed, affecting the lives of everyone involved.²³ Often times, new fads, trends, and conspiracies emerge, causing research to become quickly diluted with fiction and inaccuracies. The inadequate communication of proper scientific information leaves many areas associated with a negative connotation, such as climate change.²³ Numerous amounts of scientific evidence are presented each day, often times contradicting one another and making opposing claims about the reality and seriousness of an issue.²³ Upon reading the information, skepticism enters the public's perception of scientists and the entirety of the science field, followed by distrust.²³ Without the proper presentation of science and the failure to swiftly clarify statements, the consequences of these actions will begin to appear altering our way of life.²³

When engaging with the public, scientists need to be ready to answer difficult questions regarding their research and communicate any uncertainties.⁸ Engagement with the public is vital in increasing the influence of their research, forming and building trust, and enabling open conversation.⁸ This allows for the public to ask questions surrounding the science and importance

of their research, rather than asking questions about what they are discussing.⁸ Although there is limited evidence, scientists who have formed a strong connection with the public have had their research papers cited more often by the public and other scientists than researchers who lacked that connection.⁸ This aids in spreading accurate science, which is the result of proper science communication.

Study Motive

There remain gaps in the current state of science communication training and little consensus on how it should be conveyed. Undergraduate students continue to receive poor formal training in the communication of scientific theories. In this area of academia and pedagogy, there is a lack of research examining the communication of science skills at a whole degree level. A significant portion of research on science communication skills focuses on teaching practises only at a microlevel, such as an individual course or a single assessment. Evidence surrounding how current students are experiencing the teaching and absorption of knowledge of these skills also remains scarce. These gaps prove that there is a demand to further investigate scicomm training, practises, and teaching at a whole degree across various types of courses. Such exploration would contribute to curriculum development by providing insight into how current science students are experiencing the teaching and learning of communication skills throughout their degree. Using these results can influence and provide the appropriate needed changes to the existing curriculum and activities and assessments, to facilitate the scaffold and development of these skills for science students as they progress through their undergraduate degrees.

Study Objective

The focus of this study is to examine the impact and effectiveness of science communication training. This is to be accomplished by mapping it throughout the undergraduate Life Sciences program at McMaster University. Conducting this study will provide an evidence-based record of the comfortability of undergraduate science students with regards to practising various communication skills. Specifically, we pose the research question: Are students at their current undergraduate level (II to V) comfortable with performing various science communication skills? Additionally, we explored a secondary area of research by posing the question: Do dedicated science communication courses effectively teach (train) students the skills necessary to succeed in academia and the workplace?

To investigate this, we administered a survey that presented students with a variety of topics regarding science communication and asked them to rate their level of comfort, agreement with statements, and open-ended questions to express their opinions.

METHODS AND MATERIALS

Ethics approval for this study was granted by McMaster University's Research Ethics Board (Approval Number: 4985).

Survey Administration

A survey was advertised on McMasters' learning management system, Avenue to Learn, and was open to all Honours Life Sciences students during the Winter 2021 academic term. The survey was administered by Dr. X and Dr. X from the Faculty of Science and posted on Avenue to Learn on April 15th, 2021 and remained available until May 24th, 2021. Completion of the survey was anonymous and voluntary; however, a \$100 Amazon gift card was an incentive advertised to participants and awarded to two respondents randomly selected by an individual independent of the research team.

In order to be eligible, participants must have been enrolled in the Honours Life Sciences program (level II to V) and completed or were enrolled in a variety of courses during the 2020-2021 academic year. These courses included: *Level II*: LIFESCI 2AA3: Introduction to Topics in Life Sciences and SCICOMM 2A03: Foundations in Science Communication; *Level III*: ENVSOCTY 3UW3: Cities of the Developing World, HISTORY 3CH3: Catastrophic History: Natural & Technological Disasters, HLTHAGE 3D03: Perspectives on Disability, Chronic Illness and Aging, HLTHAGE 3N03: Aging and Mental Health, LIFESCI 3AA3: Human Pathophysiology, LIFESCI 3BB3: Neurobiology of Disease, LIFESCI 3E03: Reproductive Endocrinology, LIFESCI 3G03: Introduction to Epidemiology, LIFESCI 3M03: Cellular Dynamics, LIFESCI 3P03: Science Communication in Life Sciences, LIFESCI 3Q03: Global Human Health and Disease, LIFESCI 3RC3: Radioisotopes in Medicine; *Level IV*: LIFESCI 4J03: Science Communication in the Media and LIFESCI 4E03: Science & Storytelling.

Survey Content

The survey contained a total of 28 questions and was administered using the Lime Survey software. The survey asked questions on a student's perception of science communication, its importance, their interest in the discipline, how well prepared they were to complete certain courses based on the course prerequisites, how comfortable they were with performing science communication skills (i.e. writing to a non-scientific audience, designing an infographic, etc.), engagement, and future career opportunities in science communication. All questions presented in the survey were optional, unless otherwise indicated that an answer was necessary. The mandatory question asked by

this survey was which courses the participant have taken, have not taken, were currently enrolled in, and which ones were taken prior to Fall 2020; in addition to answering what year they were currently in at the time of the survey (Level II to Level V). Level II acts as the ‘introduction of communication skills’ since science communication courses are offered beginning in second year of the Honours Life Sciences program to meet program and course requirements in upper year courses.

The survey presented participants with Likert Scale responses to the questions including: numerical ranking of 1-5, strongly disagree to strongly agree, very high to very low, very comfortable to very uncomfortable. It also used open-ended responses for participants to discuss their opinions and thoughts, yes/no/unsure, and multi-select options.

The survey was completed by 95 students, specifically 26, 41, 22, and 6, from levels II, III, IV, V respectively. Due to the small sample size in level 5, the responses from that academic year were combined with level 4 for a total of 28 responses. This new value was used when calculating percentages for the results of the primary research question.

Data analysis

Microsoft Excel was used to gather, analyze, and visualize the data by designing the graphs presented in the results section. The function “COUNTIF” was used to calculate the number of responses for each individual question and by academic year, in addition to the “SUM” function when calculating the percentage of each response to the applicable question.

For the context of this study, the word “Comfortable/Comfort” is a direct indication of one’s ability to practise/perform the skill in question.

RESULTS

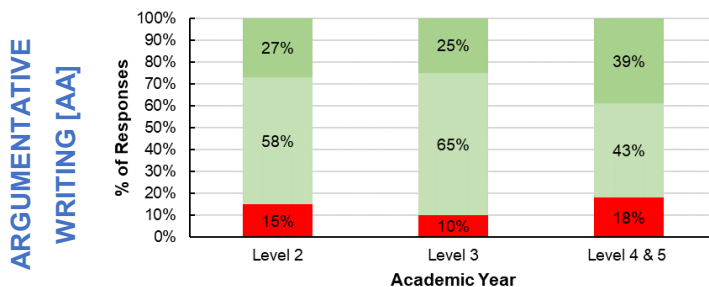
As stated in the figure captions presented in Figure 1 below, the abbreviation [AA] denotes Academic Audiences (i.e. other university students in a formal setting, faculty members, other researchers, or subject experts), and [NAA] denotes Non-Academic Audiences (i.e. general adults, children, community members, policy makers). As seen in the x-axis of Figure 2 below, each letter (i.e. A, B, C, etc.) indicates a specific course objective relevant to all the dedicated science communication courses presented (LIFESCI 2AA3, SCICOMM 2A03, LIFESCI 3PO3) (refer to Table I for an explanation of all alphabetical letters and the applicable course objectives). As seen on the graphs, all findings were converted into a percentage and round

ed to the nearest whole number for easier comprehension.

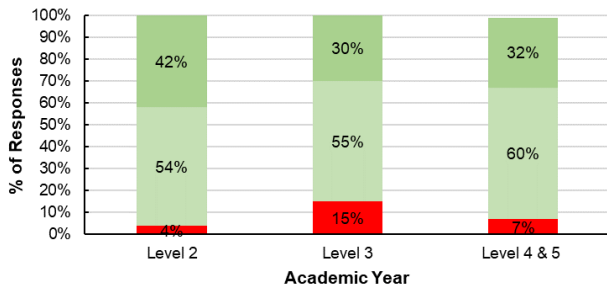
Primary Research Question: Are students at their current undergraduate level (II to V) comfortable with performing various science communication skills?

As depicted in Figure 1, the communication skills *Literature Review [AA]* (15% increase in comfort and a 1% decrease in discomfort), *Research Proposal [AA]* (6% in comfort and a 17% decrease in discomfort), *Oral Presentation [AA]* (30% increase in comfort and 16% decrease in discomfort), *Video [NAA]* (1% increase in comfort and a 16% decrease in discomfort), and *Public Lecture-Style Presentation [NAA]* (19% increase in comfort and a 6% decrease in discomfort), all illustrated a simultaneous increase in comfort and decrease in discomfort. Therefore, this pattern indicates that dedicated science communication courses are teaching these applicable skills and a student’s ability to perform (practise) them is improving. The skills *Argumentative Writing [AA]* (12% increase in comfort) and *Research Paper [AA]* (15% increase in comfort), although showed a minor increase in discomfort (less than 10%), demonstrated a considerable increase in a students’ comfort level with performing the applicable skills.

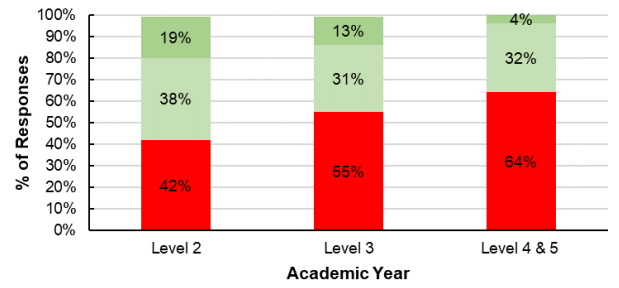
Moreover, as shown in Figure 1, the communication skills *Debate [AA]* (22% increase in discomfort), *Graphic Design [NAA]* (7% increase in discomfort), *Audio [NAA]* (18% increase in discomfort), *Policy Communication* (19% increase in discomfort), all illustrated a substantial increase in a students’ discomfort level with performing the applicable skills. Although these skills also showed a minor increase in comfort levels, the considerable increase in discomfort over academic years indicates a gap in skill practise and teaching. As seen in Figure 1, the other applicable skills, such as *Argumentative Writing [NAA]*, *Research Poster [AA]*, *Popular Science Writing [NAA]*, *Outreach Activities [NAA]*, and *Media Interview [NAA]*, all illustrated a simultaneous minor increase and/or decrease in comfort/discomfort levels (less than/equal to 10%).



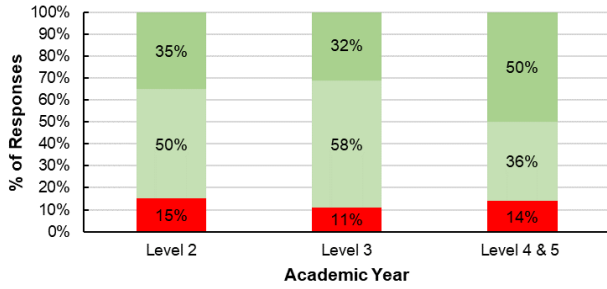
ARGUMENTATIVE WRITING [NAA]



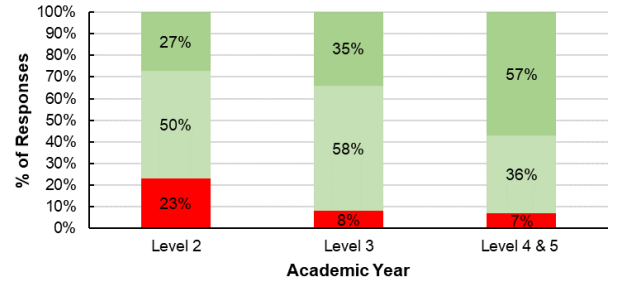
PUBLIC DEBATE [AA]



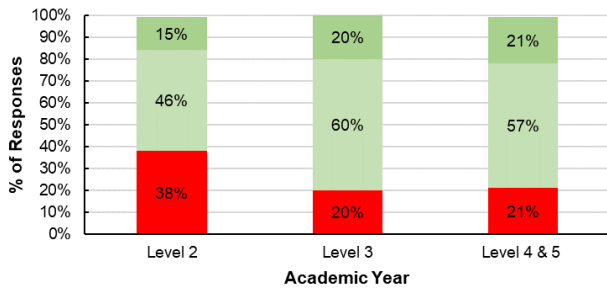
LITERATURE REVIEW [AA]



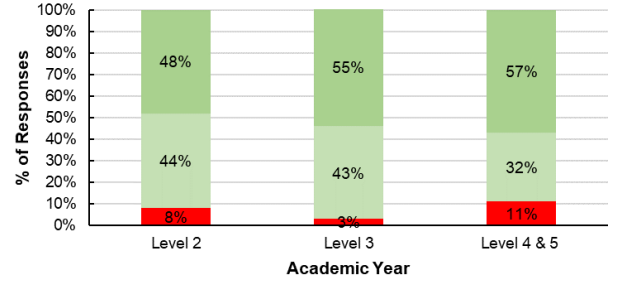
ORAL PRESENTATION [AA]



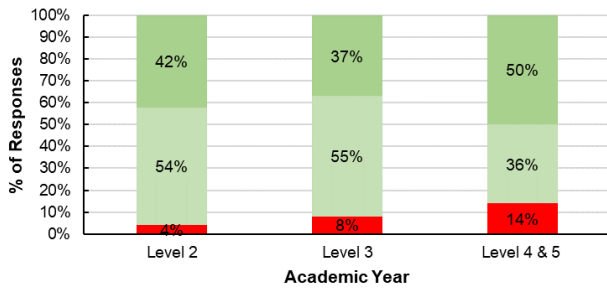
RESEARCH PROPOSAL [AA]



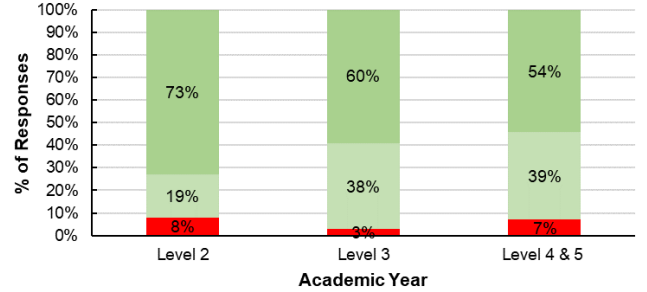
POPULAR SCIENCE WRITING [NAA]



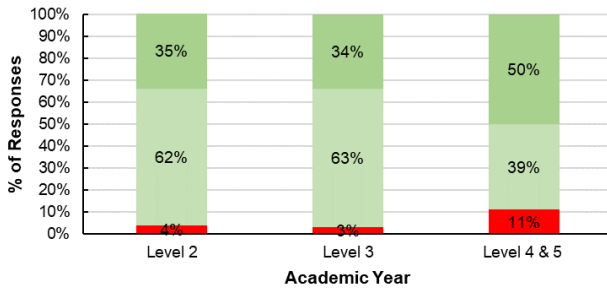
RESEARCH POSTER [AA]



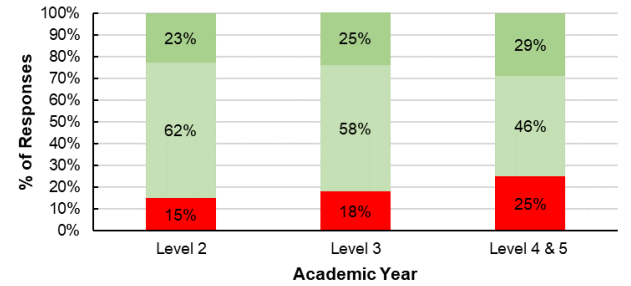
SOCIAL MEDIA POSTS [NAA]



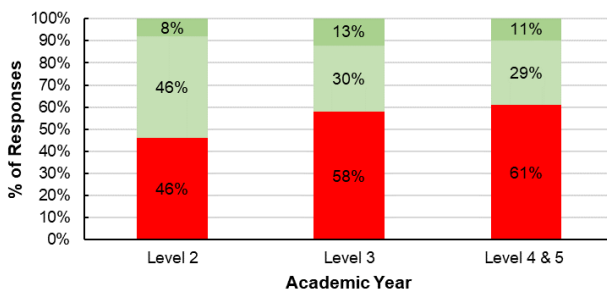
RESEARCH PAPER [AA]



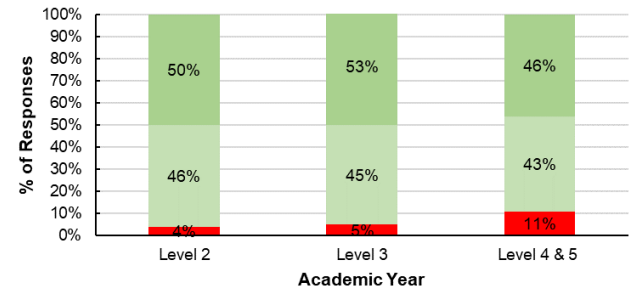
OUTREACH ACTIVITIES [NAA]



