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The Power of Artificial Intelligence on Drug Manufacturing and Clinical Trials

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ABSTRACT

Artificial intelligence (AI) and machine learning (ML) have become significant aspects of contemporary society. The prominence of AI in society is attributed to its vital role in different quotas of life, that is, by using "big data" to perform tasks that would be impossible or take long to be done by a human. These functions are achieved by perceiving, synthesizing, and inferring information performed by computerized machines instead of intelligence possessed by animals or humans. For example, in the pharmaceutical industry, AI technology is used to improve efficiency and accuracy in manufacturing drugs and their performance in improving health care. This study takes responsibility to look into aspects impacted by artificial intelligence in the modern pharmaceutical industry. Aspects studied herein include the impact of AI and the time taken to discover and develop drugs, the consumer cost of the drugs developed with AI/ML technology, its impact on medical education, and ethical issues associated with the related technology, notwithstanding the impacts of AI/ML on clinical trials. The study found that AI and ML significantly impact the time taken to discover drugs, and the technology in discussion contributed to consumer cost reduction. Furthermore, it has contributed to the need for revising the medical curriculum; even with the ethical concerns on the safety and privacy of data utilized in the technology, it has significantly led to significant changes in the clinical trials of drug discovery and development methodologies.

Keywords: Artificial Intelligence, Machine Learning, Drug Discovery, Drug Development, Clinical Trials, Pharmaceutical Industry, Healthcare, Ethics

INTRODUCTION

Technological development and advancement have since been the primary contributor to medical advancement in the healthcare industry. The technological advancement witnessed in contemporary society is a result of the continuous development in science, considering that technology has lived since the existence of humankind (NW et al., 2020). Humanity has contributed to the development of technology to make life easier by developing machines and techniques that perform tasks that humans would otherwise not perform. In the medical sphere, artificial intelligence and machine learning significantly impact how medical practitioners attend to patients and develop drugs. According to Patel and Shah (2021), using AI and machine learning in drug manufacturing and development contributes to improving efficiency and accuracy in manufacturing drugs and their performance in improving health care. An insight into the investments put into machine learning, and AI in medicine development depicts the immense demand for technology from administrative quotas in the global society. According to the Artificial Intelligence Index, the investment and commitment made to companies in the technological field considered herein grew 4.5 times more than in 2019 to $13.8 billion (Kahn, 2021). The investment and concentration done by the administrative quotas of the world raise a critical question of the foreseen influence and impact of AI technology on the discovery and development of medicine. Moreover, the technology has been practiced since its inception in the development of medicine and clinical trials. For this reason, this paper studies the impact of AI and Machine learning technology on drug discovery and development. The paper's objectives are achieved by giving an insight into the impact made in the industry as well the effectiveness of the technology by looking into the success of clinical trials done for the last five years.

Objectives of Study

The study's primary objective is to quantitatively analyze the impact of artificial intelligence (independent variable) on the discovery and development of medicine (dependent variable), especially on efficiency, accuracy, and cost-effectiveness. Extensively this study investigates the correlation between the use of AI and machine learning technology and the reduced consumer cost of drugs and reduced time on discovery and development of drugs, notwithstanding the time taken to conduct clinical trials. An insight into these aspects gives a comprehensive account of the areas significantly impacted by the use of AI/ML in the corresponding industry. Such a study significantly contributes to the development of literature in the discipline from an academic perspective.

