Mathematical models in nursing research

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Abstract

This paper discusses the use of advanced mathematical tools in nursing research, such as mathematical models used in medicine for description and prediction of experimental tumor growth. They are rarely used in nursing research, but fortunately in the last decade, their use is increased, mainly due to artificial intelligence and Big Data, with great benefits for further nursing development. Therefore, a strong interaction between nurses and mathematicians is needed to improve nursing research, and consequently, the nurses’ performance in daily work.

Objective

The goal of this paper is to discuss the use of advanced mathematical models in nursing research.

Methods and search criteria

A mathematical model represents the real world, characterized by using of mathematics to describe the parts of the world as a whole that are of interest and the relationships between those parts.10

The purpose of mathematical models is to predict or describe the evolution of the phenomena being studied and, subsequently, to choose the best strategy.

The main requirements of a mathematical model are the following:
• It must be able to predict the progress of a phenomenon, taking into account any perturbations that led to it;
• It must include any prior knowledge;
• It must have a sound theory that presides over its construction.

In general, an excellent method to evaluate a mathematical model is to verify if the produced data, describes a curve which fits as much as possible to known experimental distributions.

There are different types of mathematical models, whose use depends on the data available and the knowledge degree of the modeling system, as follows:
• Statistical models: These models are used when many data are available, but knowledge about the system is relatively scarce. The data have not been collected in unfinalized way. This model does not attempt to explain the random connections or the system dynamics but limits itself to detecting the overall characteristics of the available data. Based on this information, it is possible to make qualitative deductions on the phenomena that have generated the data, their statistical properties, the classification by categories, and the identification of anomalous data. At the same time, the internal dynamics of the system remain unknown.

In particular, Artificial Neural Networks (ANNs) belong in this category. ANNs11-13 are a processing mechanism that is particularly suitable for solving non-linear problems and obtaining close
relationships that optimally regulate the solutions to these problems. ANNs are data-processing mechanisms that do not follow specific rules or mathematical laws to process the data but use the vast amounts of data available to discover the mathematical laws that connect them. However, these mathematical laws, which are deciphered by the ANNs, are not provided, so they are useful when there is a lot of data available on a problem but no functional theory to explain them.

This class of models is generally connected to the use of Big Data.14 Big Data is a field that treats pathways to investigate, analyze, and systematically extract information. Data sets are extensive and complex to be dealt with by traditional data-processing application software, and therefore, they are analyzed with specific software.

- **Stochastic or probabilistic models**: These models are used to obtain an operational tool that best reproduces the observed output trend using experimental or synthetic input data and separating the predictable part of the output from the totally

| Year | Number of articles | Country | First author | Journal |
|------|--------------------|---------|--------------|---------|
| 1980 | 1                  | USA     | Thomas R. Willemain | Medical Care |
| 1982 | 1                  | USA     | A.J. Hogan      | Socio-economic Planning Sci |
| 1986 | 1                  | USA     | P.A. Patriarca  | American Journal of Epidem |
| 1987 | 1                  | Australia | G.A. Preston   | Australian Health Review |
| 1991 | 2                  | USA     | R.H. White     | Clinical Trial |
|      |                    | USA     | JM Korth-Bradley | Journal of Intravenous Nursing |
| 1992 | 2                  | UK      | Murray PJ      | Intensive Crit Care Nurs |
|      |                    | USA     | Dan G. Blazer  | The Gerontologist |
| 1994 | 1                  | China   | A. Jeang       | Journal of Medical Systems |
| 1995 | 1                  | USA     | D’Agostino RB  | Statistics in Medicine |
| 1996 | 2                  | China   | A. Jeang       | Journal of Medical Systems |
|      |                    | USA     | R.W. Maathe    | Arch Phys Med Rehab |
| 1998 | 2                  | USA     | G.T. Shumock   | Am J Health Syst Pharm |
|      |                    | USA     | V.L. Greene    | J Gerontol B Psychol Sci |
| 1999 | 1                  | UK      | D.J. Austin    | Proc Natl Acad Sci USA |
| 2001 | 2                  | USA     | D.M. Nierman   | Crit Care Med |
|      |                    | USA     | D.J. Newport   | Semin Perinatal |
| 2002 | 1                  | USA     | R. Suri        | Biol Psychiatry |
| 2003 | 1                  | USA     | T.J. Reeder    | Acad Emerg Med |
| 2004 | 3                  | Japan   | Kayoko Inoue   | Risk Analysis |
|      |                    | Greece  | T. Botsis      | Comput Inform Nurs |
|      |                    | Brazil  | M. V. de Oliveira Lopes | Rev Lat Am Enfermagem |
| 2005 | 1                  | USA     | Sunhee Park    | Nursing Research |
| 2006 | 2                  | Italy   | Laura Gerbaudo | La Medicina del Lavoro |
|      |                    | UK      | E. Kirk        | Ultrasound Obstet Gynecol |
| 2008 | 2                  | USA     | Cécile Viboud  | PLoS Medicine |
|      |                    | Netherlands | van den Dool C | PLoS Medicine |
| 2010 | 1                  | Turkey  | Ebru Yilmaz    | Journal of Medical Systems |
| 2011 | 1                  | Italy   | Ilario Gardini | Ital Med Lav Ergon |
| 2012 | 1                  | USA     | Jason W Beckstead | Multivariate Behav Res |
| 2013 | 1                  | Brazil  | Bruna Kosar Nunes | Rev Lat Am Enfermagem |
| 2014 | 4                  | China   | Wei Xiang      | Artif Intell Med |
|      |                    | UK      | Alison Leary   | Clin Nurse Spec |
|      |                    | France  | Jordi Ferrer   | Epidemics |
|      |                    | Finland | Kristiina Junttila | J Biomed Inform |
| 2015 | 1                  | USA     | Douglas S McNair | Nurs Adm Q |
| 2016 | 1                  | Turkey  | A. Kokangul    | Health Care Manag Sci. |
| 2017 | 2                  | Malaysia | Zuraida Abal Abas | Health Care Manag Sci |
|      |                    | India   | M Rajeswari    | Comput Intell Neurosci |
| 2018 | 1                  | Portugal | Ana Respicio   | BMC Med Inform Decis Mak |
|      | 5                  | Iran    | Mahdi Hamid    | Proc Inst Mech Eng H |
|      |                    | Brazil  | Sant’ana JLG   | Rev Lat Am Enfermagem |
|      |                    | Japan   | Nakai H        | Gen To Kagaku Ryoho |
|      |                    | USA     | Anna Camille Svirkso | J Emerg Nurs |
|      |                    | USA     | Sara Miliani   | J Neurosci Nurs |