DEBATE [AA]



GRAPHIC DESIGN [NAA]



■ Not comfortable ■ Comfortable ■ Very comfortable

■ Not comfortable ■ Comfortable ■ Very comfortable

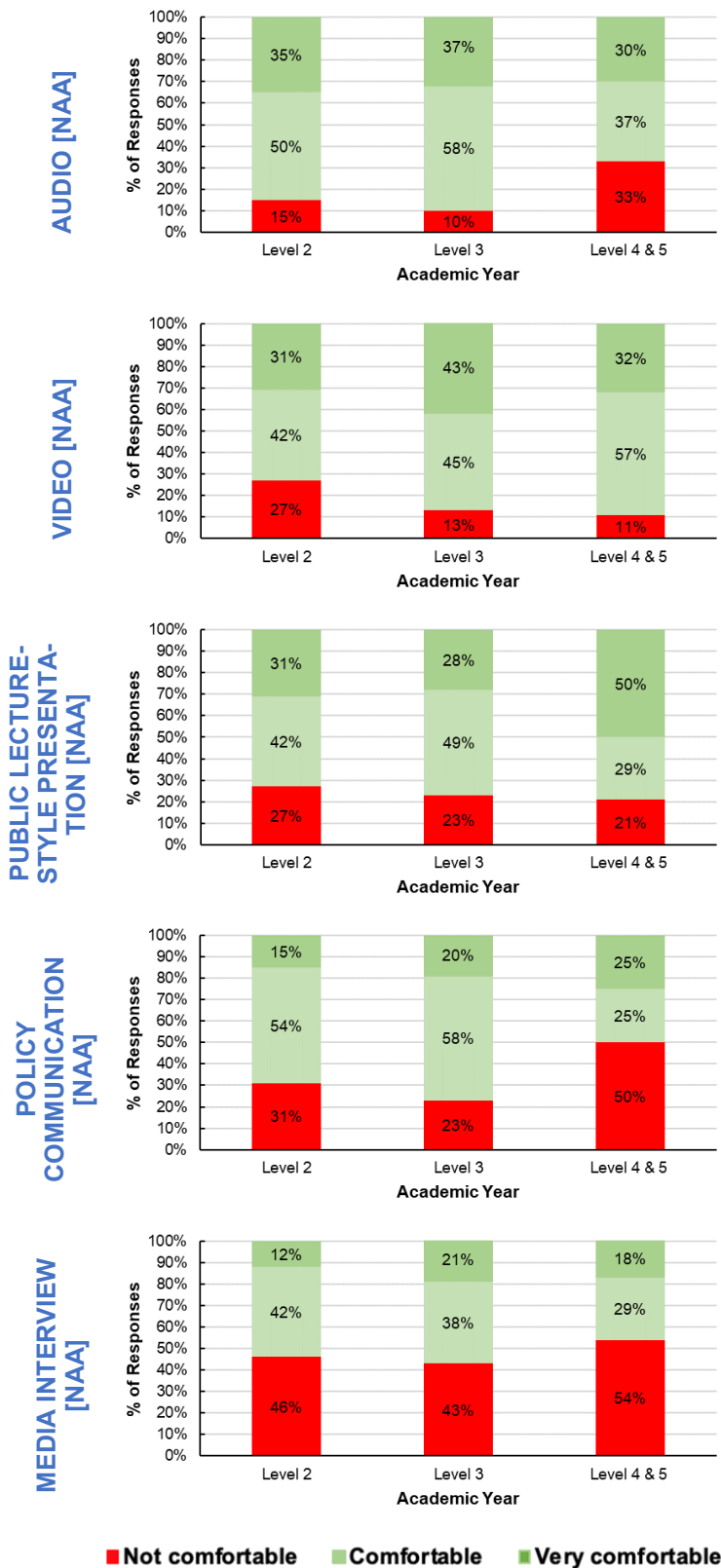


Figure 1. All responses of undergraduate Honours Life Sciences students by academic year (Levels II to V) (n=95). This figure depicts various types of science communication skills and the level of student comfort assessed by academic year; Level II (n=26), Level III (n=41), and Level IV & V (n=28). Due to the small sample size in Level V (n= 6), re-

sponses from Level V were combined with Level IV. [AA] denotes Academic Audiences and [NAA] indicates Non-Academic Audiences.

Table 1. Science Communication Objectives for LIFESCI 2AA3, SCICOMM 2A03, and LIFESCI 3P03. This table provides an explanation to each alphabetical letter presented on the X-axis as depicted in Figure 2.

Letter on Graph	Science Communication Course Objective
A	The assessment of communication skills (i.e. task, rubric, feedback etc.) appropriately aligned with what I was taught in the course.
B	I feel more comfortable communicating science topics through writing due to this course.
C	I feel more comfortable orally communicating science topics due to this course.
D	I feel more comfortable visually communicating science topics due to this course.
E	I feel more comfortable understanding and dissecting primary research papers due to this course.
F	I feel more comfortable gathering and synthesize research due to this course.
G	I feel more comfortable selecting and using appropriate written, oral, or multimedia tools due to this course.
H	I am more interested in science communication due to this course.
I	I have a deeper understanding of science communicating due to this course.
J	My knowledge of written, oral, and multimedia TOOLS has improved as a result of this course.
K	My ability to communicate science to NON-ACADEMIC AUDIENCES has improved as a result of this course.
L	My ability to communicate science to ACADEMIC AUDIENCES has improved as a result of this course.
M	My ability to gather and synthesize research has improved as a result of this course.
N	My ability to read, understand, and dissect primary research papers has improved as a result of this course.

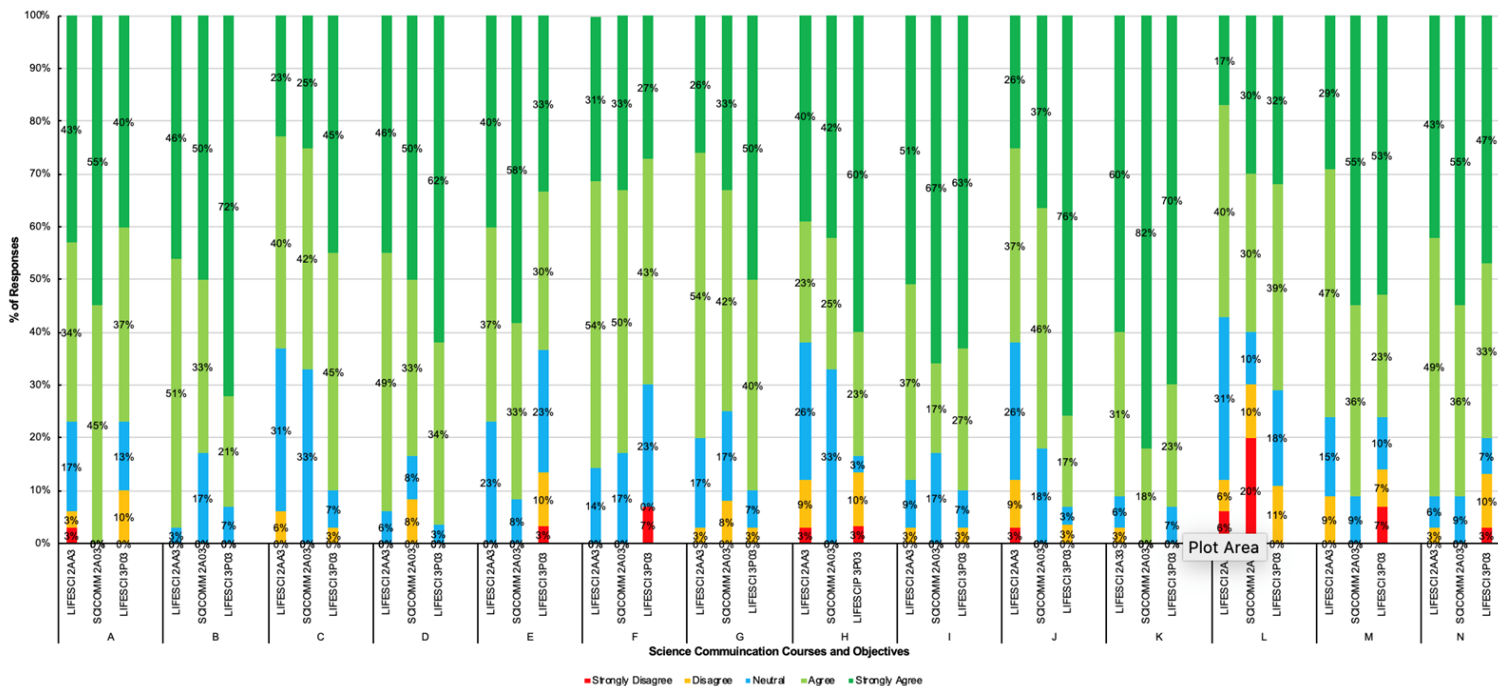


Figure 2. Science Communication Courses and Course Objectives. This figure depicts the course objectives and students’ responses (in percentages) with regards to their agreement in obtaining those outcomes as a result of the applicable course (refer to Table I on page 24 for explanation of all alphabetical letters and the applicable course objectives). All responses (n=75): LIFESCI 2AA3 (n=35), SCICOMM 2A03 (n=11), and LIFESCI 3P03 (n=30). Courses LIFESCI 4J03 and LIFESCI 4E03 were omitted from the analysis due to their small sample size (n=4 and n=2, respectively).

Secondary Research Question: Do dedicated science communication courses effectively teach students the skills necessary to succeed in academia and the workplace?

As exhibited in Figure 2, the letters *B* (I feel more comfortable communicating science topics through writing due to this course), *C* (I feel more comfortable orally communicating science topics due to this course), *D* (I feel more comfortable visually communicating science topics due to this course), *F* (I feel more comfortable gathering and synthesize research due to this course), *I* (I have a deeper understanding of science communication due to this course), *K* (My ability to communicate science to NON-ACADEMIC AUDIENCES has improved as a result of this course), *M* (My ability to gather and synthesize research has improved as a result of this course), and *N* (My ability to read, understand, and dissect primary research papers has improved as a result of this course) all illustrated a substantial increase in agreement (shift from strongly disagree to strongly agree) upon completing the applicable science communication courses (LIFESCI 2AA3, SCICOMM 2A03, and LIFESCI 3P03). Respectively, letters *B*, *C*, *D*, *G*, *H*, *J*, and *L* had a 26%, 22%, 16%, 24%, 20%, 50%, and 15% increase in students’ comfort levels. Furthermore, the increase in agreement with regards to letter *J* validates the substantial increase in *Oral Presentation [AA]* skills found when analyzing the data for the pri-

mary research question. This growth demonstrates that students are gaining skills (and comfort) as they progress through their undergraduate degree and complete higher level science communication courses.

Furthermore, as seen in Figure 2, letters *A* (The assessment of communication skills appropriately aligned with what I was taught in the course), *E* (I feel more comfortable understanding and dissecting primary research papers due to this course), *F* (I feel more comfortable gathering and synthesize research due to this course), *I* (I have a deeper understanding of science communication due to this course), *K* (My ability to communicate science to NON-ACADEMIC AUDIENCES has improved as a result of this course), *M* (My ability to gather and synthesize research has improved as a result of this course), and *N* (My ability to read, understand, and dissect primary research papers has improved as a result of this course), all demonstrated an increase in agreement from LIFESCI 2AA3 to SCICOMM 2A03, but showed a decrease between SCICOMM 2A03 and LIFESCI 3P03. Specifically, letters *A*, *E*, *F*, *I*, *K*, *M*, and *N* had a respective decrease of 15%, 25%, 6%, 4%, 12%, 2%, and 9% in students’ comfort levels.

DISCUSSION

Science students are intended beneficiaries of an undergraduate science program. Their perception on the view of the discipline, understanding, and ability to perform communication skills across a BSc program provides valuable insight into the teaching of these fundamental skills. The academic curriculum is a conduit for the delivery of relevant and required skills that should remain constant regardless of discipline or its specific content. This is particularly relevant in the current state of placing increasing emphasis on the development of generic and commonly taught skills that are often not course-specific. Regardless of this necessary increase in skill-teaching, the skill communication and its various forms (i.e. written, oral, graphic) seem to be consistently falling short of requirements, specifically in BSc programs.

This study provides insight into the comfort level of undergraduate science students within the Honours Life Sciences program (Levels II to V) when performing science communication skills in the present, as well as after completing various Scicomm courses. Research in this area is limited. This study provides a broad yet commendable set of student perspectives and highlights an area of the existing curriculum that requires future focus. Additionally, this study raises awareness on other relevant areas in the same matter requiring further investigation/justification to current results. The literature review revealed that there are communication skills or elements cited that consistently align across the fields of science, communication, education, and science communication that are following short of requirements. This was further validated by the supporting results obtained from this study, revealing that certain science communication skills, such as *Debate*, *Public Debate*, *Graphic Design*, *Audio Tools*, and *Policy Communication* consistently showed an increase in discomfort as one progressed through their undergraduate degree in the Honours Life Sciences program at McMaster University. This increase may be attributed to dedicated Scicomm courses either minimally or not explicitly teaching these fundamental skills. Therefore, students' ability to regularly practise them is limited or impossible, which may be contributing to the rise in student discomfort. Although these same skills showed a minor increase in comfort levels, the considerable increase in discomfort over academic years indicates a gap in skill practise and teaching. The skills of Debating, Graphic Design, Audio Tools, and Policy Communication directly contribute to the modern notion of science communication as a two-way interaction in the process of sharing information and perspectives, and represents the recent shift in science communication theory from focusing on public understanding of science to public engagement with science.²⁴ Students struggle with making science engaging to others while presenting and transferring infor-

mation in a way that encourages others to like science, due to the ambiguity around the word "engagement" and how best to formulate an argument or opinion.² It is possible that the increase in discomfort levels from a student's perspective could be reflective of some experts in science courses struggling to teach engagement skills in undergraduate courses.² As discovered in the primary research question, there was an increase in a student's comfort level with regards to oral presentation and written forms of science. This increase in comfort level may be attributed to Scicomm courses regularly teaching these skills which allows students to practice and familiarize themselves with them. Moreover, the findings obtained from the primary research question, in addition to the increase in a student's personal knowledge of written, oral, and multimedia tools after completing dedicated Scicomm courses, represents consistent teaching practises. These two research questions demonstrated a similar increase in parallel skills, indicating that they have been the central focus to effective science communication as well as being the most relevant in teaching science students how to communicate with different audiences. Although there are numerous other Scicomm skills that a science student must acquire, I believe it is important to mention that teaching these particular fundamentals at a minimum introduces the most essential aspects of science communication skills to students.

The implication of these findings is that while course objectives make the "what" clear, such as "After completing this course, students will be able to..." in syllabuses, we are overlooking the "how" process of actually practising the skills (i.e., applicable/relevant assessments to test student knowledge). Examining the "how" aspect is required for adequate development and transferal of such integral skills needed in academia and the workplace.³ This study found differences in skills across academic levels, which provides evidence that there is little consistency across other BSc programs at McMaster University and other academic institutions regarding the way communication skills are being taught (each year) and assessed.³ An ongoing debate exists over where to teach communication skills in science degrees and whether it should be with the addition of a dedicated course to teach a single or subset of similar skills, or to integrate them into existing courses instead. This challenges professors' abilities to effectively teach all core science communication skills.² A new course approach offers a student the ability to adequately obtain greater knowledge of a certain or relevant subset of skills. Integration into multiple current courses across a program allows a student to have multiple opportunities to practise and develop skills over time, which has been shown to be more effective in developing complex learning outcomes such as communication.² However, an integration approach can lead to the lack of communication skills, due to the amount of other necessary content

already encompassing the course, such as theory, could limit the amount of Scicomm skills being taught and the ability to practise them. Therefore, research has shown that the inclusion of core communication skills in undergraduate science courses are limited and in general, this key skill is not being taught explicitly or in a cumulative manner.³

Knight argued that curricula with which communication skills are taught should support the progressive development of skills over time as a result of coherent, outcome-aligned, curriculum planning.²⁵ This argument validates the findings of the second research question, which demonstrated an increase in a student's comfort level and personal knowledge level to be able to select, use, and explain science with various communication tools and styles as a result of course curriculum and learning outcomes upon completion of the class. Therefore, a continuous and particular focus should be on consistent levels of inclusion and assessment of communication skills in an effort to make those skills more clearly visible to students to comfort in all learning outcomes and skills.

An implication of this study is that it attempted to assess a critical aspect at the whole degree level, as opposed to a course level or single assessment view (individual skill), which has been the traditional route of research in this field. This endeavour was an attempt to truly represent overlap and gaps across the BSc program with regards to science communication skills. The educational implication of the study is potentially important for university professors and science educators to enable a more holistic view of science learning, the best way to communicate the science they teach, and how students should communicate science.

