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Current applications of precision medicine: a bibliometric analysis

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Abstract

A bibliometric analysis was conducted to describe trends in the publication of precision medicine literature over time. Searches identified 5552 articles with exponential growth from 2012 to 2018. Most were published in medical specialty journals, particularly oncology. Precision medicine definitions focused on tailored/individualized/personalized treatments and genetics/biology. Little attention was given to social and environmental determinants of health and health disparities. To fulfill the promise of precision medicine to positively impact broad populations, work is needed to develop the science of precision medicine for addressing health disparities and social and environmental determinants of health. While some precision medicine definitions include all factors that contribute to individual differences in health (e.g., genes, environments and lifestyles), future empirical work that includes and integrates all three areas is also required.

Executive summary

- The terms individualized and personalized medicine have often been used interchangeably with precision medicine in recent literature, thus leading to ambiguity.

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Author contributions

JR Williams had primary responsibility for the conceptualization of this project and writing of the manuscript. D Lorenzo and J Salerno contributed to the conceptualization of the methods and had primary responsibility for conducting searches, abstracting data and data visualization. VM Yeh, VB Mitrani and S Kripalani contributed to the conceptualization of the project and interpretation of results. All authors read and approved the final manuscript.

Supplementary data

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No writing assistance was utilized in the production of this manuscript.

- Given the escalating interest in precision medicine, there is a critical need to understand how precision medicine is defined in the extant literature, identify commonalities and discrepancies in how the concept is applied, and highlight gaps.
- A systematic electronic literature search was conducted using MEDLINE and CINAHL Plus databases to identify all articles published before November 2018 with ‘precision medicine’ in the abstract and/or title.
- Precision medicine articles were examined to identify those that included terms related to social and environmental determinants of health, health disparities or health equities in the abstract and/or title.
- A subset of articles was identified to examine differences in precision medicine definition *foci*.
- Searches identified 5552 articles containing ‘precision medicine’ in the abstract and/or title with most published between 2012 and 2018.
- Almost half were published in medical specialty journals, with a predominant focus on oncology.
- Only 1.6% of articles included terms related to social and environmental determinants of health, health disparities or health equities in their abstract and/or title.
- Most precision medicine articles use definitions of precision medicine related to tailored/individualized/personalized treatment and genetics/biology, with less than a third including environment and lifestyle.
- Precision medicine oncology can provide a blue print for advancing precision medicine efforts in nononcology fields (such as policy, public health, environmental, occupational and social health).
- A greater attention to advancing definitions that include environment and lifestyle is needed before precision medicine can be used to address health disparities.
- Advancement of a singular precision medicine definition will help transdisciplinary fields coalesce around a shared understanding of concepts and further enhance collaborative ideas.

Keywords

bibliometric analysis; environmental determinants of health; health disparities; health equity; personalized medicine; precision health; precision medicine; social determinants of health; systematic review

With the launch of the Precision Medicine Initiative, there has been an exponential increase in published literature describing the potential applications of precision medicine [1]. Excitement for this initiative (now called *All of Us*) within the scientific and medical community is growing with precision medicine’s growing promise. *All of Us* aims to create a cohort of research participants that will share data on environment, lifestyle and biology/genetics and to use this cohort to pioneer a new model of research [2]. In the near term, the focus is on cancer prevention with the eventual aim of extending this knowledge to other

health needs and diseases [3]. Given the burgeoning interest in precision medicine, it is important to understand how related terminology is being applied and whether there is consensus among research and scientific constituencies. Therefore, this paper reviews the findings from a bibliometric analysis aimed at identifying current definitions and applications of precision medicine.

The terms individualized and personalized medicine have often been used interchangeably with precision medicine in recent literature, thus leading to ambiguity [4]. Individualized medicine has been defined as a “therapeutic approach tailoring therapy for genetically defined subgroups of patients” [5]. Individualized medicine first arose from a study regarding the structure of the genome, mapping genes and sequencing DNA to emphasize genetic differences between patients [6]. Personalized medicine, which was first mentioned in published literature in 1971 [5], has been defined as a “broad and rapidly advancing field of healthcare that is informed by each person’s unique clinical, genetic, genomic and environmental information” [7].

