

Brief Report

Mathematical models in nursing research

Teresa Rea,¹ Assunta Guillari,¹ Consolato Sergi,² Nicola Serra³

¹Department of Public Health, University Federico II of Naples, Italy; ²Department of Lab. Medicine and Pathology, University of Alberta, Edmonton, AB, Canada; ³Department of Molecular Medicine and Medical Biotechnology, University Federico II of Naples, Italy

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.

Introduction

Nursing, an integral part of the health system, encompasses autonomous and collaborative care of individuals of all ages, families, groups, and communities, both sick or well and in all settings. Within this broad spectrum of healthcare, the particular areas of concern are the patient as an individual, their family, and group responses to current or potential health problems. These human responses vary widely in terms of the reactions to restoring health from a single episode of illness and developing policies to promote long-term health in the population.¹

Many tools have been developed through scientific research to help healthcare workers. The tools developed in nursing research are defined with reasonable procedures of validation and are usually based on evaluation scales, assessment tools, and questionnaires. Questionnaires, especially those composed of two or more sections (depending on survey type), are used, where every part includes more items. The polls are carried out through interviews with patients, parents, or nurses. For example, they can be used in the evaluation of the risk of videogame addiction in younger people,^{2,3} the stress levels of parents with children with a chronic disease,⁴⁻⁶ and taste alteration in patients undergoing chemotherapy.^{7,8} Moreover, in the management field, they can be used to identify overcrowding in the emergency department as well as for bed management.⁹

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

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.

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

Table 1. Articles published in Nursing Research, based on mathematical models, and reported in PubMed from 1980 to 2019.

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	PA. 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 P.J.	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. Mauthe	Arch Phys Med Rehabil
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 Perinatol
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	G 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 Junntila	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
2019	5	Iran	Mahdi Hamid	Proc Inst Mech Eng H
		Brazil	Sant'ana JLG	Rev Lat Am Enfermagem
		Japan	Nakai H	Gan To Kagaku Ryoho
		USA	Anna Camille Svirsko	J Emerg Nurs
		USA	Sara Mithani	J Neurosci Nurs

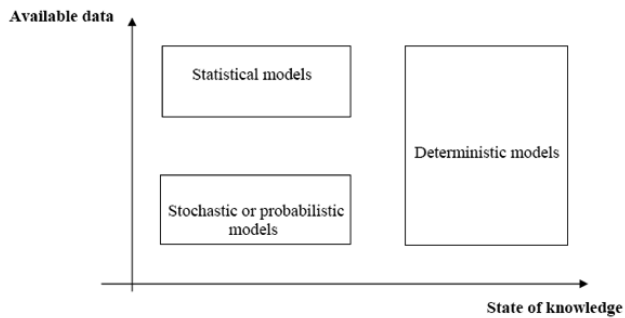


Figure 1. Classification of mathematical models.

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.^{15,16} Their use is still very limited in nursing research applying both linear and logistic regression models in data analysis.¹⁷⁻¹⁹ 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:

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(((((“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])
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Subsequently, all results were verified and filtered, and only 45 results were included in our study (Table 1).

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. 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.

Correspondence: Nicola Serra, Department of Molecular Medicine and Medical Biotechnology, University Federico II of Naples, Italy.
E-mail: nicola.serra@unina.it

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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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