Limitations, Recommendations, Next Steps, and Future Research

The most significant limitation impeding our ability to obtain more concrete results is the small sample size of the study (n=95), which hindered a complete and truly accurate representation of the Honours Life Sciences program. When attempting to answer the primary research question, response for Levels IV (n=22) and V (n=6) were combined due to small sample sizes. Since the nature of the survey did not require participants to answer every single question, data was limited regarding particular questions. This may have skewed our results. For future reference, researchers should hold all questions mandatory for students to answer in order to obtain more applicable data. Students currently enrolled in Levels IV and V of the Honours Life Sciences program have the option to complete lower level (SCICOMM 2A03) as well as upper year (LIFESCI 3P03) Scicomm courses. Thus, students in Levels IV and V are better equipped to accu-

rately complete assignments within the course, possibly reflecting greater results on the comfort level scale. With regards to the secondary research question, LIFESCI 4J03 and LIFESCI 4E03 were omitted from analysis due to the small sample size (n=4 and n=2 respectively), which limited an accurate representation of student comfort throughout the entire Honours Life Sciences program and dedicated Scicomm courses. The current survey hindered an accurate representation of participant responses, particularly comfort level, due to the restricted options to select from (Not comfortable, Comfortable, Very comfortable). In the future, using a new measure, such as a Likert Scale (a numerical scale from 0-10) might improve the specificity of student's comfort level and allow for a greater representation (variability) of the results. To more clearly define a student's comfort level at their current academic year, designing new questions (i.e., Completed LIFESCI 2AA3, Completed LIFESCI 3P03, Completed LIFESCI 4J03, etc.), and incorporating follow-up questions specific to each science communication course would ensure accurate comparison of a student's comfort level as either being "greater than" or "lesser than" for specific skills to previous courses.

Regarding future implications, the results in this study validate the need to incorporate more science communication courses across the Life Sciences curriculum, reducing discourse between science students and their ability to communicate information. Research seminar courses are limited by the capacity of students able to enroll in these classes. Therefore, not all students in their senior year of the program will be completing a higher-level Scicomm course. Similarly, not all students will be able to enroll in elective Scicomm courses due to student capacity, and might not have the desire to take these courses beyond their required class (LIFESCI 2AA3), which briefly introduces some skills. Designing science communication courses that are tailored to one area of expertise (i.e. outreach activities) or particularly an area where students demonstrated a higher discomfort (i.e. debate, policy communication, media interviews, public lecture-style presentations, etc.) would ensure that students are gaining the communication skills necessary in academia and the workplace.

A new area of research would be to look at all disciplines of sciences (i.e. biology, chemistry, psychology, mathematics) to measure the level of science communication skills one possesses. We strongly believe each science course, regardless of the discipline (i.e. physics, biochemistry, astronomy) should include an assignment dedicated to writing towards a lay audience. A student will typically direct most of their attention to the required courses in their program or major. However, in general, elective courses do not receive the same level of effort as program-specific courses. This results in a lack of assertiveness to actively learn the

content in elective courses. Often times, science communication courses are offered as electives, which does not motivate students to enrol in them as they tend to place moderate or limited importance on Scicomm skills.^{26,27} Therefore, we strongly suggest mandatory enrollment for science students in science communication courses for each academic level of undergraduate study. This would ensure that they are developing these fundamentals throughout the entirety of their programs. Within all science programs, Scicomm courses should be required rather than electives, as a significant portion of literature on this topic concludes that students in undergraduate BSc programs fail to acquire science communication skills.

CONCLUSION

This study paints a picture how undergraduate science students perceive the development of communication skills across year levels and over the course of their degree. Improvement is necessary in current teaching practises and course design in BSc programs to equip graduates with the proficiency in a diverse range of communication skills. Building these fundamentals are a challenging undertaking involving the restriction of discipline-specific jargon, effective engagement with the target audience, and extensive practise. Higher education must focus on developing these skills in courses that incorporate a balance of knowledge through scientific content, research training, and the ability to effectively communicate to form well-rounded, aspiring science graduates. This study found that a students' ability to perform various science communication skills varied in their level of comfort as there was both an increase in "comfort" and "discomfort", which could be attributed to the explicitness of the dedicated science communication course learning objectives to teach those skills (i.e. debate). However, completion of the dedicated science communication courses did indicate both a moderate and substantial increase in students' comfort levels and personal knowledge of communication tools. Although more research must be conducted using a larger sample size and examining higher level science communication courses, these findings must be incorporated into the design of existing curriculums in order to facilitate an improvement in course structure (teaching), learning objectives, and assessment(s).

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ARTICLE INFORMATION

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The Historical Analysis of Prevalence and Public Perception of ADHD in Adults Within International News Coverage

Hassan Masood¹, Ryan Ziae¹, Waslat Waizi¹, Nia Katani¹

1. McMaster University, Life Sciences, Class of 2022

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SUMMARY

Attention Deficit Hyperactivity Disorder, also known as ADHD, is a medical condition affecting one's ability to stay attentive and display impulsive behaviours. Although media coverage has extensively reviewed ADHD in children, there is a lack of exposure to ADHD among adults. Understanding the tone of widespread media coverage of ADHD can help better to understand the general public's perceptions of the disorder. The results showed that between 2000-2020, there was a significant increase in news coverage and a trend toward using more respectful descriptors of ADHD among adults.

ABSTRACT

Attention Deficit Hyperactivity Disorder (ADHD) is a mental health disorder characterized by the inability to focus or control impulsive, hyperactive behaviour. The research manuscript investigates how the prevalence and language use of media coverage has changed in reporting ADHD among adults. Quantitative data was obtained from news articles published from the Nexis Uni database every 5-years from 2000 to 2020. The prevalence of the articles was determined by inspecting the number of publications during each respective period. The study investigated the language use of ADHD in adults by using the ADHD Descriptive Language (ADL) scale from 1 (derogatory) to 3 (respectful). Results showed an increase in the number of news articles published within each 5-year time frame: 62, 86, 119, and 161 news articles between 2000-2005, 2005-2010, 2010-2015, and 2015-2020, respectively. Language use, determined from the ADL scale, showed a relative percent increase of 4.55%, 9.38%, and 14.6% between each period, respectively. The trend observed for the descriptive language is associated with improved public perception used for the disorder in adults. Further research is necessary to raise awareness and decrease existing prejudice regarding the prevalence and language use of adult ADHD in the media.

Keywords: Attention-deficit hyperactivity disorder, ADHD, public perception, news coverage, mental health

INTRODUCTION

Attention Deficit Hyperactivity Disorder (ADHD) is attributed to the inability to focus or control impulsive, hyperactive behaviour, typically diagnosed in childhood.³ Scientists discovered the first case of ADHD in children in 1902, and ever since, researchers have regarded ADHD as a well-known issue solely within the youth population.⁵ However, extensive research has suggested that the disorder was prevalent within adults, which led to the recognition of its incidence as a universal condition in 1994.¹ Some of the challenges surrounding the diagnosis and prevalence of ADHD may be due to the disorder's variation in its manifestation. Typically, ADHD causes one or more of the following behaviours; inattention, impulsiveness, and hyperactivity.³ Common symptoms of ADHD include issues remaining focused over long periods, difficulties managing time, inability to complete tasks,

fidgiting, inability to wait, being easily distracted and being talkative.³ As a result, those with ADHD often have trouble performing well in school, work and socially.³ Individuals with ADHD tend to have lower self-esteem, linked to a higher risk of substance abuse.³

The symptoms of ADHD can progress throughout one's lifetime, which can disrupt individuals' everyday functions and activities.⁸ The majority of diagnoses are made based on a child's academic performance in pre-school to elementary school, as they display disruptive or inattentive behaviours.⁸ Additionally, over 70% of children with ADHD also display other diagnoses that impact their everyday functions, including oppositional defiant, learning, and anxiety disorders.⁸ In approximately 65% of cases, many symptoms associated with ADHD will persist up to 25 years of age.⁹ Majority of these symptoms are persistent within adulthood and compromise the daily functioning of impacted individ-

uals.⁸ More than 80% of adults with ADHD are undiagnosed and continue to live without the proper treatments.¹⁰ Undiagnosed adults have experienced difficult upbringings, higher incarceration rates, and comorbidities such as drug abuse and other health-related disorders.¹¹ Proper diagnosis as adults can often be accompanied by effective treatment plans to improve one's daily functions.

Several treatment options are available for individuals with ADHD during their early childhood, adolescence, and adult stage. For children around six years of age up to 12, the American Academy of Pediatrics (AAP) recommends a holistic treatment plan that involves teaching the affected child behavioural and organization skills within a school setting and providing parental education.¹² According to the United States Food and Drug Administration, medication containing stimulants such as methylphenidate increases the dopamine in the brain to promote calmness while reducing the disorder's symptoms.¹³ Non-stimulant medications, including Intuniv and Strattera, are alternative medications approved in children as young as six.¹³ Around one-third of ADHD in children persists into adulthood, which adds to a total of 4% of the adult population with the disorder (F,G).^{12,13} The recommended treatment for adults with ADHD involves the biopsychosocial intervention model, combining psychosocial treatments and the appropriate medication.¹⁴ Psychosocial treatments can include cognitive behavioural therapy and coaching geared towards ADHD.¹⁴ The recognition of ADHD as a disorder is relatively new with its addition to the Diagnostic and Statistical Manual of Mental Disorders (DSM) in 1968.¹⁵ The DSM used descriptors such as "overactivity" and "short attention span" to initially categorize children with ADHD.¹⁵ Modern genetic research has shown that the disorder is heritable in around 70% of cases; however, this requires more research to understand the disorder's origin.¹⁵

This paper focuses on scrutinizing the changes in how media outlets have communicated the existence of ADHD in adults. This subject matter is of interest as it allows us to study trends in the way ADHD in adults is portrayed across news outlets globally. Thus, emphasizing the need for further research and detailed documentation in addition to existing literature. Articles discussing ADHD in adults within the 2000-2020 period were analyzed. We aim to discover how media coverage of adults with ADHD has changed over time using our findings. To maximize the accuracy of our results, a detailed procedure was developed to select appropriate and relevant research articles to obtain data. After a thorough analysis, the collected information was used to visualize the results effectively.

We hypothesize that there is an increasing shift in its reporting and a positive shift in the language used within journals. We believe a shift in the perspective

regarding ADHD in adults has led to increased accessibility of resources and an opportunity for a more in-depth analysis of the disorder. Moving forward, we are hopeful that novel discoveries can help educate the public and raise awareness about the severity of the issue and its ability to influence all age groups.

METHODS

The purpose of the research manuscript is to investigate how the prevalence and language use of media coverage have contributed to the shifted public perception of adults with ADHD.

Source of Data

Qualitative and quantitative data was retrieved from the following search engine: Nexis Uni, which provides access to thousands of sources that cover a wide range of subject areas, including international news. Other reliable sources covering neurodegenerative disorders were considered, including Globe and Mail and The Guardian and Observer. These respective sources contained an insufficient number of news articles which met the selection criteria and thus were discarded.

Search Criteria and Process

The data will be collected based on the following criteria: 1) titles of the papers, including the following keywords: "Adults," AND "ADHD," OR "ADD," OR "Attention deficit hyperactivity disorder." 2) the time frame was for 5-year intervals between 2000-2020: every 5 year period was considered from the beginning of that year till the end of the fourth year. I.e., for 2000-2005, the timeframe was between January 1, 2000, until December 31, 2004, 3) Newspapers only were selected 4) English only was selected 5) Excluded stocks stories, non-business news and obituaries 6) Turn on the removal of "News Group Duplicate" 7) The first five articles regarding language use within each period were picked based on the relevance category.

Data Synthesis

A) Prevalence

One of our goals for this manuscript is to investigate the number of articles published each year regarding adults with ADHD. The prevalence of articles was captured by analyzing the number of articles published at 5-year intervals starting from 2000 to 2020. The published articles obtained using guidelines were mentioned in the search criteria and process. The number of results was then recorded as a numerical value.

B) Language use

The use of language to describe ADHD is key to investigating the public perception of the disorder among adults. Within the four time periods selected (2000-2005, 2005-2010, 2010-2015, and 2015-2020), we read through the first five articles categorized based on relevance. Adjectives describing ADHD and adults with ADHD were written down for each paper and included in an extensive list. Each adjective was then categorized to create the ADHD Descriptive Language Scale (ADL Scale), whose possible values range between 1 and 3 (1 involving derogatory adjectives such as annoying, mental illness, and disease, 2 involving neutral adjectives such as spontaneous, impulsive, and hyper-focused, and 3 involving respectful adjectives such as creative, hardworking, and innovative). For each article, an average score within the ADL scale will be calculated based on the adjectives present, considering the number of adjectives used and each adjective's ADL Scale score. It's also important to note that all adjectives in the article will be factored into this average, even if the same term appears multiple times. These averages will then be compared on MS Excel to analyze the possible language trends used when describing ADHD in adults within the four time periods ranging from 2000 to 2020.

RESULTS

A) Prevalence

A total of 427 articles were found between 2000-2020 using the search criteria. The data synthesis search criteria retrieved a total of 62 articles between 2000-2005, 86 articles in 2005-2010, 119 articles in 2010-2015, and 161 articles in 2015-2020.

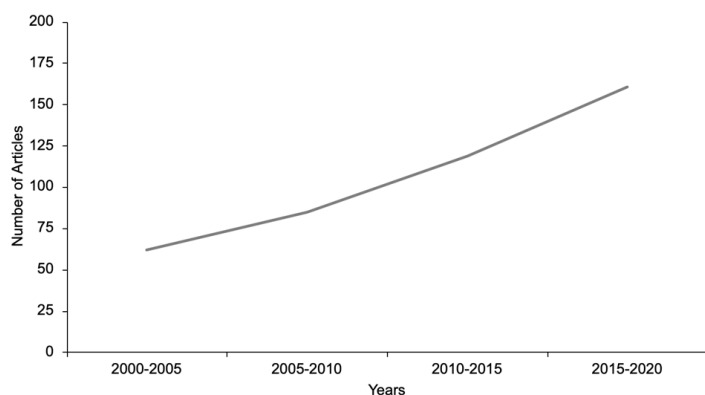


Figure 1. Number of articles published within each period. Line graph indicating the number of news articles published by the database Nexis Uni regarding adults and ADHD between the years 2000-2020 in 5-year intervals. The timeframe for the 5-year interval was set between January 1 of the first year and

ended on December 31 of the fourth year. The line graph was created using Microsoft Excel 2021.

B) Language use

The news articles from Nexis Uni database (n = 20) were individually analyzed based on the ADL Scale. The scores from the five news articles within each time period combined as an average. The average scores obtained for the 2000-2005 period, 2005-2010 period, 2010-2015 period, and 2015-2020 period were 1.64, 1.71, 1.88, and 2.15, respectively. This increasing trend is further seen in Figure 2. Over time, the percent increase between the four time periods was 4.55%, 9.38% and 14.6%, respectively. This trend is visualized by a bar graph in Figure 3, showing an increase in the ADL Scale within each progressive period.

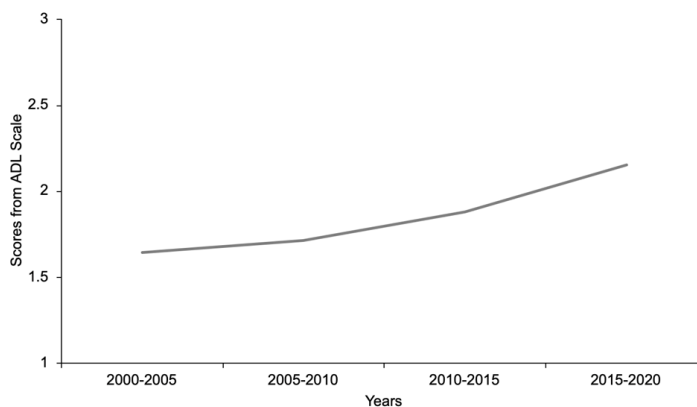


Figure 2. Scores from the ADL Scale within each period. A line graph showing the average scores of five news articles within each time frame, from 2000 to 2020, based on the ADHD Descriptive Language Scale. The line graph was created using Microsoft Excel 2021.

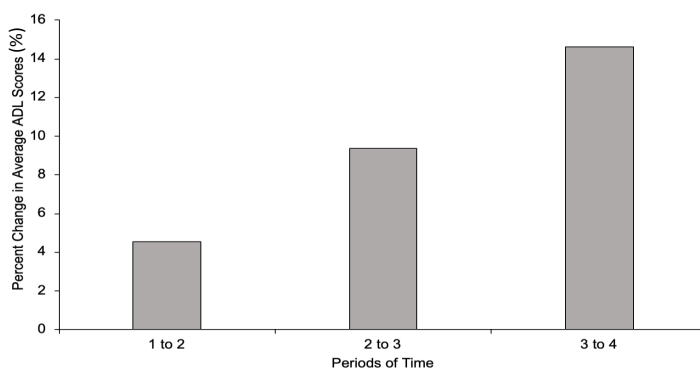


Figure 3. Percent change in average ADL scores between periods. A bar graph illustrating the difference in percent change of the average scores derived based on the ADHD Descriptive Language Scale from time period 1 to 2 (2000-2005 to 2005-2010), time period 2 to 3 (2005-2010 to 2010-2015), and from time period 3 to 4 (2010-2015 to 2015-

2020). The bar graph was created using Microsoft Excel 2021.