Trends seen in the development of personalized medicine and precision medicine are similar. In 2006, then Senator Barack Obama, introduced the Genomics and Personalized Medicine Act, with goals and aims similar to *All of Us* [8]. Both, *All of Us* and the Genomics and Personalized Medicine Act proposed the creation of a national database and the use of a ‘personalized’ approach to prevent and diagnose diseases. Unlike *All of Us*, the Genomics and Personalized Medicine Act was never enacted into law. The push on advancing legislation related to personalized medicine along with the development of the Human Genome project did, however, allow for a steady progression of the adoption of practices of personalized medicine in the healthcare fields [7]. Remarkably, with the completion of the Human Genome Project in 2002, a 160% growth rate in published literature related to personalized medicine was seen [5].

However, the progression of the paradigm into practice was partially stunted by imprecise definitions [9]. This led to challenges communicating across disciplines, difficulty establishing regulatory mechanisms, unwarranted fears and unfounded hopes of patients and a lack of clarity for stakeholders on how they may benefit [5]. Precision medicine’s similar lack of a precise definition may also impede its progression.

Additionally, although personalized medicine expanded upon the definition of individualized medicine by recognizing clinical and environmental factors in health, the focus remains on the role of genomics [10]. Public health experts are concerned that a similar pattern is being seen in the field of precision medicine – a larger focus on the genetic aspects of precision medicine, which may stem from the emphasized role of genetics in the predecessor fields of precision medicine (individualized and personalized medicine) [5,7]. This imbalance further increases confusion and ambiguity of the intended definition of precision medicine and has led to recent calls for stronger emphasis on social and environmental determinants of health (SDH) in this type of work. Research shows SDH exceed the effects of genetics alone [11–13]. Individuals with different SDH may respond differently to medical treatments [14], and the ability to genetically predict chronic conditions is limited without understanding how SDH may moderate this effect [15]. Moreover, disparities exist in health outcomes among

those who are socially disadvantaged and of racial/ethnic minority status [16], and research suggests that epigenetic alterations due to SDH may at least partially explain these disparities [17]. This stresses the importance of considering SDH and including racial/ethnic minority and socially disadvantaged populations in precision medicine research to address health disparities and make a more significant public health impact [10].

Given the importance of bringing precision medicine's promise to real world clinics, there is a critical need to understand how precision medicine is defined in the extant literature, identify commonalities and discrepancies in how the concept is applied, and highlight gaps. A comprehensive bibliometric analysis, a method used to quantify publications [18], was conducted to meet these aims. Specifically, this paper aims to describe:

- Trends in the use of the term precision medicine over time;
- Publication of precision medicine literature by journal area;
- Differences in the application of precision medicine across clinical specialties;
- Differences in precision medicine definition *foci*.

Methods

This bibliometric analysis and review were registered with the International Prospective Register of Systematic Reviews (CRD42016047869). In addition, the Principles of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines for data retrieval and reporting were used [19].

A systematic electronic literature search was conducted in May 2017 and updated in November 2018 using MEDLINE and CINAHL Plus databases. The main search term entered in each database was 'precision medicine'. Searches were limited to English language articles. This included articles written in English by foreign non-US-based authors. No limits were placed on article type, study characteristics or year of publication.

A three-tiered approach was used to identify relevant articles. First, searches were limited to articles published through November 2018 that contained the term 'precision medicine' in the abstract and/or title. This set of articles was used to examine trends in the use of the term 'precision medicine' over time, by journal area, and by clinical specialties. The year of publication and journal title were extracted from each article in this set. Journal titles were then collapsed into specialty focus areas based on the *InCites Journal Citation Reports* categorizing system [20]. These focus areas are not mutually exclusive; as such, an article may be counted in multiple categories.

Given our previous discussion about the importance of examining SDH in the context of precision medicine, our next step was to conduct a targeted search to further examine the extent to which SDH is included in the precision medicine literature. We refined our searches, limiting articles published through November 2018 to those that included 'social determinant', 'environmental determinant', 'determinant of health', 'disparit' or 'equit' in the abstract and/or title. The abstracts were then reviewed to ensure that the article included a focus on SDH, health disparities and/or health equities.