Table 1. Articles published in Nursing Research, based on mathematical models, and reported in PubMed from 1980 to 2019.
Mathematical models are an additional tool that nursing research could use compared to devices that are based on questionnaires and evaluation scales. The use of mathematical models in medicine was introduced in the 1970s. Their use is still very limited in nursing research applying both linear and logistic regression models in data analysis. In contrast, advanced mathematical models based on mathematical relationships among variables in problems connected to nursing research are minimal.

Regarding the use of the mathematical models in nursing research included regression models, in Table 1 we showed the number of scientific papers published in the nursing field, stratified for a geographical area, author, and journal, and reported in PubMed from 1980 to 2019. Notably, 158 initial results were obtained with an advanced search in PubMed (last access on November 12, 2020), considering the following search options:

```sql
(((("1980"[Date - Entry]: "2019"[Date - Entry])) AND (Model[Title/Abstract])) AND ((Nurse[Title/Abstract])) OR (Nursing[Title/Abstract])) AND (Mathematical)[Title/Abstract]) NOT (Review[Title/Abstract])
```

Subsequently, all results were verified and filtered, and only 45 results from 1980 to December 2019. In particular, four papers were published from 1980 to 1989, 11 from 1990 to 1999, 12 from 2000 to 2009, and 18 from 2010 to 2019, with a significant increase in the last decade, confirming their important role in nursing research. Also, the USA (20 articles), following to UK (4 articles) were the Countries where the mathematical models were more used in nursing research. These results showed more frequent multidisciplinary approaches in nursing research in the USA than in other Countries. Moreover, papers published from January 1st to November 12th, 2020 were not included in this discussion, because we only considered full years, i.e. from January 1st to December 31st.

Finally, despite using many combined key words, the number of articles found in PubMed was minimal; therefore, due to the possibility of a few records being incorrectly excluded, this does not, in any way, counter what has been discussed in this paper.

The new frontier of nursing research should include defining advanced mathematical models through an interdisciplinary approach to solve problems related to the nursing discipline in different areas - from clinical practice to management to education, working alongside, and integrating the current nursing research tools. A strong collaboration between mathematicians and nurses is needed to improve nursing research results and, consequently, the nurses’ performance.

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**Key words:** Nurse; nursing research; mathematical models; nursing tools; questionnaires; artificial neural networks; Big Data.

**Contributions:** TR, NS, study concept, design and carrying out, manuscript drafting; AA, CS, manuscript writing, review and editing. All the authors have read and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

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**Significance for public health:** The study described in this paper is significant for public health, because it discusses the importance of using mathematical models in nursing research. Mathematical models used in many scientific areas could impact nurses’ daily work, guiding their decisions and helping them choose better strategies, resulting in an improvement in their performance.

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**Figure 1. Classification of mathematical models.**

stochastic, and therefore unpredictable, one. Therefore, these models must already know which variables are considered inputs and which are considered outputs. In any case, the stochastic approach is used to investigate, in any way, the internal mechanics of a system. Therefore, even if it is entirely useless to explain the phenomenon, this model is beneficial for providing predictions of the behavior of a system whose characterization is uncertain or too complex for it to be convenient to model it deterministically.

- **Deterministic models:** These models try to reproduce the observed behavior through mathematical relationships based on more or less extensive experimental observations. The higher the amount of data and the system’s knowledge, the more complex the model becomes.

  The model classifications are shown in Figure 1.

  Mathematical models are an additional tool that nursing research could use compared to devices that are based on questionnaires and evaluation scales.

  The use of mathematical models in medicine was introduced in the 1970s. Their use is still very limited in nursing research applying both linear and logistic regression models in data analysis. In contrast, advanced mathematical models based on mathematical relationships among variables in problems connected to nursing research are minimal.

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  The new frontier of nursing research should include defining advanced mathematical models through an interdisciplinary approach to solve problems related to the nursing discipline in different areas - from clinical practice to management to education, working alongside, and integrating the current nursing research tools. A strong collaboration between mathematicians and nurses is needed to improve nursing research results and, consequently, the nurses’ performance.

**Discussion**

Few studies regarding mathematical models in nursing research were found. We searched all scientific papers published in the field of nursing in PubMed, according to the search method described in the Methods and search Criteria paragraph. We found 45 results from 1980 to December 2019. In particular, four papers were published from 1980 to 1989, 11 from 1990 to 1999, 12 from 2000 to 2009, and 18 from 2010 to 2019, with a significant increase in the last decade, confirming their important role in nursing research. Also, the USA (20 articles), following to UK (4 articles) were the Countries where the mathematical models were more used in nursing research. These results showed more frequent multidisciplinary approaches in nursing research in the USA than in other Countries. Moreover, papers published from January 1st to November 12th, 2020 were not included in this discussion, because we only considered full years, i.e. from January 1st to December 31st.

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