DISCUSSION

The objective of the present study nationwide study was to explore changes in the representation of news articles covering ADHD in adults from the year 2000 through 2020. There were two objectives in conducting this study. First, we examined trends in the prevalence of news articles published discussing ADHD in adults within the selected time period. Following this, we assessed how the language describing this mental disorder shifts public perception regarding ADHD in adults during the selected period.

The findings indicate a surge in articles published regarding adults and ADHD over the past two decades. The greatest rise was observed in the number of articles published from 2015 to 2020 with a 36% increase. These findings entail that ADHD in adults is gathering more attention, and an increased number of articles now discuss how ADHD can be present in adults. Additionally, a positive increase was found in the language used to address ADHD in adults over the past two decades. According to the ADL scale, results showcase an increase in the usage of positive and respectful descriptive words over time while discussing the prevalence of ADHD in adults. Specifically, the most rapid increase in positive language use was observed from 2015 to 2020. These observations may suggest an increase in the acceptance of ADHD as a disorder present among adults. It is also plausible that there is a positive shift in the coverage style of articles and reduced stigmatization.

Following the assessment of news articles published by Nexis Uni, there appears to be an increase in the overall number of articles published within the database discussing ADHD in adults. These results may suggest increased awareness and respectful language used for the topic. Diagnosis of ADHD at early stages is essential to controlling the symptoms and preventing worsening with age. Research by Joffe⁶ suggests early diagnosis is key to creating an accommodating environment. Early screening leads to proper treatment intervention to implement necessary adjustments to rapidly improve symptoms in a short amount of time.⁶ As most cognitive development occurs in childhood, children can adapt to environmental changes swiftly compared to adults.⁶ Thus, spreading awareness can help normalize the onset of ADHD, encouraging patients to seek testing and preventative measures. Joffe⁶ mentions that hesitancy in seeking treatment leads to more severe cases of ADHD. Additionally, several longitudinal studies have been conducted to examine the different types of damage that can result from not being diagnosed promptly.² Findings from these studies point to increased impair-

ments and complications of mental illness that are difficult to tackle later in life.²

According to a study conducted by Brown and Bradley¹⁶, derogatory terms used to describe mental illnesses fuel stigma and negative attitudes toward patients. Therefore, the negative language used to describe ADHD in the media leads to hesitancy to seek out testing. Although the findings elucidate an increase in the positive language used for adults with ADHD, further improvements can be made. Raising awareness globally regarding the prevalence of ADHD can help bolster familiarity with the disorder.¹⁷ Research by Corrigan and Niewegłowski¹⁷ indicates an inverse relationship between familiarity and stigma. Therefore, as familiarity with ADHD in adults increases, the public stigma surrounding it will decrease. Stigmatization regarding disorders is based on public knowledge.⁷ People develop conceptions about mental illness through personal experience, social interactions, and the media's portrayal of individuals with mental illnesses.⁷ The development of misconceptions leads to stereotyping, where others devalue and reject people with mental illnesses such as ADHD. People with ADHD are then subject to exclusion from opportunities, low self-esteem, and constricted social networks.⁷ Based on these consequences, reducing the stigma surrounding adults with ADHD is vital to help improve their health outcomes. The first step to creating an accepting atmosphere is altering how people refer to ADHD. A nurturing environment involves using respectful language to acknowledge the individual rather than the condition itself. Supporting ADHD patients and shifting towards a positive community that fosters inclusivity will improve their life satisfaction and encourage optimism.

LIMITATIONS AND NEXT STEPS

While this study revealed many insights about changes in language describing ADHD, it is partially limited by the methodology. The ADL Scale was created after a read-through of five articles on the topic of ADHD. Adjectives were then categorized based derogatory, neutral, or respectful connotation. The first issue with this system is that a read-through of five articles may not grasp all of the descriptive words used to describe ADHD. Synonyms or other similar descriptive words may have been omitted due to their absence in the first five articles. The selective word choice list also reduces the reproducibility of this study. Another limitation is the subjectivity of the words to specific categories. Although words can have a specific connotation, or defined meaning, depending on the placement or circumstance they are presented their meaning can completely change. To illustrate, the word 'perfect' can be used to describe excellence in nature. However, when used in a way such as 'perfect disaster,' the connotation of the sentence becomes negative. Therefore, hav-

ing a rigid categorization system of adjectives may work most of the time but is not guaranteed in its effectiveness due to possible variations in word use. Lastly, there are confounding factors that may have skewed the results to some degree, specifically concerning the prevalence of ADHD in the media. The study focuses on ADHD prevalence between the years 2000 and 2020. The important thing to note is the increase in internet use and access to information. With the rise of the internet in the early 2000s, the production of resources about ADHD in adults has increased.

Further research must be done regarding the prevalence of adult ADHD in the media and the connotations surrounding it to raise awareness and reduce existing prejudice and discrimination. Future directions regarding research on this topic would be the creation of a sentence-based undertone analyzer to better recognize derogatory, neutral, or respectful discussions about ADHD. For example, one existing program that can be utilized for sentiment analysis and language detection is the AYLIEN software.¹⁸ Furthermore, confounding variables such as a natural increase in prevalence should be explored. This can be done by producing a formula to estimate the expected increase in the topic (based on trends) and comparing it to the increased adult ADHD in media.

CONCLUSION

In conclusion, the findings demonstrate an overall increase in the number of articles published regarding ADHD in adults in international news since the year 2000. Specifically, the research and discussions of relevant scientific material have shown to increase most rapidly from 2015-2020. These results may suggest an increase in awareness regarding ADHD as a disorder not specifically affecting children, but one that is present in adults as well. Furthermore, scores from the ADL analysis reveal a rise in the respectful language being used to discuss ADHD in adults. The greatest increase in positive descriptive word usage was observed from 2015-2020, which proposes an increase in acceptance of ADHD in adults. However, future research should focus on a wider sample range and make use of an automated tone analyzer to observe further the increase in the literature about ADHD in adults and its acceptance within society. Doing so will help bring attention to this area of concern and reduce the associated stigma, which will help promote proper diagnosis and treatment of patients.

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ARTICLE INFORMATION

Senior Editor
Zani Zartashah

Reviewers and Section Editors
Mira Ishak, Tresha Sivanesanathan

Formatting and Illustrations
Zak de Guzman

APPENDIX

Table 1. The table shows the number of news articles published by the database Nexis Uni regarding adults with ADHD between the years 2000-2020 in 5-year intervals. The timeframe for the 5-year interval was set between January 1 of the first year and ended December 31 of the last year.

Nexis Uni Articles Relating to ADHD in Adults from 2000	
5-Year Interval	Number of News Articles
2000-2005	62
2005-2010	85
2010-2015	119
2015-2020	161

Table 3. The table shows the number of news articles published by database Nexis Uni regarding adults and ADHD between the years 2000-2020 in 5-year intervals. The timeframe for the 5-year interval was set between Jan 1 of the first year and ended Dec 31 of the last year.

ADL Scale Scores						
Years	Averages					Total Averages
2000-2005	1A: 1.5909	1B: 1.6666	1C: 1.5238	1D: 1.8235	1E: 1.6111	1.6432
2005-2010	2A: 1.5000	2B: 1.6923	2C: 1.7059	2D: 1.6667	2E: 2.0250	1.7179
2010-2015	3A: 1.6111	3B: 2.0270	3C: 2.0769	3D: 2.0000	3E: 1.6800	1.8790
2015-2020	4A: 2.0566	4B: 1.5862	4C: 2.3333	4D: 2.6061	4E: 2.1852	2.1535

Table 2. The table shows the names of all news articles retrieved from Nexis Uni between the years 2000-2020 in 5-year intervals. The title of these articles contained the keywords: “Adults” AND “ADHD” OR “ADD” OR “Attention deficit hyperactivity disorder”. These articles were sampled using our search criteria and further analyzed with the ADL scale.

Nexis Uni Articles Used for ADL Scale Analysis					
5-Year Interval	Nexis Uni Article Names				
2000-2005	1A: The hyperactive adult Most people associate attention deficit hyperactive disorder with kids. But what happens when those youngsters grow up?	1B: YOUR HEALTH; Growing up restless; hyper ac thought attention deficit/ hyper activity disorder affected only youngsters. Researchers now believe millions of adults have the ailment, and a new drug offers some of them hope.	1C: Attention, please; With experts’ support that ADHD is real, millions of adults are taking medication for a disorder once associated only with kids	1D: Adults distracted by ADHD	1E: ADD affects adult population
2005-2010	2A: ADHD has serious consequences on multiple aspects of adult life	2B: I’ve been told I suffer from ADHD (that’s attention deficit hyperactivity disorder); It’s a condition associated with children, but Nicola, 36, is one of many adults who blame it for their problems. But are they actually ill?	2C:Adults living with ADHD studied; ATTENTION DEFICIT HYPERACTIVITY DISORDER	2D: Help for adults with ADHD	2E: Understanding adult ADD/ADHD
2010-2015	3A: Challenges of adult ADHD	3B: ADULTS LIVING WITH ADHD DEAL BETTER WITH SUPPORT	3C: When having a hundred things to do is a disorder; Are you running late and is your ‘to-do’ list driving you crazy? You could, like me, have adult ADHD, says Helen Croydon	3D: Adults can suffer from ADHD	3E: Help for ADHD adults
2015-2020	4A: I’m not lazy, I have ADHD: Adults can have the condition too;Adults can have the condition too, which involves difficulty focusing, being impulsive and hyperactive, say doctors	4B: Think you’re depressed? It could ADULT ADHD	4C: Married to ADHD; When her husband’s eccentric quirks were diagnosed five years ago, Lucy Nichol found it strengthened their marriage and shed light on a condition not often associated with adults	4D: Study finds high levels of creativity, originality in adults with ADHD	4E: ‘My ADHD diagnosis made me a high flyer’; As adult cases soar, Sandra Scott says discovering she had the condition in her 40s only spurred her on to greater business success

Impacts of Air Pollution on the Respiratory System of Adults in Relation to Socioeconomic Status

Kleiton Strobl¹, Syed Asad Irfan¹, Layla Halwagi¹, Shane Shrikanth¹

1. McMaster University, Honours Life Sciences, Class of 2022

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SUMMARY

Air pollution has many negative effects on the body, especially on the respiratory system. However, thorough summaries on this topic are limited, especially in relation to other factors, such as income, education, and occupation. This study summarizes existing research on this topic and outlines important steps for the future. It was found that air pollution aggravates multiple lung problems, such as coughing, wheezing, chronic obstructive pulmonary disease, asthma, and cystic fibrosis. Small solid particles were usually the culprit of this because they can pass through lung filters and damage tissues. This is problematic for lower-income individuals, as they tend to live near industrial areas where air pollution is high. Unfortunately, many countries take this matter less seriously than others. Some measures that were taken to tackle this issue, including introducing more green spaces to allow for trees to absorb air pollutants, resulting in improved air quality. However, the effects were minimal. In the future, there needs to be more research on the health impacts of air pollution and how it can be effectively tackled on a policy level, especially for low-income families.

ABSTRACT

Air pollution has a significant impact on respiratory health, yet comprehensive summaries of specific impacts are limited. This study reviews previous research done on this link, while connecting it to socioeconomic factors. Common air pollutants, such as particulate matter, have a large impact on respiratory health and can exacerbate diseases and medical conditions, such as coughing, wheezing, chronic obstructive pulmonary disease, asthma, and cystic fibrosis. Specifically, PM₁₀ pollutants can deposit in the upper airways, and PM_{2.5} can reach deep into the lungs, leading to many complications. The efficacy of measures taken to combat these issues are also discussed. In recent years, governments have introduced national climate policies and green-space designs in urban municipalities to reduce negative health outcomes. These measures accomplish this goal to a limited degree but require further investment and development. To outline how socioeconomic status impacts air pollution-related respiratory illnesses, our study discusses five studies investigating socioeconomic disparities in air pollution exposure in various parts of the world. Evidence shows that low-income people typically reside in areas with high air pollution because housing is more affordable. This provides an opportunity for new research in social determinants of health to better understand its connection with human health.

Keywords: Human health, impact of air pollution, respiratory health, socioeconomic factors, public health

INTRODUCTION

Air pollution refers to the presence of harmful particles in the atmosphere.¹ This includes gasses, such as nitrogen oxide, sulfur dioxide, carbon monoxide, polycyclic aromatic hydrocarbons (PAHs), and many more.¹

Another type of air pollutant is called particulate matter (PM), which are solid particles with a very small diameter dispersed in the air.² These are mainly emitted into the atmosphere from the burning of fossil fuels.² This includes but is not limited to the use of gasoline and diesel-based automobiles, factories, and

coal power plants. However, natural sources of air pollutants also exist in the form of volcanoes, wildfires, etc.¹ The sources of the most abundant air pollutants are further explained in Table 1. In addition, these pollutants are linked to negative effects on human health.¹ For example, long-term exposure to nitrogen dioxide (NO₂) can impair a person's ability to smell.³ Furthermore, exposure to carbon monoxide (CO) can induce symptoms, such as headaches, nausea, and vomiting.⁴ However, there is a notably high impact of air pollution on the respiratory system, which is why it will be the primary focus of our paper.

The purpose of this review is to provide a critical analysis of the effects of air pollution on the respiratory

system and its potential link to socioeconomic status. The term socioeconomic status (SES) defines the social standing of people or their class. It is primarily based on the dimensions of income, occupation, and education.⁶⁻⁸ A person of high SES is one who is well educated, has a high income, and/or holds a high-ranking position within their occupation. In contrast, people considered to hold a low

Table 1. Artificial and natural sources of common air pollutants sulfur dioxide, carbon monoxide, nitrogen oxide, and particulate matter. The information within this table was derived from a study conducted by the IARC Working Group on the Evaluation of Carcinogenic Risks to Humans.⁵

Air pollutant:	Artificial Sources:	Natural Sources:
Sulfur dioxide (SO ₂)	Fossil fuel combustion through gasoline/diesel-powered vehicles, metal processing facilities, etc.	Volcanic eruptions, oceanic microbial activity, anaerobic degradation of organic matter, etc.
Carbon monoxide (CO)	Incomplete combustion of fossil fuels by gasoline/diesel-powered vehicles, combustion of biomass, etc.	Volcanic eruptions, wildfires, etc.
Nitrogen oxide (NO)	Fossil fuel combustion through gasoline/diesel-powered vehicles, power plants, agricultural fertilizers, etc.	Lightning strikes, stratospheric oxidation of nitrous oxide (N ₂ O) etc.
Particulate matter (PM)	Fossil fuel combustion by gasoline/diesel-powered vehicles, vehicular abstraction, fugitive dust emission from mining, etc.	Volcanic eruptions, wind driven disbursement of dust, pollen, etc.

SES are characterized by lower education levels, low income, and having less prosperous occupations. Previous studies have investigated the link between air pollution and specific respiratory disorders or the association between air pollutant concentrations and SES; however, few studies have attempted to connect the two on a larger scale. Our article aims to inspire advancements in the disciplines of respiratory health,

environmental pollution, and socioeconomic status. Our goal is to encourage other scholars to conduct more studies in these areas worldwide to discover if the link between them is consistent.

Within this paper, the effects of air pollution on the respiratory system, such as coughing, wheezing, chronic obstructive pulmonary disease (COPD), asthma, and cystic fibrosis are discussed first. Then, the discussion shifts to the various socioeconomic factors associated with the frequency of air pollution, which include the locations where low SES individuals live and the quantity of green space around their neighborhoods.