Finally, a subset of articles was identified to examine differences in precision medicine definition *foci*. This was accomplished by limiting articles to those that include ‘precision medicine’ in the title and then examining the full text of each article. Articles were included if they provided a clear definition of precision medicine or description of the aim(s) of precision medicine in the article text. This subset was derived during the initial searches conducted in May 2017. The definition and/or aim(s) were extracted from the subset of articles. Definitions were collapsed into five categories based on overarching themes that emerged among the definitions: genetic/biology, environment and lifestyle, tailored/individualized/personalized treatment, data and technology. The genetic/biology category signified that the definition considered genetics, genomics or biologics. The Environment and Lifestyle category signified that the definition included environmental factors, lifestyle factors or other social determinants of health. The tailored/individualized/personalized treatment category signified that the definition mentioned, implied or considered that medical treatment was to be tailored, personalized or individualized. The data category signified that the definition considered genomic data sources, data management and/or data analytic techniques. Last, the Technology category signified that the definition mentioned, implied, or considered the purposeful application of technology in the field of precision medicine.

Results

A general search for ‘precision medicine’ in MEDLINE and CINAHL Plus resulted in 18,040 articles published through November 2018 (Figure 1). Limiting articles to those that contained the term ‘precision medicine’ in the abstract and/or title resulted in 5552 articles that were then examined for publication trends. A total of 95 articles were found that contained language related to SDH, health disparities and/or health equities in the abstract and/or title. Four articles were excluded after reviewing the abstracts resulting in a final subset of 91 articles. For our targeted search for precision medicine definitions, we identified 1151 articles that only included ‘precision medicine’ in the title. After full text review, 850 articles were eliminated because they did not meet the inclusion criteria. Most articles were excluded because they did not provide a clear definition of precision medicine. A total of 301 articles met the inclusion criteria and were included in our review of precision medicine definitions (Supplementary Material).

Trends in publication of precision medicine literature by year and journal focus area are presented in Figures 2 & 3, respectively. Six articles were published prior to 2012 (1979: 1, 1997: 1, 2009: 1, 2010: 2 and 2011: 1), an additional four had a publication date of 2019 and one did not provide a date. Most articles were published between 2012 and 2018 (n = 5547), with consistent growth seen across this 7-year period (Figure 2). The most rapid growth was seen from 2012 to 2016, with the number of articles doubling or tripling each year. Smaller growth occurred from 2016 to 2018; instead, high numbers of publications were maintained during this period.

A wide range of journal focus areas were represented (Figure 3). Almost half (n = 3169; 44.9%) were published in journals that focused on specialty areas of medicine, with 40 clinical specialty areas represented. The most common focus was on oncology (n = 1060;

33.4%); which included clinical research trials, as well as nonresearch study articles that focused on implications and considerations of precision medicine in the field of oncology. Other common specialty areas included respiratory (n = 197; 6.2%) and cardiac/cardiovascular (n = 155; 4.9%). Table 1 provides a breakdown of the 10 most common specialty areas among the included articles (Supplementary Materials for full listing of the 40 specialty areas).

Other common journal categories (outside medical specialty journals) included basic science (n = 1193; 16.9%), computer science/informatics/technology/statistics (n = 764; 10.8%) and pharmacology/pharmacy/toxicology (n = 506; 7.2%). Notably, only 1.5% (n = 104) were published in public, environmental, occupational and social health journals. Similarly, SDH, health disparities and health equities were not a primary focus across the precision medicine literature. Only 1.6% (n = 91) of articles discussed these topics to some extent in their abstracts.

The most commonly used definitions of precision medicine in the literature were those developed by:

- NIH [21]: an emerging approach to disease treatment and prevention that takes each person's variability in genes, environment and lifestyle into account;
- US FDA [22]: the right patient with the right drug at the right dose at the right time; and
- National Research Council [23]: tailoring of medical treatment to the individual characteristics of each patient.

There was, however, a large amount of variation in the wording of definitions and many articles did not cite a specific source. Given the wide variation, definitions were further categorized by their inclusion of major themes to better understand commonalities across each. Most article definitions described precision medicine as including some form of tailored/individualized/personalized treatment (n = 265; 88%) and genetic/biological component (n = 186; 61.8%). A total of 90 articles (29.9%) referred to environmental and lifestyle factors as part of their definition and a small proportion included data (n = 19; 6.3%) or technology (n = 9; 3.0%) in their definition. Figure 4 illustrates this breakdown of the definition components.