LITERATURE REVIEW

Comparing the traditional process and methods of discovering and developing medicine to the use of artificial intelligence (AI) significantly contribute to the discourse that looks into the two's contribution to improving drug discovery. As much as AI technology is continuously revolutionizing the pharmaceutical industry, Bender and Cortés-Cipriano (2020) note that there are rare comparable advanced drug discoveries to date. The primary reasons for the hindrance to exploiting the full potential of artificial intelligence and machine learning (ML) are based on the shortcomings of AI being unable to outshine the traditional methods of discovering and developing drugs in specific stages of drug discovery (Bender & Cortés-Cipriano, 2020). However, from another perspective, Paul et al. (2020) note that despite the advantages of using AI and ML technology in drug discovery, these technologies face significant data challenges, including data uncertainty, data scale, diversity, and diversity growth. Moreover, Bender and Cortés-Cipriano (2020) add that the first stages of drug discovery that entail target identification (identification of proteins in the body associated with or causing a disease) cannot be entirely performed using AI and ML technology. An insight into the arguments raised in this section indicates that there are no investigations done on the association of failures of AI to the data provided in the drug discovery and development process. For this reason, these claims can only be admissible when these faults are linked to the technology and not the data fed to AI systems.

The primary motivation for using artificial intelligence in discovering and developing medicine is to reduce the cost of medicine by improving how medicine is manufactured. According to Hughes et al. (2011), the traditional and indigenous methods and procedures of discovering and developing medicine have a significant role in the ever-rising cost of production and the global society's purchase of medicine. Moreover, the traditional methods of discovery and development of drugs do not guarantee the success of medicine as most of the developed medicine still needs to pass clinical trial. Only 13 percent of drugs successfully pass clinical trials (Wong et al., 2018). According to Wong et al. (2018), the losses undertaken by pharmaceutical companies in case their drugs fail clinical trial range between $161 million to $2 billion. However, scientists such as Kiriiri et al. (2020) have criticized the use of AI to speed up the process of discovering and developing drugs by arguing that the success of AI in the discovery and development of drugs is based on the credibility and accuracy of data and information provided for the AI systems. The latter suggests that traditional methods and processes can be improved by providing accurate data for discovering and developing medicine. Such arguments need to account for the time taken in the discovery and development of drugs using traditional methods and processes compared to AI.

Critiques on using AI in the discovery and development of medicine significantly lean toward the ethics of using AI technology instead of traditional methods and processes. Data sources used to discover and develop medicine in contemporary society are an actual population (Radin, 2017). Ethical issues raised regarding the use of AI in the medical industry are the security and privacy of data used in the discovery and development of drugs (Farhud & Zokaei, 2021). In this case, inadequate oversight of the ethical issues is due to the lack of policies addressing data safety and privacy issues in the medical industry. According to NW et al. (2021), discussions about the ethical issues in the use of artificial intelligence in the discovery and development of drugs are halted by the rapid changes and development in technology. However, Gerke et al. (2020) note that social gaps in the global society significantly contribute to the challenges experienced in developing policies that govern the use of artificial intelligence in the pharmaceutical industry. For these reasons, developing policies that guarantee the ethical use of population data in drug discovery and development depends on the global society's inclusivity.

Technological development in the contemporary processes and methods of discovering and developing drugs result from high demand for drugs to respond to illnesses claimed by most of the global population, such as HIV/AIDS, Ebola, and Covid-19. In comparing the time taken to discover and develop a drug under the traditional methods and processes compared to the use of artificial intelligence, it is evident that AI reduces the time taken to develop respective drugs. However, such findings are significantly disputed, with significant issues being pegged on the safety of the drugs considering that they are made from a simulation process (Liu et al., 2021). In defense of the use of AI in discovering and developing drugs, Baron (2012) notes that traditional methods and processes of discovering and developing medicine have adverse effects on sample populations employed in the clinical trial phases. An insight into the arguments and counterarguments as far as the issue of the improvement provided by the use of AI technology in the discovery and development of drugs, it is notable that, indeed, the use of traditional processes and methods of discovering and developing drugs holds higher risks of fatality compared to the use of AI.