2. IMPACT OF AIR POLLUTION ON THE RESPIRATORY SYSTEM

Air pollution has been proven to have many negative effects on human health. It is a known contributor to stroke, brain damage, cancer, and most of all, acute and chronic effects on respiratory health.^{9,10}

These adverse effects on respiratory health are primarily brought about by air pollutants, such as nitrogen oxides (NO_x), ozone (O₃), sulfur dioxide (SO₂), carbon monoxide (CO), and particulate matter (PM).¹¹ These pollutants affect different parts of the respiratory system, leading to increasingly more severe health outcomes, ranging from minor respiratory irritations to chronic respiratory disease, lung cancer, lung infections, etc.¹¹

An air pollutant with strong evidence linked to adverse health effects on the respiratory system, is particulate matter. Often used as a measure of air pollution, two important types of particulate matter which will be discussed in depth are coarse particulate matter (PM₁₀) and fine particulate matter (PM_{2.5}). These particles have a diameter smaller than 10µm and 2.5µm, respectively.¹² Coarse particulate matter mainly deposits in the upper airways and the trachea, whereas fine particulate matter can penetrate deep inside the lungs.¹² Fine particulate matter is also associated with cardiorespiratory disease and mortality. Both types of particulate matter can cause symptoms, such as persistent coughing, wheezing, and inflammation in the airways which exacerbates chronic obstructive pulmonary disease (COPD), cystic fibrosis, and asthma.^{12, 13}

2.1 COUGHING & WHEEZING

Air pollution leads to an increased frequency of wheezing. Specifically, PM₁₀ and PM_{2.5} pollutants enter the respiratory tract and cause bronchoconstriction.³ Additionally, PM_{2.5} can corrode the alveolar wall, reducing overall lung function.¹⁴ The presence of foreign material in the lungs was also found to induce inflam-

matory responses in the respiratory tract, such as the increased presence of phlegm.¹⁵ All these factors combined can cause wheezing in subjects for long periods of time, which can make their breathing laboured.¹²

Furthermore, air pollution can cause significant coughing when inhaled. For instance, sulfur dioxide (SO₂) is a common air pollutant and a well-known respiratory tract irritant.¹⁵ Thus, when sulfur dioxide is inhaled, it is converted into bisulfite (HSO₃⁻), which affects sensory receptors in the lungs and causes bronchoconstriction.¹ More importantly, inhalation of PM_{2.5} pollutants can lead to persistent coughing because these particles are small enough to enter the walls of the larynx and trachea, agitating the area.^{12, 16} Additionally, these particles typically induce an inflammatory response, which increases phlegm and ultimately aggravates coughing. Within elderly patients, this persistent coughing causes fatigue and eventually leads to fluid buildup in the lungs and subsequent onset of pneumonia.¹⁷

2.2 CHRONIC OBSTRUCTIVE PULMONARY DISEASE

Chronic obstructive pulmonary disease (COPD) is typically diagnosed in people who have long-term complications with breathing, specifically due to the limited amount of airflow allowed to reach the lungs. This airflow is typically restricted because of inflammation from consistent particulate matter and/or noxious gas exposure.¹⁸ According to the World Health Organization, COPD is responsible for 3.23 million deaths in 2019 and is the third leading cause of death worldwide.¹⁹

In most cases, COPD is caused by cigarette smoking; however, especially in recent years, poor air quality arising from pollution has also raised questions as to whether it can increase one's risk of COPD.¹²

One study evaluated non-smoking individuals in China who were over the age of 50 through spirometry.²⁰ Spirometry is a common test which measures a person's lung functional integrity. By using this technique, Lam and colleagues diagnosed COPD those who had a forced expiratory volume (FEV) to forced vital capacity (FVC) ratio less than the lower limit of normal (LLN – which was predicted from Chinese populations). Interviews were also conducted with participants of the study to understand their occupation and personal lifestyle.²⁰ Overall, this study found that COPD diagnosis has a positive association with those who have a high exposure to air polluted environments. Moreover, occupational exposure to polluted air was found to be the most vulnerable risk factor for COPD.²⁰ Lam and researchers did not analyze specific air pollutants; however, further research by Doiron

and colleagues (2019) narrowed on the key pollutants.

Specifically, Doiron's team assessed concentrations of specific noxious gasses in comparison to lung function. They discovered that PM_{2.5} concentration increases of 5µg·m⁻³ were associated with decreases in FEV. This finding explains why researchers also observed an increased prevalence of COPD in areas that contained higher concentrations of PM_{2.5}. Areas with higher concentrations of PM₁₀ and NO₂ also noticed a greater prevalence of COPD.²¹ Therefore, PM_{2.5}, PM₁₀, and NO₂ are all significant air pollutant culprits in lung physiology.

It is important to note that although these findings are promising when it comes to making connections between air pollution and COPD, such observations are not always replicable and are inconclusive instead.²² Therefore, more research is warranted in this field to gain a firmer grasp on the issue and to investigate a definite connection.

2.3 ASTHMA

Asthma is a well-known, chronic respiratory disease that can be defined by obstruction of airflow, airway inflammation, and bronchial hyperresponsiveness, an increase in sensitivity to a wide variety of airway narrowing stimuli.²³ The disease is characterized by a variety of respiratory symptoms including wheezing, dyspnoea, coughing, and tightness of chest. The prevalence of asthma ranges from between 1% and 18% in countries globally.²⁴ There is increasing evidence that shows a connection between indoor and outdoor air pollution and new-onset asthma.

A main contributor to asthma development is traffic-related air pollution (TRAP) and power generation, creating a pollutant mixture that not only contains components such as PM_{2.5}, PM₁₀, NO₂ and black carbon, but also rich in particulate matter.²⁵ There is also evidence that outdoor air pollution can exacerbate pre-existing asthma conditions. Urbanization is an important contributor to asthma, which is due to increased outdoor air pollution.²⁵ Since many regions are developing and experiencing growing populations (resulting in increased levels of air pollution), the global burden of asthma is likely to increase.

Why are individuals with asthma susceptible to air pollution? When looking at areas with high concentrations – for example, Delhi, India – air pollutants may have direct inflammatory effects accompanied with more serious health concerns.²⁵ However, cases of high concentrations are not common in higher-income locations, such as Melbourne in Australia. At these lower concentrations, specific pollutants can contribute to features of asthma. For example, ozone, nitrogen dioxide, and PM_{2.5} can potentially contribute to

airway inflammation. Also, ozone and nitrogen dioxide are contributors to bronchial hyperresponsiveness.²⁵ In more severe cases of asthma, oxidative stress (the imbalance between oxygen reactive species and anti-oxidative abilities of the body) can be associated with ozone, nitrogen dioxide, and PM_{2.5}.²⁶ Although there are links between the specific pollutants and features of asthma, the exact mechanisms and processes by which the pollutants influence asthma are not known and require more research.

2.4 CYSTIC FIBROSIS

2.4.1 Pathophysiology of CF pulmonary exacerbation and clinical epidemiology of CF pulmonary exacerbation

The pulmonary system, namely the upper and lower airways, is responsible for the morbidity and death associated with cystic fibrosis (CF).²⁷ Based on *in vitro* evidence, the postulated mechanism of CF airway illness is the volume of periciliary lining fluid decreases relative to the dryness of the layer. Relative dryness of the layer occurs due to sodium hyperabsorption and lack of chloride absorption.²⁷ This results in reduced fluid volume, poor ciliary function, and delayed mucociliary transfer, allowing germs to thrive. When there is infection, neutrophils (a type of white blood cell from the immune system) are drawn to the airway while producing proinflammatory cytokines. These cytokines create a vicious cycle of persistent infection and inflammation that eventually damages the airways.²⁷

Despite our deep understanding of CF at the cellular level, relatively little is known about the pathophysiology of exacerbations — recurring bouts of worsening pulmonary symptoms.²⁷ Exacerbations of pulmonary illness are quite prevalent and reflect clinically as changes in cough, sputum output, dyspnoea, reduced energy and appetite, weight loss, and declines in spirometric parameters. These events are most likely connected to a complicated interplay between host defense and airway microbiology, which influences sputum production and airflow restriction.²⁷ Although data on the impact of immunization against viral infection is sparse, viral infections, especially respiratory syncytial virus, may play a role in the onset of these events.²⁷⁻³⁰ Aggravations of pulmonary disease have also been linked to the acquisition of additional organisms or a change in the bacterial density of the colonizing flora.^{27, 31-34}

Some of the symptoms of exacerbation of cystic fibrosis include a fever; increase in coughing rates by 50%; a 10 breath-per-minute rise in respiratory rate; 50% increase in sputum volume; decrease in forced vital capacity of at least 10%; symptoms of upper respiratory

tract infections; appetite loss and a weight loss of at least 1 kg; a peripheral blood neutrophil count of 15000 or higher per cubic millimeter; and absence from school or work (at least three or the previous seven days) due to sickness.³⁵

2.4.2 Pulmonary exacerbation rates

Rates of CF pulmonary exacerbation rise with age and severity of pulmonary impairment.²⁷ A pulmonary exacerbation is defined as a CF-related lung disease that necessitated hospitalization or the use of home intravenous antibiotics. When participants reach adolescence and young adulthood, the proportion of CF patients who have at least one pulmonary exacerbation each year increases. Adults have a linear association with rising exacerbation rates and decreasing lung function.²⁷

2.4.3 Pulmonary exacerbation and air pollutants

Past research has found that increasing yearly average exposure to ambient air pollutants, especially PM₁₀, PM_{2.5}, and ozone, relates to an increased risk of two or more pulmonary exacerbations in CF patients. The link is strongest among individuals who have two or more exacerbations per year.³⁶ Even when there are no symptoms, CF patients have signs of airway infection, inflammation, and tissue breakdown products; the process that leads to the deterioration of the integrity of the CF airway is lifelong.³⁶

The CF lung has high quantities of free white blood cells and their enzymes (myeloperoxidase and neutrophil-derived proteases), as well as low levels of different enzymes which impact the airways, such as S-nitrosoglutathione.³⁷ This means that air pollutants might irritate and injure the airways more in environments of high oxidative stress and inflammation. In turn, this may impact the rate of airway infection as well as its severity.³⁶ Also, it is important to note that PM_{2.5} and PM₁₀ exhibited the most consistent relationships with significant clinical outcome markers in this study. This conclusion may be supported by recent research in CF patients, but further research is warranted.³⁶

3.0 SOCIOECONOMIC VARIABLES RELATED TO PREVALENCE OF AIR POLLUTION

A person of SES is one who is well educated, has a high income, and/or holds a high-ranking position within their occupation. In contrast, people considered to hold a low SES are characterized by lower education levels, low income, and having less prosperous occupations. Although SES is usually based on a combination

of income, occupation, and education, they do not always need to be present together to determine a person's SES.⁶ For example, a person may not be well-educated and yet may own multiple successful companies. This person would still be characterized as having a high SES. In contrast, another individual may hold a PhD designation and yet have a low-income level. This individual would be characterized as having a low-to-middle socioeconomic status.

SES contains many economic and societal forces that affect health. Examples of economic and societal forces on health can be seen in Table 2.

Table 2. Examples of economic and societal forces on health

Income	Occupation	Education
Spending power	Responsibility	Skills and qualifications needed social and economic resources
Housing	Prestige	
Diet	Work opportunities	
Medical care	Recreation opportunities	

3.1 STUDIES ON SOCIOECONOMIC DISPARITIES IN AIR POLLUTION EXPOSURE

One study conducted by Fan and colleagues, researched the impact of socioeconomic status on air pollution exposure in Hong Kong.³⁹ The specific levels of air pollutants assessed included carbon monoxide, nitrogen oxides, sulfur dioxide, and PM₁₀.³⁹ It was found that within the private housing market, there was a considerable inequality in exposure to air pollution. Specifically, neighbourhoods comprising lower SES families had higher levels of air pollution compared to higher SES neighbourhoods, and the greatest disparity was found for the air pollutant PM₁₀.³⁹ Interestingly, public housing provided by the government for lower SES families had lower air pollution levels than similar neighbourhoods in the public housing market.³⁹ This demonstrates that government intervention in the housing market is a potential strategy for reducing SES disparities.

Another study by Rooney et al. (2012) found that community SES was inversely associated with particulate matter pollution.⁴⁰ This study was conducted in four

communities: Jamestown/Ushertown, Asylum Down, Nima, and East Legon in Accra, Ghana.⁴⁰ The results showed that particulate matter pollution was higher in low SES neighbourhoods with PM_{2.5} and PM₁₀. The PM_{2.5} and PM₁₀ concentrations were 34% and 20% higher, respectively, in the lowest SES neighbourhood compared to the highest SES one.⁴⁰ Sources of pollution in these communities included transportation, dust from unpaved roads, household/small business biomass stoves and fuel burning, and trash burning. Moving forward, financial support and increased accessibility to alternative fuels for lower-income communities will help reduce/limit air pollution.⁴⁰

Furthermore, few studies have investigated differential vulnerability to air pollution by socioeconomic status, and all have been concentrated in one or a few cities in a single country.⁴¹⁻⁴⁶ These studies consistently found that subjects of SES are more vulnerable to the health impacts of air pollution, independent of exposure.^{46, 47} As a result, differential exposure and susceptibility to air pollution may contribute to the persistence of health inequalities in Europe.^{46, 48} However, the extant European research is restricted in breadth, raising concerns about the conclusions' generalizability to other contexts, notably Eastern Europe.⁴⁶ Additionally, one study looked at Europe as a whole and considered if low-income European people were: (a) exposed to disproportionately high levels of particle air pollution (PM₁₀) and/or (b) disproportionately vulnerable to pollution-related death consequences.⁴⁶

The study discovered evidence of environmental disparity. The double disadvantage of low income and bad air quality was disproportionately concentrated in Eastern European regions and was drove the Europe-wide association.⁴⁶ Lower-income populations were more vulnerable to the impacts of PM₁₀, but only in terms of cardiovascular disease mortality in Eastern Europe and male respiratory mortality in Western Europe.⁴⁶ They discovered considerably higher odds of male and female cardiovascular- and- respiratory- illness-caused death and female all-cause mortality in Eastern European locations.⁴⁶ Thus, income-related disparities in exposure to ambient PM₁₀ may contribute to Eastern European-wide mortality disparities.⁴⁶

Another study, conducted by Su and colleagues (2010), found similar results with median household income as a socioeconomic variable, and its association with air pollution in two major North American cities: Vancouver and Seattle.⁴⁹ Specifically, nitrogen dioxide (NO₂) levels were utilized as a measure of air pollution and were compared to census data taken from these cities.⁴⁹ At the end of the study, the strongest and most consistent negative correlation existed between NO₂ concentration levels and median household income of a neighbourhood. For example, the higher the median household income, the lower the

observed NO₂ concentration levels were in a given neighbourhood.⁴⁹

Evidently, these studies show that SES is strongly associated with the amount of air pollution exposure in a given neighbourhood.⁵⁰ Understanding this connection is key to linking lower SES individuals with higher risk of respiratory disease. As previously discussed, air pollution has made extraordinary impacts on human respiratory health. Therefore, lower SES individuals would be exposed to polluted air more often and, in turn, carry a higher risk of experiencing respiratory complications during their lifetime.

4. EFFICACY OF CURRENT EFFORTS AGAINST AIR POLLUTION AND ITS ASSOCIATED RESPIRATORY CONDITIONS

4.1 POLICIES

National climate policies may be ineffective in lowering consumption-based CO₂ emissions (carbon footprints) in a world with varying emission reduction objectives.⁵¹ For instance, reducing carbon emissions is a lower priority in China where economic growth is primarily based on industrial processes for manufacturing of goods.⁵² In this case, efforts to reduce carbon emissions could have a direct impact on economic prosperity which is why it is not as emphasized.⁵³ In other countries, such as Denmark, whose economy is less dependent on industrial processes, carbon reduction efforts are more prominent.⁵⁴ Additionally, Denmark has a high GDP allowing it to withstand an economic reconstruction away from the consumption of fossil fuels.^{55,56} A study looked at whether well-designed policies could reduce global material, energy use, and carbon emissions while having minor effects on living standards.⁵⁷ They assessed global decoupling potential using a novel combined economic and environmental modeling approach. This novel approach entails production (territorial) and consumption methods to examine regional differences in natural resource use and carbon emissions across three stylized policy outlooks.⁵⁷ A reference case with no significant changes to the environment and climate policies consisted of a high efficiency outlook with a global carbon price rising from US\$50 to US\$236 per tonne of CO₂ between 2010 and 2050, and improvements in resource efficiency (rising from 1.5 percent historically).⁵⁷ The authors discovered that the amount of carbon emissions would be less than half of the reference case with a global carbon price, and material use would grow at a slower rate. Organization for Economic Co-operation and Development (OECD) economies have significant potential to reduce material throughput and carbon emissions while maintaining economic

growth.⁵⁷ In contrast, developing economies, such as China, could expand their economies at a much lower environmental cost. Globally, very strong reduction and resource efficiency policies have negligible effects on economic growth and employment until 2050.⁵⁷ According to the 2016 study, decarbonization and dematerialization are possible with well-designed policy settings and would not conflict with efforts to improve human well-being and living standards.⁵⁷

An investigation of the National Policies for Effectiveness of Carbon Emission Reductions in International Supply Chains found that in the case of building construction, adding a carbon tax is highly effective in reducing consumption-based emissions.⁵¹ In contrast, due to reallocated investment capital, an information obligation on vacant dwellings combined with a penalty payment if vacant buildings are not made available is ineffective.⁵¹

Another study concluded that since 2015, the once-dominant theme has now proceeded backwards: maintaining, if not growing, support for fossil-fuel extraction and burning while decreasing support for cleaner alternatives.⁵⁸ Although the consequences of these measures have yet to be quantified, it is plausible to infer that they will result in increased carbon emissions and subsequent consequences on respiratory health.

4.2 GREEN-SPACE DESIGN IN URBAN MUNICIPALITIES

Another measure taken to combat air pollution and its adverse effects on human health is the introduction of public green spaces – understood as outdoor grounded vegetation – in cities. Green spaces and vegetation have been proven to reduce concentrations of air pollution, with a greater effect on particulate matter.⁵⁹ A study conducted by Selmi et al. in Strasbourg from 2012-2013 calculated that public trees remove approximately 7% of emitted PM₁₀ from the atmosphere, with effects on other air pollutants being small.⁶⁰

Research has also indicated that urban green space has a significant effect in the reduction of mortality of respiratory diseases and conditions. A study conducted by Jaafari et al. (2020) in Tehran applied equation modeling and metrics to predict and evaluate the effects of green space on health.⁶¹ This study found that the most important variable when considering urban green space was its area, and that maximizing urban green space (and its cohesion) contributed not only to a reduction of air pollution, but also the mortality of Tehranian citizens.⁶¹

It was suggested that trees and public green spaces are methods of reducing air pollution, but more work is

necessary to reap the full benefits of these methods. Urban planning strategies, such as the location of local sources of pollution, street design, traffic management, built structures, as well as other factors must also be carefully monitored.⁶⁰ Additionally, the density of tree groupings, gender of trees, and other variables must be considered to reduce the incidence of allergens and trapped pollutants that can be dispersed by air currents.⁶² Urban green space implementation can yield beneficial results, but in order to avoid negative health impacts, more research must be done to understand its limits.