Discussion

There has been exponential growth in the publication of precision medicine articles since 2012, likely reflecting increases in extramural funding and the initiation of *All of Us* [2]. Our findings demonstrate that a majority of precision medicine literature have been published in specialty medical journals and particularly in oncology. There was little representation of the term 'precision medicine' in other practice-oriented journals, such as healthcare sciences, policy, and services journals and public, environmental, occupational, and social health journals. Precision medicine was more widely represented in basic science and methodological journals, which may reflect precision medicine's newness and the need to develop the methodology for the field.

Precision medicine was also found to have wide application across different clinical specialties, with articles represented in 40 clinical specialty journal areas. A preponderance of articles focused on the field of oncology, the first specialty to consider precision medicine as an approach to treat disease. Precision medicine oncology has presented a new means for diagnoses based on the specific set of genomic alterations present in tumors. With the advancement of precision oncology medicine, targeted therapy is already taking place based on specific biomarkers in different cancer types [24]. Precision medicine oncology provides a blue print for other medical specialties to learn from and use as a starting point to strengthen implementation of precision medicine.

One challenge for the field of precision medicine is the wide variation in definitions, as indicated in our results. The issue of definition variation has historically been linked to issues in personalized medicine, including a reduction of the term's use in the field, regulatory complications, patient confusion and use of definition vagueness by stakeholders to further their own agenda [5,9]. Researchers and practitioners in the field of precision medicine need to ensure that the same issues do not deter the field of precision medicine from advancing and that the promise of precision medicine to improve health is realized.

Considering the most commonly used precision medicine definitions found in this review, the NIH definition provides the most specificity regarding the specific components of precision medicine, with emphasis on genes, environment and lifestyle. Components of the NIH definition are reflected in the definition *foci* of articles which focused primarily on tailored/individualized/personalized treatment (88.0%), genetic/biology (61.8%) and, to a lesser extent, environment and lifestyle (29.9%). These findings reflect an emphasis on the genetic/biological components of precision medicine in the current literature. There is no argument that genetics/biology are a critical part of the precision medicine approach. However, considering SDH through environmental and lifestyle factors is equally important. Existing literature has documented that SDH may exceed the impact of genetics alone, the limitations of predicting chronic disease without consideration for SDH, that individuals exposed to differing SDH may respond differently to medical treatments, and the role of SDH among health disparities and inequalities [11–17,25]. The existing lack of consideration for SDH in the field is particularly important for health disparity populations, who are more likely to have their health impacted by SDH [10].

Health disparity populations are those who experience disproportionately poorer health outcomes and often include racial/ethnic minority, low socioeconomic, disabled, rural and sexual/gender minority groups [26]. Precision medicine, which seeks to take an individualized approach to healthcare treatment by taking into account a person's genes, environment and lifestyle, has great potential to address many of the factors that contribute to health disparities. Results from this paper, however, found that only 1.6% of articles discussed SDH, health disparities or health equities in relation to precision medicine. This demonstrates a significant gap in understanding about the application of precision medicine for addressing these areas. Work has begun to address this gap and increase understanding as to the best approaches for the implementation of precision medicine to address health disparities. In 2016, the National Institute on Minority Health and Health Disparities, part of the NIH, committed approximately \$50 million to fund new Transdisciplinary Collaborative

Centers for health disparities research aimed at the role of precision medicine in promoting health equity and furthering knowledge of minority health and health disparities [27]. These centers will serve as leaders in advancing science so the promise of precision medicine for improving patient care and reducing health disparities can be realized.

Finally, the results of this paper should be interpreted through consideration of the methodological approach. This review took a broad approach to understanding trends in the use of precision medicine in the literature by examining all articles which include the term ‘precision medicine’ in the title and/or abstract and by focusing on journal categories and characteristics. As such, we are unable to report on more nuanced information about the applications of precision medicine across these articles. Examining this body of literature may provide additional insight regarding the application of precision medicine. In addition, we focused our search on the term ‘precision medicine,’ given the predominant use of this term by policy and funding agencies. This likely under-represents the full body of literature which may include other terms that have been used somewhat interchangeably with precision medicine, such as precision health. The term precision health has been used to demonstrate the applicability of precision medicine beyond the medical field to include other disciplines such as nursing and public health [28,29]. Omitting this term from our search strategy may have resulted, in part, in the under-representation of these other disciplines in our findings.