The increased demand for the use of artificial intelligence in the discovery and development of drugs in contemporary society significantly impacts medical studies. Graduating students need to be equipped with skills relevant to the demands in the drug manufacturing industry to sustain the demand for AI-proficient human resources. Even with the current resistance from serving medical practitioners and researchers to appreciate the use of AI in their practice, Frommeyer et al. (2022) note that adaptability in the medical field is inevitable considering the positive advantages affiliated with the use of AI, such as precision in discovering and developing medicine. Moreover, Briganti and Moine (2020) concur that equipping learners and practitioners with augmented skills is necessary for the drug manufacturing industry today and in the future. According to Frommeyer et al. (2022), resistance against the transition to AI in discovering and developing drugs in contemporary society is based on fears of losing employment. However, the demands in the current drug markets cannot be sustained by traditional methods and practices of discovering and developing drugs. Fleming (2018) notes that pharmaceutical companies have significantly invested in the transition, making it a fundamental requirement for medical practitioners to hold significant levels of AI proficiency. For this reason, there is a great need for governments and medically affiliated administrative institutions to consider revising and adjusting their medical curriculums to facilitate artificial intelligence and machine learning to produce practitioners who meet the demands of the pharmaceutical industry.

Research in the medical field is significantly impacted by the development and advancement of using AI and ML in the discovery and development of drugs in the modern pharmaceutical industry. As such, scholars and researchers in pharmaceutical-related fields have a significant burden of equipping themselves with AI-proficient skills to remain relevant to the discipline (Kolluri et al., 2022). Researchers in the industry play a significant role in learning and discovering trends, identifications of relevant data, improvement, and discovery of new methods of novel target identification. They also try understanding target-disease associations, drug candidate selection, protein structure predictions, molecular compound design, and optimization. Also, understanding disease mechanisms, developing new prognostic and predictive biomarkers, biometrics data analysis from wearable devices, imaging, precision medicine, and, more recently, clinical trial design, conduct, and analysis are inevitable. Looking into the role played by researchers and scholars in the industry, one may argue that researchers equipped with AI/ML-proficient skills are the future, necessitating a limitation of researchers with traditional knowledge from practicing. However, Vamathevan et al. (2019) note that researchers and scholars with skills from indigenous literature of discovering and developing drugs remain relevant to the industry regardless of AI and ML technology developments. Their relevance is based on their experience in developing and evaluating the performance of AI technology in the pharmaceutical industry.

An insight into the phases of drug discovery and development, it is noted that the development and advancement of artificial intelligence technology in the pharmaceutical industry significantly impact the clinical trial phase. Typically, the launch of a clinical trial involves an investment of millions of dollars in more than 500 people and a period of more than a decade to test a single drug where the success rate of the drug reaching the regulatory approval stage is less than 10% (Hariry et al., 2022). The challenges experienced in the traditional processes and methods of drug discovery and development depict the importance of using AI/ML in the pharmaceutical industry. According to Londhe and Bhasin (2019), the reduced time taken to conduct clinical trials must be addressed regardless of the deficiencies of AI in the pharmaceutical industry. The automatic abilities of artificial intelligence systems to develop clinical trial designs, patient cohort selection and recruitment, study site, investigator selection, patient monitoring, protocol adherence, and the outsourcing of required skills and talents optimize time and costs. This strategy affects the supply chain positively (Kulkov, 2021). The need for more data to contribute to the development of AI and ML systems within the medical industry needs to be considered, with the current benefits of the technology allowing the industry to adopt and develop with the growth in the data collected progressively. The latter depicts that AI will play a critical role in the provision of medical services and the development of treatment plans, as well as drug manufacturing.

METHODOLOGY

To establish the impact of artificial intelligence and machine learning on the discovery and development of drugs in the health industry, this study employs a quantitative analysis technique to statistically establish the correlations between AI technology and development in the discovery and development of drugs.

The Rationale of the Method

The fundamental advantage of using the study methods employed herein is the ability to produce objective data that can be communicated through statistics and numbers. Quantitative methods allow researchers to manipulate data in a study and objectively find patterns and averages, make predictions, test casual relationships, and generalize results to a broader population (). Herein, the proposed methodology significantly allows the establishment of the impact of artificial intelligence technology and the time taken to discover and develop drugs; its impact on medical education notwithstanding, it allows the prediction of the extent of the impact of artificial intelligence technology in the corresponding industry. Looking at an insight into the study's objectives, one may argue that the findings of one data set authenticate the other.