5. LIMITATIONS AND NEXT STEPS

While our paper can provide valuable insight for the medical and urban planning fields of the future, it is important to acknowledge that limitations do exist. Many studies mentioned throughout our paper show strong associations between air pollution and respiratory disease as well as air pollution and SES. While this can provide context on relationships between variables, they remain strictly correlational. More research is warranted in these areas to determine whether these connections exist and are causal.

Our review analyzes studies from all over the world. However, we recognize that we did not present data from every region. Therefore, our findings should be approached with caution due to the potential of lacking generalizability for regions not mentioned.

In the future, there should be more systematic reviews conducted to assess the situation on a global scale with a more comprehensive overview of different countries. In addition, a larger set of socioeconomic variables should be assessed in future studies, including immigration status, race, gender inequalities, and more. Such studies would also benefit from incorporating direct responses from underprivileged and discriminated groups to better understand the situation from the perspective of those affected.

5. CONCLUSION

Ultimately, this review comprehensively summarizes the impact of air pollution on the respiratory system, comments on the efficacy of efforts being done to tackle the problem, and introduces how socioeconomic variables come into play. This review sets a good starting point for others to further research the topic while thoroughly becoming acquainted with the respiratory impacts of air pollution.

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APPENDIX: SEARCH STRATEGY

To ensure an optimal method of scoping research, we conducted systematic literature searches on Google Scholar and PubMed with five key terms: “human health”, “impact of air pollution”, “respiratory health”, “socioeconomic factors”, “public health”. Each author individually compiled a list of articles to select the ones most relevant to the research question. Collectively, overlapping articles were selected for analysis.

The inclusion criteria consisted of any primary research study article in English that mentioned air pollution's impact on human respiratory health and/or the socioeconomic factors which affect their exposure to air pollution. The exclusion criteria were any study that analyzed participants who were of 18 years or younger of age. Secondary research was also used as well to supplement the topic; however, it was limited to less than three articles.

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An Interdisciplinary Review of the Qualities of Glioblastoma Multiforme

Nrithya (Rith) Bal¹, Lauren Mutton¹

1. McMaster University, Integrated Science, Class of 2024

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SUMMARY

Using a cross-disciplinary approach, this review aims to cover the defining features of Glioblastoma Multiforme (GBM), an aggressive and highly lethal brain tumour. GBM is the most commonly diagnosed malignant brain tumour that has one of the lowest survival rates of any cancer today. In this review, a discussion of the epidemiology, prevention measures, detection methods, and treatment methods are provided to present a holistic analysis of the current and future medical approaches to GBM. Although the genetic risk factors of GBM cannot be prevented, certain lifestyle-related changes can potentially decrease one's chances of developing GBM. Additionally, through its many properties, CT scans offer a detailed account of the condition of various areas of the brain. Furthermore, a fractionation schedule of 2.21 Gy was calculated to maximize cancer tissue death and minimize normal cell death in potential treatments. These findings illustrate the importance of understanding GBM and how modern-day strategies can shape future attempts to combat malignant growth.

ABSTRACT

Brain cancer, despite being one of the rarest forms of cancer, is one of the most substantially impactful cancers known to humankind. In this review, a comprehensive analysis of the multifaceted nature of brain cancer is conducted, with a particular focus placed on Glioblastoma Multiforme (GBM). Epidemiology, prevention measures, treatment techniques, and determinants of susceptibility are investigated to gain a deeper understanding of GBM. Additionally, the biophysical concepts used in Computed Tomography (CT) scanning for tumour detection are explored. Radiation therapy as a treatment modality for GBM is examined using Intensity Modulated Radiation Therapy (IMRT). Furthermore, the mechanism of action of Temozolomide, the prevailing chemotherapeutic drug used to hinder GBM growth by methylating target DNA sites, was also analyzed. Additionally, a cell survival curve outlining a traditional fractionation schedule of 2.21 Gy installments was created to effectively model a conventional radiation treatment plan. As a result, we are able to gauge the efficacy of such radiation treatments. In summation, we present a broad synopsis of the current strategies, insight, and approaches used to detect, image, and treat the malignant growth of GBM.

Keywords: Brain cancer, glioblastoma multiforme, CT scans, chemotherapy, radiation therapy

INTRODUCTION

Cancer belongs to the family of diseases typified by the development and uncontrollable growth of abnormal cells with the ability to destroy surrounding body tissue.¹ Brain cancer is defined as the uncontrollable growth of abnormal tissue in the brain and is divided into two main categories based on the tumour's area of origin: primary and metastatic.² Primary brain tumours may originate in the brain itself, or in nearby tissue such as the meninges, cranial nerves, or pituitary or pineal glands.³ This review is centered around GBM, a primary brain tumour. GBM is a fast-growing glioma, a general term used to describe primary brain tumours.⁵ Metastatic brain tumours are more com-

mon, and arise from cancer developing elsewhere in the body and metastasizing to the brain.^{3,4} Recent studies indicate that GBM develops from astrocytes, which are star-shaped glial cells that support neuronal function, and also carry various neural stem cell-like properties.^{2,7} The most frequent location of origin for GBM is the cerebral hemispheres of the brain, with a smaller percentage of GBMs occurring in the cerebellum, brainstem or spinal cord.⁵ GBM is an invasive intracranial tumour that commonly spreads through direct infiltration and extension into adjacent brain tissue. The metastatic spread of GBM outside of the central nervous system (CNS) is rare.⁶ Additional research into GBM reveals incidence is slightly higher in men than women, and in Caucasians relative to other ethnicities.⁷

1.1 EPIDEMIOLOGY

Although brain tumours and other such malignancies of the CNS are rare, their mortality remains disproportionate to their global incidence.⁸ In Canada, a GBM diagnosis is a grave predicament, and only 4% of diagnosed Canadians aged 45-54 retain a five-year relative survival.⁹ Despite survival rates varying worldwide, a strong correlation exists between lower Human Development Index (HDI) and increased incidence and mortality of brain cancers.¹⁰ Increased monitoring of risk factors and access to earlier detection and treatment plans are instrumental to controlling brain cancer in higher HDI level nations.¹⁰

As of 2015, GBM is the most common malignant tumour in Canada, and the third-most reported tumour at an average of 5691 cases per year.¹¹ For Canadian men, GBM was the most commonly diagnosed brain tumour, with an average annual incidence of 562 cases.¹¹ As seen in Figure 1, three major nations, England, United States, and Canada, each saw visible GBM incidences increase from 1995 to 2015. In this 20-year span, Canada witnessed a crude percent increase of 26.4% in age-standardized GBM incidence rates, and by 2015, Canada held a rate of 4.50.¹²

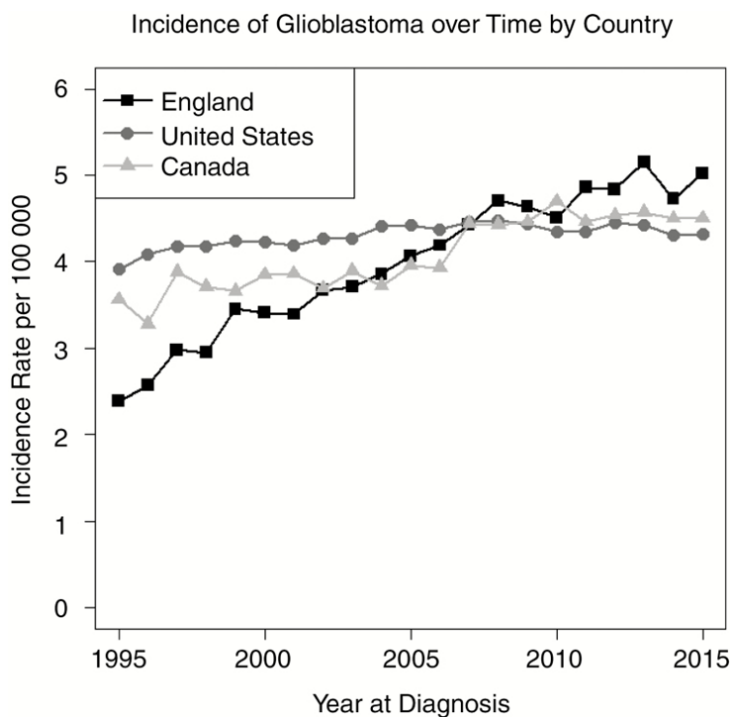


Figure 1. Graphical representation of the incidence rate of GBM as a function of time in years from 1995 to 2015. The graph shows an increase in GBM incidence for all three of these developed nations. Canada saw a 26% increase in GBM incidence in this 20-year span of data collection.¹²

Despite these findings, it is widely accepted that the attribution of any environmental factor as a conclusive explanation for historical GBM incidence rates is premature.¹² Philips et al. postulates that the frequent exposure to ionizing radiation from CT imaging in nations such as England and Canada may be contributing to rising GBM incidence within the past 25 years.¹³ Risk factors will be expanded upon in the following section. In spite of the recent advancements in treatment and diagnosis of GBM, long-term survival rates remain stagnant, as prognosis and risk factors of GBM are rudimentary.¹⁴

2.1 RISK FACTORS, GENETIC SUSCEPTIBILITY, AND PREVENTION

Many insights into the driving factors behind oncogenic transformation have been uncovered over the past few decades. In essence, cancer is a genetic ailment that is caused by alterations to gene structure and expression. However, many external factors contribute to its diagnosis. Numerous risk factors have been associated with the development of brain cancers, however, most brain tumors are not linked to any known predisposing risk factors and have no obvious cause.¹⁵ This section details both lifestyle-related and non-modifiable risk factors associated with GBM.

2.1.1 Behavioural and Lifestyle-Related Risk Factors

Despite the vast research into the etiology of GBM, most of its causes remain unknown.¹⁶ A plethora of lifestyle-related risk factors such as alcohol consumption and smoking, along with other considerations such as infectious agents, and blood transfusion have been explored. Regardless of all this research, the evidence for their role as risk factors for GBM is inconclusive.¹⁶ Although statistical correlation to GBM incidence is low, three variables are worthy of further investigation: dietary levels of glucose, the intensity of carbon tetrachloride exposure, and radiation exposure.

Bao et al. investigated the effects of hyperglycemia on the growth of GBM cells and discovered high glucose promoted proliferation and inhibited GBM cell apoptosis through enhancement of growth factor receptors and chemoattractant production. This team concluded that type 2 diabetes mellitus is an independent risk factor for GBM cell growth.¹⁷ Additionally, Nelson et al. determined the consequences of occupations with medium or high exposure to carbon tetrachloride, such as firemen or machinists, were independently associated with GBM development. Carbon tetrachloride exposure was not linked to the development of any other cancer.¹⁶ Finally, a systematic review conducted posits that moderate-to-high-dose ionizing ra-

diation exposure is positively associated with glioma, meningioma, and various other CNS-related tumour risks, however, the precise nature of this relationship at lower-level exposures is not well characterized.¹⁸ The direct relation between these factors and GBM development remains unclear, thus further research is required to elucidate the degree of their significance.

2.1.2 Genetic Susceptibility

Genetic susceptibility refers to the possibility of developing a particular disease due to changes to genetic composition. Unlike the lifestyle factors discussed, genetic risk factors are not avoidable, as they are often pre-existing. Genetic factors for GBM often come in the form of mutations, which can lead to the overexpression of genes that support oncogenic transformation. There are numerous genes and cancer predisposition syndromes that may influence the risk of GBM. If these factors can be identified, therapeutic treatments can be designed to target these specific genes.

Epidermal growth factor receptor (EGFR) proteins are receptor tyrosine kinases that control signal pathways responsible for the growth, reproduction, motion, and survival of tumour cells.¹⁹ The EGFR gene mediates the production of these proteins, and therefore influencing the susceptibility to develop GBM. Nearly 50% of glioma patients have amplified EGFR expression, indicating that the overexpression and/or variance of EGFR is likely correlated with brain tumours.²⁰ Tumours that contain EGFR amplifications also may also consist of numerous EGFR mutations such as EGFRvIII, a common mutation found in 30% of GBMs.¹⁹ EGFRvIII-mutated cells are resistant to EGFR inhibitors, providing a greater chance of survival and a more malignant phenotype.^{19,20}

In recent studies, the overexpression of Advillin (AVIL) has shown links to GBM and tumorigenesis. Xie et al. demonstrated that AVIL overexpression is found in the majority of GBMs, suggesting that GBM cells depend on excess AVIL for survival.²¹ AVIL interacts with F-actin, an essential protein involved in various cellular functions, such as cell motility and transcription regulation, that is vital for the motion and signaling pathways of GBM cells.^{21,22} As silencing AVIL would reduce GBM growth, it acts as a good therapeutic target.²¹

GBMs are associated with numerous familial cancer predisposition syndromes. Li-Fraumeni syndrome results from mutations in mitotic checkpoint genes, such as TP53 and CHEK2, and Turcot's syndrome is the result of mutations in various genes required for DNA repair.²³ Due to the high amount of gene mutations, these two syndromes increase the risk of GBM development through uncontrolled cell growth and replica-

tion.²³

When considering the risk factors of GBM, it is also important to consider family history. Brain tumours may cluster within families due to shared environmental exposures and gene inheritance.²³ Identifying a family history of GBM would allow patients to seek testing early. Furthermore, since immune system effectiveness decreases with aging, individuals older than 65 have a greater risk of GBM development.²⁴

Considering these factors, there are currently no verified methods to prevent GBM. Although exposure to these factors may increase the likeliness of developing GBM, further research is required to illuminate a stronger correlation to GBM.

3.1 OVERVIEW OF CURRENT DETECTION METHODS

Cancer detection is a crucial and challenging aspect of cancer treatment. There are various neurological symptoms a GBM patient may experience, such as headaches, vomiting, or speech difficulty that imply the need for further testing.²⁵ Magnetic Resonance Imaging (MRI) and CT scans provide valuable diagnostic imaging for GBM.^{26,27} Early detection, however, is challenging. As of 2019, there are no standard diagnostic methods for early-stage GBM.²⁸ Researchers have attempted to use MRI technology to study early stages of tumorigenesis. However, the challenge with this approach is that it is difficult to distinguish the early-stage tumour from non-cancerous disorders from the images generated.^{26,27} As a result of late detection, GBM is difficult to treat, resulting in a poor prognosis with a median survival time of 14.6 months.²⁸ In general, new detection technologies must be developed to improve GBM detection.

3.1.1 Imaging Technique

GBM is an aggressive brain cancer that is difficult to treat, so its early diagnosis is crucial to a patient's long-term health. Patients that display neurological symptoms will first be administered a physical exam consisting of an assortment of neurological function tests, including reflex, coordination, and alertness evaluations.²⁹ Subsequently, GBM is diagnosed with a series of imaging tests, generally MRI and CT scans.³⁰ To aid in diagnosis, a biopsy may be performed to extract a sample of abnormal cells for testing in a pathology laboratory.²⁹

Head MRI is an advantageous evaluation technique because it possesses higher contrast of available soft tissue, higher sensitivity for brain abnormalities, and depicts anatomy in greater detail.³¹ Compared to a 62.35% sensitivity of CT screening, MRI is 78.82%

sensitive.³² CT scans, however, are faster and less expensive than MRI scans, making CT screening the preferred option.³¹

3.1.2 Computed Tomography Scans

A CT scanner is a large, donut-shaped machine with a short tunnel in the center (Figure 2).³³ The patient lies on a narrow examination table that slides within the tunnel while image processing occurs in a separate control room.³³ CT screening employs X-ray images taken from various angles around the body to provide a detailed image of the brain.³⁴ If a potential abnormality is identified, a follow-up exam will be scheduled for further evaluation. The doctor will examine any changes in the abnormality over time and determine whether the prescribed treatment is causing the abnormality to change or remain stable.³⁵

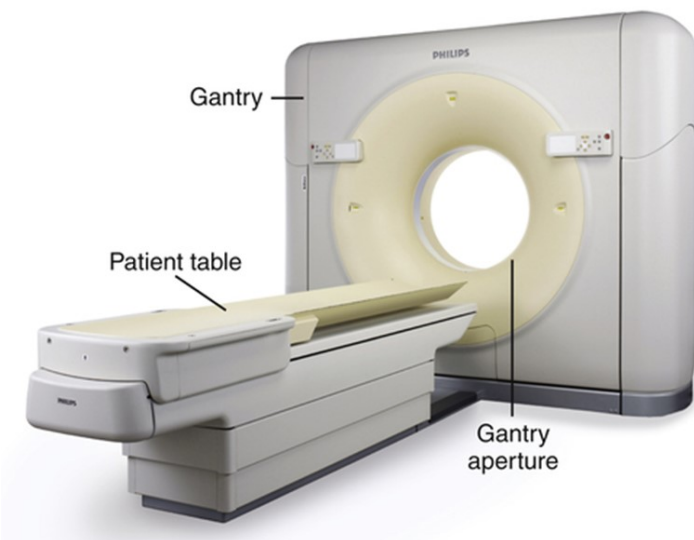


Figure 2. Model of a standard CT scanner. The patient will lie on the patient couch (patient table), which is led through the tunnel opening, or the X-ray tube gantry. The imaging and data collection occur within the opening, as this is where the X-ray tubes are located. During imaging, these tubes move around the patient to create an image.³⁶

As several electronic X-ray detectors and X-ray beams rotate around the patient, the CT scanner measures the amount of radiation absorbed throughout the body. A computer produces a large volume of data to create individual two-dimensional images or grouped three-dimensional cross-sectional images of the body.³³ CT scans use X-rays with energies ranging from 20 to 150 keV, as the tissue density in the body greatly varies.³⁷ The drawbacks of CT scanning have been widely studied; the financial burden patients experience when taking multiple CT scans can be debilitating.³⁸ Furthermore, the radiation a patient receives may lead to further cancer complications in the future. However, if GBM is diagnosed at an early stage, this

disadvantage may be considered admissible. Additionally, due to the comprehensive nature of a CT scan, its results may suggest against further testing, allowing a potentially false report to prevent definitive testing.