The field of precision medicine has seen tremendous growth in recent years and is expected to continue for years to come. The scientific and medical advancements have great potential to revolutionize the ways healthcare is practiced in the future. Given the newness of the precision medicine field, however, it is important to continue to develop the methods and science as the foundation for the application of precision medicine in practice. Achieving this goal will require stretching beyond the medical discipline and, as such, interdisciplinary perspectives are critical to its success. Those involved in the development of future precision medicine innovations have a responsibility to ensure they are based on new interdisciplinary methods that take into account all factors that contribute to individual differences in health including genes, environments and lifestyles.

Future perspective

Advancement of a singular precision medicine definition will help transdisciplinary fields coalesce around a shared understanding of concepts and further enhance collaborative ideas. Building a shared precision medicine definition will facilitate collaboration between the transdisciplinary fields that comprise precision medicine and further the development of broad conceptual frameworks that address the core drivers of health across specialty areas. This will enable precision medicine to potentially better understand and mitigate health disparities. Further, in the next 5–10 years, it may be advantageous to develop a set of guidelines that help determine whether or not research endeavors or treatments meet precision medicine criteria. These guidelines could establish the extent to which the endeavor ‘should’ include efforts to individualize treatments, focus on genetics/biology, environment and or lifestyle as well as the extent to which these unique considerations interact. This will allow future research on how these factors may mediate and moderate one

another's impact on health outcomes. Translated into real world settings, this will allow the promise of precision medicine to come to fruition by providing critical information about to whom precision medicine may benefit and when, thereby improving health outcomes across broad populations.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Financial & competing interests disclosure

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References

Papers of special note have been highlighted as: • of interest; •• of considerable interest

1. Fradkin JE, Hanlon MC, Rodgers GP. NIH precision medicine initiative: implications for diabetes research. *Diabetes Care* 39(7), 1080–1084 (2016). [PubMed: 27289128]
2. NIH. *All of Us* Research Program (2018). <https://allofus.nih.gov/> •• Website for the National Institutes of Health *All of Us* Research Program, which provides information about the program, funding opportunities, resources and how to participate.
3. Baker KA. A new era for healthcare: precision medicine. *Gastroenterol. Nurs* 38(4), 249–250 (2015). [PubMed: 26226018]
4. Jameson JL, Longo DL. Precision medicine—personalized, problematic and promising. *N. Engl. J. Med* 372(23), 2229–2234 (2015). [PubMed: 26014593] • Review article provides perspectives on the precision medicine field including definitions, technological advances, implications for the practice of medicine, challenges and future opportunities.
5. Schleidgen S, Klingler C, Bertram T, Rogowski WH, Marckmann G. What is personalized medicine: sharpening a vague term based on a systematic literature review. *BMC Med. Ethics* 14(1), 55–55 (2013). [PubMed: 24359531] •• A systematic literature review aimed at clarifying and refining the definition of personalized medicine.
6. Hoffmann W, Krafczyk-Korth J, Völzke H, Fendrich K, Kroemer HK. Towards a unified concept of individualized medicine. *Pers. Med* 8(2), 111–113 (2011).
7. Ginsburg GS, Willard HF. Genomic and personalized medicine: foundations and applications. *Transl. Res* 154(6), 277–287 (2009). [PubMed: 19931193]
8. Konski AF. Personalized Medicine Bulletin. President Obama revisits interest in personalized medicine. (2015). www.personalizedmedicinebulletin.com/2015/01/25/president-obama-revisits-interest-in-personalized-medicine/
9. Emmert-Streib F. Personalized medicine: has it started yet? A reconstruction of the early history. *Front. Genet* 3, 313–313 (2013). [PubMed: 23316213]
10. Dankwa-Mullan I, Bull J, Sy F. Precision medicine and health disparities: advancing the science of individualizing patient care. *Am. J. Public Health* 105(Suppl. 3), S368–S368 (2015). [PubMed: 26039545] •• Editorial introducing a special supplemental issue of the *American Journal of Public Health* focused on advances in addressing health disparities with a particular focus on precision medicine.
11. Khoury MJ, Galea S. Will precision medicine improve population health? *JAMA* 316(13), 1357–1358 (2016). [PubMed: 27541310] • Presents the authors viewpoints about the likelihood of precision medicine to improve population health and calls for improvements in the joining of biological with social and environmental determinants of health.