3.1.2 Physics of CT Scans

By design, the purpose of a CT image of the brain is to provide a detailed image of brain structures for insight into potential disease or injury. There are three dominant physical processes responsible for the interaction of an X-ray signal with brain matter: photoelectric absorption, pair production, and Compton scattering.³⁹ For clinical imaging, photoelectric effect is the primary mechanism, as CT scans occur at lower energies. The photoelectric effect describes the complete absorption of a photon when it interacts with an atomic inner electron.^{39,40} As a photon's energy exceeds the binding energy of an electron, all the photon's energy is transferred to the electron, emitting the electron from the atom, a process illustrated in Figure 3.⁴⁰

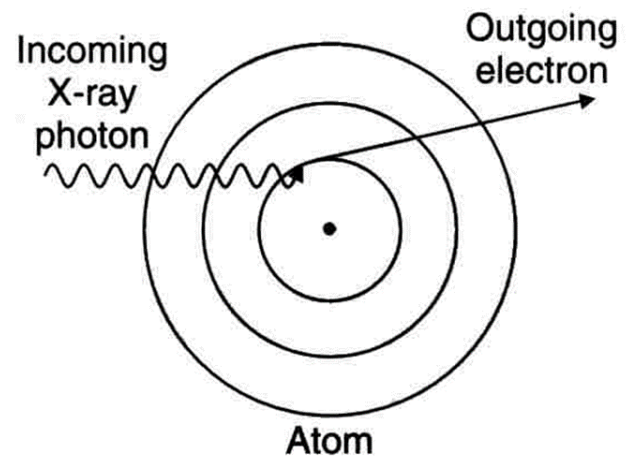


Figure 3. Pictorial representation of the photoelectric effect during a CT scan. The incoming X-ray photon is absorbed and causes an electron to be emitted, resulting in the attenuation of the incoming X-ray beam. The emitted electron, due to having a very short pathway, will also be absorbed very quickly.⁴¹

Due to the photoelectric effect, upon tissue interaction, X-ray signals either scatter or are completely absorbed.⁴⁰ This demonstrates the concept of photon attenuation; the gradual energy loss of a beam as it passes through matter, a phenomenon calculated using Beer's Law in equation (1)³⁹:

$$\text{Equation 1 : } I = I_0 e^{-\mu_t x_i}$$

Here, the transmitted intensity, I , can be calculated by raising the incident intensity of an X-ray to the power

of μ_i , the linear attenuation coefficient multiplied by x_i , the length of the X-ray path through the matter.³⁹

As the tube rotates and irradiates the head of the patient, detectors continue to compute the transmitted intensity, converting these values into an electrical signal and relaying these signals to a computer.⁴² Once these values are digitized—a process by which each signal is assigned a whole number—a digital matrix of pixels is created. Thereafter, each pixel is converted to Hounsfield Units (HU) to create a two-dimensional image. Alternatively, several two-dimensional images can be combined to create a three-dimensional image. The conversion is calculated through equation (2)⁴³:

$$\text{Equation 2: } HU = 1000 \times (\mu_{\text{tissue}} - \mu_{\text{water}}) / \mu_{\text{water}}$$

Upon conversion to HU, a visible map of low-density tissue (darker, blacker colours), organs (shades of grey) and higher-density structures (brighter, whiter) tissues is created.⁴⁴ As humans can only perceive a limited number of gray shades, the full range of density values is traditionally not displayed during imaging. Instead, brain tissue will be highlighted by devoting visible gray shades to a reduced portion of the full density, a process called “windowing”.⁴⁴

Contrast material may be applied orally, intravenously, or rectally to allow a radiologist to differentiate normal and abnormal conditions.⁴⁵ For head CT scans, iodine-based contrast materials are injected intravenously to reduce the amount of scattered radiation. Therefore, the resolution of brain tissue temporarily containing iodine-based compounds has a slightly emphasized appearance on CT images.

CT imaging is a powerful tool for GBM; its ability to rapidly create detailed images and monitor the efficacy of treatment makes it the primary choice for GBM diagnosis.⁴⁶ Comparatively, the cost and time required for MRIs make it a less ideal imaging method, constituting CT as the leading imaging technique.

4.1 RADIATION THERAPY

4.1.1 Overview of Radiation Therapy

There are various treatment approaches available for GBM patients. Due to the aggressive nature of GBM and its dangerous location within the CNS, it is challenging to remove the entire tumour surgically. Radiation therapy uses high-energy beams to kill cancerous cells and prevent further replication. GBM patients typically receive radiotherapy daily for several weeks to allow fractionation, a method that will be expanded upon below.⁴⁷ In comparison to other treatments, radiotherapy is a local treatment, meaning it affects a limited portion of the body. As a result, radiotherapy

has few side effects.

External Beam Radiation Therapy (EBRT) is the process of delivering high-energy photons from an external source such as a linear accelerator.⁴⁸ Although there are various methods of radiotherapy delivery, this review focuses on Intensity Modulated Radiation Therapy (IMRT) due to its efficiency in targeting cancerous cells while protecting surrounding healthy tissue.⁴⁸

4.1.2 Intensity Modulated Radiation Therapy

IMRT is a type of three-dimensional conformal radiation therapy (3D-CRT) that utilizes CT imaging.⁴⁸ 3D-CRT treatment planning involves the beam’s eye view which finds an optimal beam direction to deliver radiation to the tumour that will protect critical nearby organs.⁴⁸ A linear accelerator is used to generate energy beams for IMRT, such as photons or X-rays. The intensity of the beams is regulated based on the arrangement of the tumour with relation to surrounding organs. In IMRT, the intensity of radiation beams passing through organs at risk (OARs) is reduced, whereas the beams that pass through the target are increased.^{48,49} The intensity and angle of the beams are controlled using multileaf collimators, devices that consist of many individual leaves.^{48,49} These leaves can each be moved about the radiation pathway to block the beams from reaching specific destinations.⁴⁸ As a result, the radiation dose is directed to the target without interfering with OARs.

X-rays and gamma rays are preferred for radiotherapy due to their high energy levels, which are required for the Compton Effect and ionization.⁵⁰ The Compton Effect is a mechanism by which photons react with matter, such as tissue, and explains radiotherapeutic interactions in the body. When a high-energy photon such as an X-ray is directed towards tissue, it collides and releases a weakly-bounded electron. While some energy is utilized by the electron, the remaining energy is conserved by releasing a lower-energy photon.⁵⁰ This photon interacts with other electrons and the process continues further to ionize the targeted tissue.⁵⁰ The photoelectric effect is less common in radiotherapy as low-energy photons are required. The process differs from the Compton Effect as the interaction between photons and tissue only releases electrons, not lower-energy photons.⁵⁰

Ionization can damage cells directly through DNA double-strand breakage.⁴⁷ DNA breakage is prominent during mitosis. However, cells spend 95% of their life in interphase, thus spending less than 5% of their time in mitosis.⁵¹ This issue is resolved through fractionation, the process of delivering small radiation doses daily in order to affect the greatest number of cells in

mitosis. As of 2020, 60 Gy with standard fractionation (2 Gy/day) is the standard radiotherapeutic approach to GBM.⁵⁰ Fractionation is effective as normal cells repair much quicker than cancerous cells. As a result, damage towards healthy cells is minimal.

Ionization through the Compton Effect damages cancerous cells indirectly through the production of reactive oxygen species (ROS), such as superoxide anions, hydroxyl radicals, hydrogen peroxide, singlet oxygen, and hypochlorous acid.⁵⁰ These molecules are reactive due to an unpaired electron in their valence shell. Although ROS are necessary for the regulation of physiological functions, excess levels cause oxidative stress and damage to cellular components, thus provoking double-strand breakage and apoptosis.⁵²

In general, IMRT is an efficient treatment method for GBM patients that efficiently kills cancerous cells through ionization and the production of ROS. Although radiotherapy can be used solely, quality of life is improved alongside chemotherapy or surgery.

4.1.3 Cell Survival Curve and Radiation Treatment Schedule

To effectively model optimal radiation doses and the varying survival ratios of cancerous and normal tissue cells, a cell survival curve was formed. From experimental research, we identified α/β ratios of three and ten for normal and cancer tissue respectively for GBM radiation treatment. Figure 4 demonstrates the relationship between cell reproductivity and increased radiation dose during treatment.

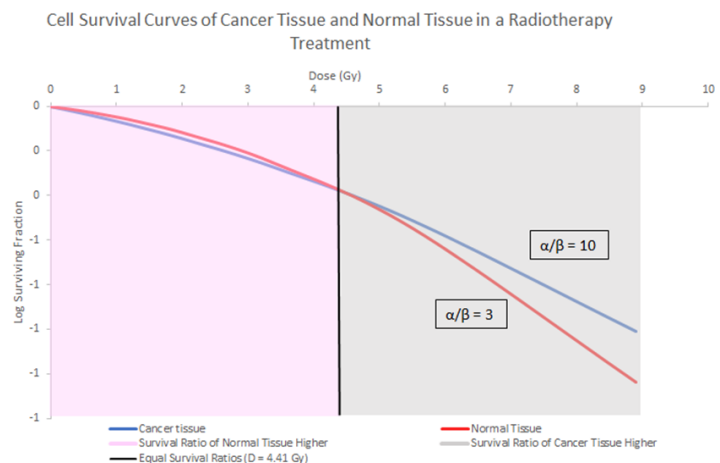


Figure 4. Graphical representation of a cell survival curve of both normal and cancer tissue within a patient undergoing radiation therapy for GBM. α/β ratios of three and ten were used for normal and cancer tissue respectively, and the dose at which there are equal survival ratios is 4.41 Gy (black line). The purple portion of the graph represents the dose at which the survival ratio for normal

tissue is greater than cancer tissue. The gray portion of the graph represents the dose at which the survival ratio for cancer tissue is greater than normal tissue. The initial population for both tissue samples was 1000 cells.^{53,54}

To calculate the number of surviving cells analogous to the dose administered, equation (3) was used. However, for graphing practicality, equation (4), the natural logarithm of equation (3), was utilized.

Equation 3:

$$\text{Number of Surviving Cells} = S = 1000(e^{-\alpha D - \beta D^2})$$

Equation 4:

$$\text{Log Surviving Fraction} = \ln(S) = -\alpha D - \beta D^2$$

Figure 4 also depicts an intersection at a dose of 4.41 Gy, indicating an equal survival ratio of cancer and normal tissue. Consequently, we observe that at radiation doses greater than 4.41 Gy, more cancerous tissue survives, while at doses lower than 4.41 Gy, more normal tissue survives. As a result, it is imperative to find the optimal dose at which the difference between normal and cancerous tissue is greatest. To determine the optimal dose, the derivative of the difference between the equations for cancer and normal tissue is set to zero (Equation 5). This enables us to calculate the dose at which the maximum number of cancer cells are eliminated while sustaining normal cells.

Equation 5:

$$f(D) = (-0.06D - 0.006D^2) - (-0.035D - \frac{7}{600}D^2)$$

$$f'(D) = 0 = -0.025 + \frac{17}{1500}D$$

$$\text{Optimal Dose} = D = 2.21 \text{ Gy}$$

After calculating an optimal dose of 2.21 Gy, a function illustrating the fractionation treatment of a typical GBM patient can be drawn. Figure 5 demonstrates the importance in determining the optimal radiation levels to curtail normal cell death and maximize cancer cell death. Furthermore, Figure 5 exhibits the increasing difference between cancer and normal cell populations at a radiation dose of 2.21 Gy.

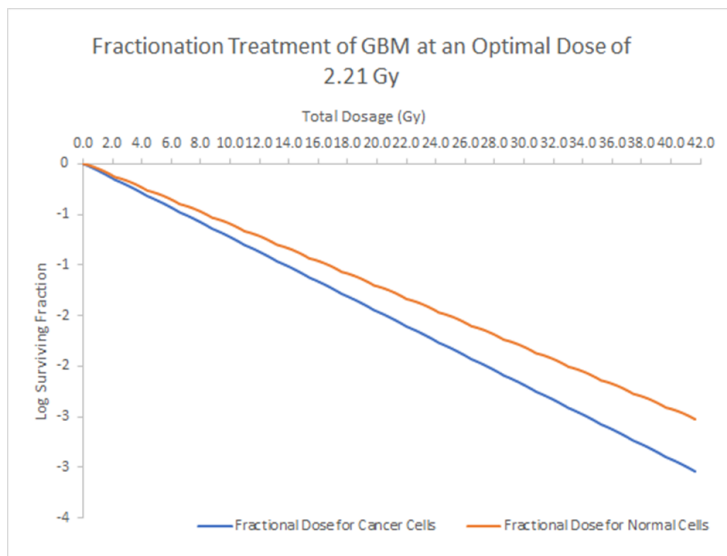


Figure 5. Graphical representation of a Fractionation Treatment for GBM at an Optimal Dose of 2.21 Gy. The curve illustrates the exact amount of radiation that can be administered to maximize cancer cell death while simultaneously minimizing normal cell death. As the dose applied increases, the disparity between cancer cell and normal cell populations grows greater. The initial population for both tissue samples was 1000 cells.^{53,54}

5.1 CHEMOTHERAPY

Chemotherapy is a drug-based treatment option for cancer patients. Chemicals are delivered to the tumour via oral ingestion or injection to inhibit cancer cell proliferation. Unlike radiation, which can be targeted to specific tissues, chemotherapy is a systematic treatment that affects most of the body, resulting in numerous side effects. Temozolomide (TMZ) ($C_6H_6N_6O_2$) is the standard chemotherapeutic agent for GBM that was first approved in 1999.^{55,56} TMZ is sold under various brand names, such as Temodar® and Temodal®. The chemical properties of TMZ, in particular, its lipophilicity, allow it to reach the brain and treat GBM efficiently.⁵⁷ TMZ can also be used to treat other gliomas, such as anaplastic astrocytoma.

5.1.1 Method of Action of Temozolomide

TMZ is delivered orally through the use of pills. Since TMZ is small and has a relatively low molecular weight of 194 g/mol, it is quickly absorbed in the digestive tract where it can enter the bloodstream.⁵⁸ Consequently, the molecule is 100% bioavailable after absorption.⁵⁸ In addition to surgical resection and 60 Gy of radiation in 30 fractions, standard care for GBM patients includes 75 mg/m²/day of TMZ for six

weeks.⁵⁹ Following initial treatment, patients typically undergo six maintenance cycles of TMZ to prevent GBM return. Patients receive 150-200 mg/m²/day for the first five days of a 28-day cycle.⁵⁹

Brain tumour treatment using chemotherapy is challenging due to the blood-brain barrier. The blood-brain barrier is an important structure that regulates the movement of ions and molecules between the blood and the brain.⁶⁰ The strict regulation protects the brain from toxins, pathogens, and unfortunately, chemotherapeutic agents. TMZ is ideal for GBM treatment due to its lipophilicity. Unlike other therapeutic agents, TMZ can easily penetrate the blood-brain barrier, quickly absorb into the cerebrospinal fluid, and distribute appropriately.⁵⁷ This property allows TMZ to reach brain tumours in sufficient concentrations.⁵⁷

TMZ is an alkylating agent prodrug, which stops the transcription of DNA into RNA through the substitution of alkyl groups for hydrogen atoms. This process halts the cell cycle by preventing protein synthesis and provokes cell death.⁵⁶ More specifically, TMZ is categorized as a triazene, a molecule that metabolizes to form intermediates that alkylate biological molecules.⁶¹ TMZ undergoes hydrolysis to form active monomethyl triazeno imidazole dacarbazine (MTIC) at blood pH, thus no metabolic activation is required.⁵⁷ The MTIC intermediate breaks apart to form methyl diazonium ions that react with nucleophilic sites on DNA. The interaction between the methylated DNA and DNA repair pathways provokes cell death.⁶²

DNA methylation occurs at specific nucleophilic sites, most of which are at guanine-N7, guanine-O6, and adenine-N7.^{57,62} However, the mutations at guanine-N7 and adenine-N3 are fixed through base excision repair and are TMZ resistant.^{56,57} Of the sites listed, TMZ is the most effective at guanine-O6. In order for TMZ to be effective, mispairing of DNA bases must take place. The methylation of O6-guanine results in mispairing with thymine during DNA replication. The mismatch pair is recognized by DNA mismatch repair (MMR) proteins, causing cycles of thymine removal and reinsertion.⁶³ This process breaks DNA strands, resulting in the activation of DNA damage response mechanisms. As a result, cell cycles halt and apoptosis occurs.⁶³ However, the methylation of O6-guanine can be repaired by a specific enzyme, O6-methylguanine-DNA methyltransferase (MGMT), once again resulting in TMZ resistance.^{62,63} Therefore, in order to ensure apoptosis by TMZ, tumours must have low amounts of MGMT and sufficient levels of MMR.⁶² Figure 6 illustrates the pathway by which TMZ is effective.

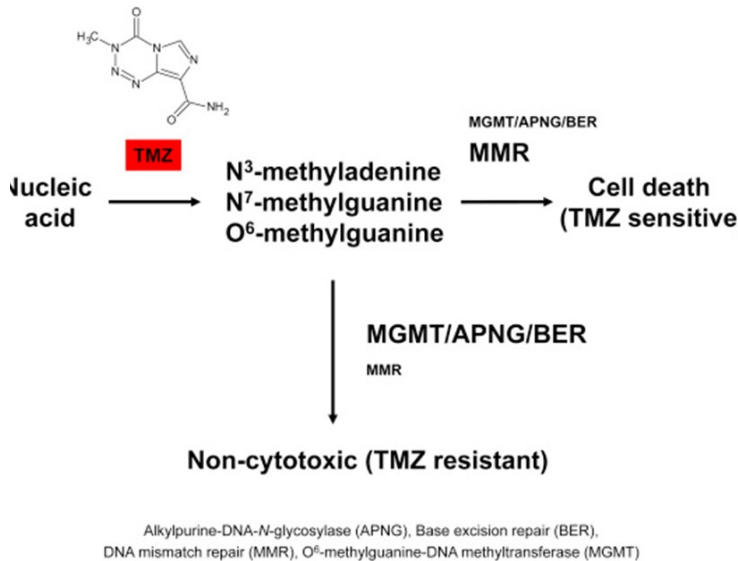


Figure 6. The mechanism of action of TMZ. TMZ adds methyl groups to three specific locations, N₃-adenine, N₇-guanine, and O₆-guanine. The modifications can be reversed by MGMT and BER, leading to TMZ resistance. Mismatch repair proteins must be present in sufficient amounts to cause cell death.⁵⁶

Since chemotherapy is a systematic treatment, it affects a majority of the body. Since healthy cells are also susceptible to TMZ action, TMZ induces numerous side effects. Bruising, headaches, constipation, and fatigue are side effects greater than 10% of patients experience.⁶⁴ Although chemotherapy is effective in prolonging patient life, more research is required to reduce the side effects of TMZ.

CONCLUSION

GBM is an aggressive brain cancer that continues to threaten public health. In this review, we analyze the potential risk factors, diagnoses, and treatment approaches to GBM. The role of CT scanning as an imaging technology in GBM diagnosis was explored while outlining the challenges neurologists face when diagnosing brain cancer. Due to the lack of early-detection methods, GBM has a low prognosis with a 14.6 month median survival.²⁸ Although GBM is challenging to cure, there are various treatment modalities used to improve patient comfort and life expectancy. IMRT damages cancerous cells both directly and indirectly through ionization, whereas TMZ passes through the blood-brain barrier to methylate target DNA sites. Both treatments result in cancerous cell death. In order to increase GBM survival rate, more cancer research regarding GBM detection and treatment is required. As technology advances, researchers will continue to uncover new information about GBM and potentially discover new methods to treat or cure this form of cancer.

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APPENDIX

Information was gathered through McMaster library keyword searches and online searches. Through a compilation of findings from journal articles, academic books, credible organizations, and academic reports, we were able to synthesize and report on our understandings. A focus was placed on finding peer-reviewed literature from the last ten years to ensure our reporting was accurate and suitable for today's environment.

ARTICLE INFORMATION

Senior Editor

Samini Hewa

Reviewers and Section Editors

Jonathan Monteiro, Eliana Abu-Manneh

Formatting and Illustrations

Zak de Guzman

Dexamethasone's Connection to COVID-19

Bianca Mammarella¹, Sarah Damiani²

1. McMaster University, Integrated Science, Class of 2024

2. York University, Biomedical Science, Class of 2025

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SUMMARY

Dexamethasone has been used for many years to treat a variety of ailments, and it illustrated positive results. Dexamethasone is well-known for its usage as an immunosuppressant, and an anti-inflammatory medication. Healthcare specialists worldwide searched for an existing or developing medication that may aid patients with the virus, especially as COVID-19 instances increased internationally. The Recovery Trial sought to identify a pharmacotherapeutic medication that would aid in the treatment of COVID-19 patients who were hospitalized. Dexamethasone's capacity to shorten hospital stays, and lower patient fatalities was observed throughout this experiment. These findings sparked more interest in Dexamethasone's potential as a treatment option for COVID-19. Investigating Dexamethasone's mechanisms of action, and how it affects various populations, will aid us in developing a standardized COVID-19 treatment plan by revealing how effective it is.

ABSTRACT

Dexamethasone is known for its use as an anti-inflammatory and immunosuppressant medication. This medication has been present for many years, and its benefits have been observed in the treatment of various conditions. With the rise of COVID-19 cases on an international scale, healthcare professionals globally searched for a therapeutic medication, either existing or under development that could help those who were ill with the virus. The Recovery Trial aims to find a pharmacotherapeutic medication that would assist in treating hospitalized individuals who were diagnosed with COVID-19. In this trial, Dexamethasone's ability to reduce hospitalization durations, and patient fatality was observed. These results increased curiosity about Dexamethasone's potential in the fight against COVID-19. As we work towards a standardized treatment plan for COVID-19, investigate Dexamethasone's mechanisms of action, and how it impacts different populations; together, these findings may help to determine this medication's effectiveness as a COVID-19 treatment option.

Keywords: COVID-19, Dexamethasone, corticosteroid, glucocorticoid, Recovery Trial

1.0 INTRODUCTION

Dexamethasone has many limitations and advantages as a pharmacotherapeutic medication.¹ Dexamethasone was approved in 1958 under the brand name, Decadron.² It is classified as a glucocorticoid, which is a unique class of drugs that can alleviate inflammation caused by a variety of diseases such as cancer, lupus, and rheumatoid arthritis.³ Dexamethasone can be administered in tablet form or intravenously.⁴ In 2021, results from the Recovery Trial – a trial which investigated many drug classes in the struggle to establish an effective treatment plan for those diagnosed with COVID-19. Dexamethasone illustrates promising results as a potential treatment for hospitalized patients with COVID-19.⁵ This essay will analyze Dexamethasone's two mechanisms, along with an overview of the Recovery Trial.

thasone's two mechanisms, along with an overview of the Recovery Trial.

2.0 MECHANISM OF ACTION

Dexamethasone is a corticosteroid medication that works as an immunosuppressant, and an anti-inflammatory agent.⁵ Dexamethasone can facilitate different routes in the inflammatory pathway, which are dependent on the dose, and duration of administration.^{6,7} Dexamethasone's mechanism of action is dependent on disease severity.⁸ In terms of COVID-19, trials have defined a low dose as 6mg once daily for 10 days (the Recovery Trial), while a high dose is 20mg once daily for 5 days, followed by 10mg once daily for 5 days (the HIGHLOWDEX trial).⁹ Specifically, higher

doses facilitate their effect through a non-genomic mechanism, while low doses use a genomic mechanism.¹⁰ Dexamethasone has the most impact through genomic mechanisms that require a longer duration, while the non-genomic mechanism is fast-acting but increases the risk of side effects.¹⁰

2.1 GENOMIC MECHANISM

Through the genomic mechanism, Dexamethasone passes through the cell membrane of the target cells via simple diffusion.⁶ These target cells have glucocorticoid receptors (GR) in the cytoplasm. Once Dexamethasone binds to GRs, this receptor-glucocorticoid complex results in the translocation of the glucocorticoid into the cell.⁶ In the cell, it can enter the nucleus to form a dimer with another complex to reversibly bind to many DNA sites, which suppresses or stimulates the transcriptions of several genes (Figure 1).¹¹ In the case of COVID-19, this causes a reduction in the generation of pro-inflammatory cytokines, such as IL-1, IL-6, IL-12, IFN- γ , and TNF- α .^{6,12} Simultaneously, Dexamethasone also initiates the synthesis of anti-inflammatory cytokines, such as lipocortin-1.⁶

2.2 NON-GENOMIC MECHANISM

The non-genomic mechanism of Dexamethasone, however, involves its binding to GRs on the membranes of T-lymphocytes. This causes a T-lymphocyte immune response, and inhibition of receptor signaling from GR (Figure 1).⁶ This high dose of Dexamethasone facilitates the cross-membrane movement of sodium and calcium ions, contributing to a large decrease in inflammation.⁶ Dexamethasone plays a role in the expression of the transient reception potential cation channel subcomponent V member 6 (TRPV6), plasma membrane calcium ATPase 1 (PMCA1), and sodium-calcium exchanger 1 (NCX1), and the level of intracellular calcium levels.¹³ Jeon et al. (2020) found that following administration of Dexamethasone, the level of intracellular calcium increases – this led to a decline in inflammation.¹³ Further, they observed a decline in the expression of PMCA1, and NCX1 genes which control calcium outflow, and an increase in TRPV6 expression which controls calcium influx. It is noted that the use of Dexamethasone helps to limit the host's inflammatory response although suppression of the inflammatory response can sometimes be detrimental.⁵

3.0 THE RECOVERY TRIAL

The 'recovery trial' is a randomized trial which began on March 19th, 2020 to investigate multiple pharmacotherapeutics, and their interactions with COVID-19.¹⁴ The outcomes that were investigated included patients with mild to severe COVID-19 symptoms that

led to hospitalizations, in addition to the lasting effects on the individual's physical state such as a persistent cough, fever, chills, and mucus.¹⁴ Examples of drugs included in this trial are Dexamethasone, Aspirin, Empagliflozin, and Hydroxychloroquine. Patients enrolled in this trial were all hospitalized with confirmed cases of COVID-19, and randomized to either 6mg Dexamethasone or placebo administered in tablet form or intravenously.¹⁴ Placebo was administered in tablet form or intravenously since this method of administration is simple, accessible, and efficient. From a pharmaceutical standpoint, the intravenous form can be easily dispensed, and can distribute the drug within the body at a fast, and efficient rate.

The RECOVERY trial illustrated that the use of Dexamethasone for ten days compared to standard treatment without the use of corticosteroids in hospitalized patients reduced mortality at 28 days (22.9% with Dexamethasone vs 25.7% without Dexamethasone).⁹ The trial results were inconclusive, referring to the recommended timeline for using Dexamethasone for patients with COVID-19, and respiratory failure. For the primary outcome of 28-day mortality, the hazard ratio from Cox regression was used to estimate the mortality rate ratio. Kaplan–Meier survival curves were constructed to show cumulative mortality over 28 days.¹⁴

A preliminary analysis of the data indicates results supporting the efficacy of Dexamethasone against COVID-19. In this analysis, 2,104 patients were treated with Dexamethasone, and 4,321 patients received standard care.¹⁴ Analyzing death within 28 days of the baseline: 482 of those treated with Dexamethasone had passed away in comparison to 1,110 standard care participants (22.9% vs. 25.7%; rate ratio, 0.83; 95% confidence interval, 0.75 to 0.93; $P < 0.001$) (Figure 2).¹⁴ These results indicate that Dexamethasone has a modest yet significant impact on reducing all-cause mortality within 28 days from the baseline.

4.0 CONCLUSION

Dexamethasone's impact on alleviating inflammation, and the significance it has in reducing mortality have motivated many more research trials to investigate its impacts further. Understanding multiple treatment options is essential to creating a diverse range of treatment options available to those who are diagnosed with COVID-19.

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AUTHOR CONTRIBUTIONS

BM is affiliated with the School of Interdisciplinary Science, and the Department of Biology at McMaster University. SD is affiliated with the Faculty of Science at York University.

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APPENDIX

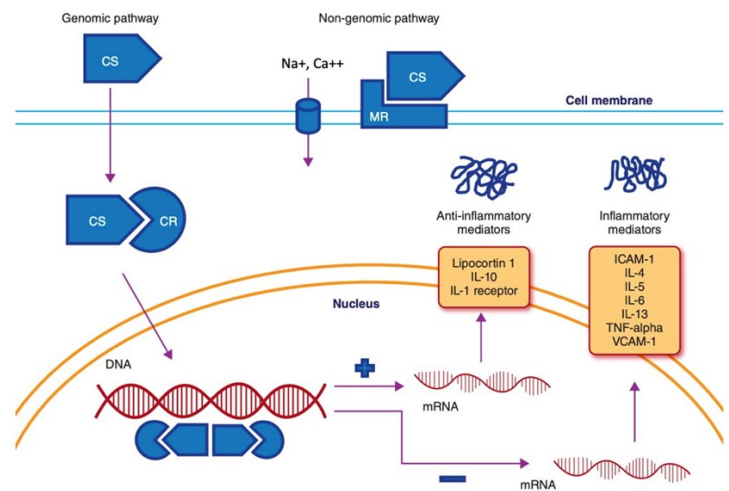


Figure 1. Shows both the genomic and non-genomic mechanisms of Dexamethasone. CS is a corticosteroid, CR is a corticosteroid receptor and MR is a membrane receptor.¹⁵ In the genomic mechanism, the corticosteroid (Dexamethasone) passes through the membrane via simple diffusion and it binds to receptors found in the cytoplasm.⁶ In relation to COVID-19, these target cells are known as macrophages situated in the alveoli. Upon binding, the corticosteroid-receptor complex will move towards the nuclear membrane where it enters through simple diffusion. In the nucleus, the receptor-corticosteroid complex will then dimerize to reversibly bind to DNA. These elements can be either negative (transcription-suppressing, anti-inflammatory agents) or positive (transcription-stimulating, anti-inflammatory agents) genes resulting in alteration of protein and mRNA synthesis.¹¹ In the non-genomic mechanism, Dexamethasone will bind to the membrane receptor of the T-lymphocytes to facilitate an influx of calcium and sodium ions which work to limit inflammation.¹⁵ Figure adapted from Sibila et al. (2015).

ARTICLE INFORMATION

Senior Editor
Zani Zartashah

Reviewers and Section Editors
Tresha Sivanesanathan, Juliana Wadie

Formatting and Illustrations
Zak de Guzman

All Participants (N=6425)

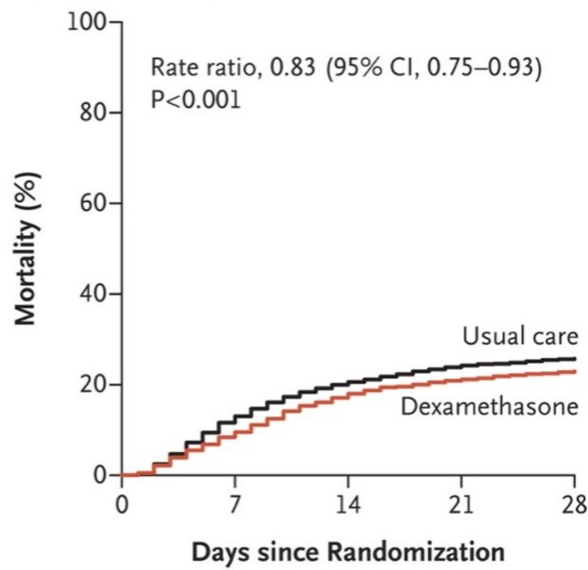


Figure 2: A graphical representation of the RECOVERY trial’s preliminary results of the RECOVERY trial. In this preliminary analysis, data from 6425 patients were analyzed; 2,104 patients received Dexamethasone while 4,321 patients received usual care.¹⁴ This relationship displays the days since randomization, versus percent mortality in patients who received usual care represented (outlined in black) and patients prescribed Dexamethasone outlined in orange. Results illustrated a significant difference in the 28-day mortality of those for whom Dexamethasone was prescribed, in comparison to those who received usual care (22.9% vs. 25.7%; rate ratio, 0.83; 95% confidence interval, 0.75 to 0.93; $P<0.001$).¹⁴ Figure adapted from The RECOVERY Collaborative Group (2021).

SCIENTIAL TEAM



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