12. Schroeder SA. Shattuck lecture. We can do better – improving the health of the American people. *N. Engl. J. Med* 357(12), 1221–1228 (2007). [PubMed: 17881753]
13. McGinnis JM, Williams-Russo P, Knickman JR. The case for more active policy attention to health promotion. *Health Aff.* 21(2), 78–93 (2002).
14. Riley WT, Nilsen WJ, Manolio TA, Masys DR, Lauer M. News from the NIH: potential contributions of the behavioral and social sciences to the precision medicine initiative. *Transl. Behav. Med* 5(3), 243–246 (2015). [PubMed: 26327928]
15. Keyes KM, Smith GD, Koenen KC, Galea S. The mathematical limits of genetic prediction for complex chronic disease. *Epidemiol. Community Health* 69(6), 574–579 (2015).
16. Chetty R, Stepner M, Abraham S et al. The association between income and life expectancy in the United States, 2001–2014. *JAMA* 315(16), 1750–1766 (2016). [PubMed: 27063997]
17. Olden K, Lin YS, Gruber D, Sonawane B. Epigenome: biosensor of cumulative exposure to chemical and nonchemical stressors related to environmental justice. *Am. J. Public Health* 104(10), 1816–1821 (2014). [PubMed: 25122010]
18. Ellegaard O, Wallin JA. The bibliometric analysis of scholarly production: how great is the impact? *Scientometrics* 105(3), 1809–1831 (2015). [PubMed: 26594073]
19. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *J. Clin. Epidemiol* 62(10), 1006–1012 (2009). [PubMed: 19631508]
20. Analytics Clarivate. InCites Journal Citation Reports (2018). <https://clarivate.com/products/journal-citation-reports/>
21. US National Library of Medicine. What is precision medicine? Genetics Home Reference (2018). <https://ghr.nlm.nih.gov/primer/precisionmedicine/definition>
22. US FDA. Paving the way for personalized medicine: FDA’s role in a new era of medical product development (2013). www.fda.gov/downloads/scienceresearch/specialtopics/personalizedmedicine/ucm372421.pdf
23. National Research Council Toward Precision Medicine: Building a Knowledge Network for Biomedical Research and a New Taxonomy of Disease. The National Academies Press, WA, USA (2011).
24. Ganesan S, Rodriguez-Rodriguez L, Dipaola RS. Precision medicine: implications for science and practice. *J. Am. Coll. Surg* 223(3), 433–439.e431 (2016). [PubMed: 27321387]
25. Bayer R, Galea S. Public health in the precision-medicine era. *N. Engl. J. Med* 373(6), 499–501 (2015). [PubMed: 26244305]
26. Lerch ML, Bauer DR, Chafin D, Theiss A, Otter M, Baird GS. Precision medicine starts with preanalytics: real-time assessment of tissue fixation quality by ultrasound time-of-flight analysis. *Appl. Immunohistochem. Mol. Morphol* 25(3), 160–167 (2017). [PubMed: 28027117]
27. NIH. NIH funds precision medicine research with a focus on health disparities (2016). www.nih.gov/news-events/news-releases/nih-funds-precision-medicine-research-focus-health-disparities
28. Taylor JY, Barcelona De Mendoza V. Improving -omics-based research and precision health in minority populations: recommendations for nurse scientists. *J. Nurs. Scholarsh* 50(1), 11–19 (2018). [PubMed: 29140597] • Provides an overview of omics-based research in minority communities from the perspective of nursing research.
29. Khoury MJ, Iademarco MF, Riley WT. Precision public health for the era of precision medicine. *Am. J. Prev. Med* 50(3), 398–401 (2016). [PubMed: 26547538]

Figure 1.
Flow chart summary of search results.

Figure 2. Trends in the use of the term precision medicine from 2012 to 2018 (n = 5541).
2018 reflects publications from January through November.

Figure 3. Publication of precision medicine literature by journal area (n = 7062).

Total number is higher than the number of articles due to journals being classified in multiple categories.

Figure 4.
Differences in precision medicine definition *foci* (n = 301).

Table 1.

Application of the term precision medicine across the top ten clinical specialty areas (n = 3169).

Clinical specialty area	Articles, n (%)
Oncology	1060 (33.4)
Respiratory	197 (6.2)
Cardiac/cardiovascular	155 (4.9)
Pathology	146 (4.6)
Clinical neurology	144 (4.5)
Immunology	135 (4.3)
Radiology, nuclear medicine and medical imaging	134 (4.2)
Urology and nephrology	123 (3.9)
Endocrinology and metabolism	112 (3.5)
Psychiatry	100 (3.2)