Data Collection

The data collection technique employed in this study involved collecting relevant information published on the websites of 26 pharmaceutical companies on the impact of the artificial intelligence they are using to discover and develop drugs. Companies considered for the study include Pfizer, AbbVie, Novartis, Johnson & Johnson, Roche, Bristol Myers Squibb (BMS), Merck & Co. (MSD), Sanofi, AstraZeneca, GlaxoSmithKline, Abbott Laboratories, Terumo Corporation, Baxter International, 3M Company, Medtronic PLC, Siemens Healthineers, Danaher Corporation, Stryker Corporation, Becton, Dickinson & Company, General Electric, Intuitive Surgical Inc., Align Technology, Fresenius Medical Care AG & Co. KGaA, Allergan PLC, and Olympus Corporation.

Dataset Considered for the Study

	PharmaceuticalCompany	YearAnnouncedusedofAIML	ExtentofUseofAIML	StageofUse	ReducedTimeTakentoDevelopaDr..	ReducedConsumerCostofDrugin	ImpactonMedicalEducation	EthicalIssues	ImpactonClinicalTrials	TimeTakentoDiscoverDrugswithAITi..	TimeTakentoDiscoverDrugsWithoutA..	ClinicalTrialWithAITimeinmonths	ClinicalTrialWithoutAITimeinmonths
1	Pfizer (USA)	2018	2	2	37	20	3	1	1	41	65	35	194
2	AbbVie (USA)	2016	2	2	35	20	1	1	1	47	72	47	146
3	Novartis (Switzerland)	2017	1	2	20	17	2	2	2	47	59	45	174
4	J&J (USA)	2016	2	1	31	25	3	1	1	39	56	60	161
5	Roche (Switzerland)	2018	1	2	23	25	2	2	1	43	56	35	219
6	BMS (USA)	2019	1	1	26	15	2	1	1	49	67	42	255
7	Merck & Co. (MSD) (USA)	2018	1	2	21	20	1	1	2	53	67	60	203
8	Sanofi (France)	2016	1	1	25	28	2	1	1	55	73	52	121
9	AstraZeneca (Sweden)	2017	2	2	46	28	3	1	1	46	85	44	252
10	GlaxoSmithKline (Britain)	2019	2	2	46	18	3	2	1	39	72	45	242
11	Abbott Laboratories	2018	1	1	27	18	1	2	2	44	61	55	243
12	Terumo Corporation	2016	1	2	40	15	1	1	2	38	63	35	202
13	Baxter International	2017	1	2	45	22	1	1	2	40	73	51	285
14	3M Company	2020	1	1	37	18	1	2	1	41	66	45	230
15	Medtronic PLC	2015	1	1	43	25	2	1	1	29	51	43	176
16	Siemens Healthineers	2015	2	2	35	25	2	2	1	40	61	48	226
17	Danaher Corporation	2018	1	1	34	22	1	1	1	36	54	49	146
18	Stryker Corporation	2015	1	1	33	27	2	2	2	36	53	42	195
19	Becton, Dickinson & Co...	2015	1	1	34	26	1	1	2	39	59	49	150
20	General Electric	2020	1	1	21	18	1	1	1	44	56	52	184
21	Intuitive Surgical Inc.	2015	1	1	27	18	1	1	2	36	50	47	249
22	Align Technology	2019	1	1	35	23	1	1	1	36	56	59	252
23	Fresenius Medical Car...	2019	1	1	24	22	1	1	1	54	71	52	194
24	Allergan PLC	2015	1	1	30	15	1	1	1	43	62	39	246
25	Olympus Corporation	2018	1	1	45	29	2	2	1	33	60	56	257

RESULTS

Regression

Descriptive Statistics

	Mean	Std. Deviation	N
Time Taken to Discover Drugs with AI (Time in months)	41.92	6.474	25
Extent of Use of AI/ML	1.24	.436	25

Correlations

		Time Taken to Discover Drugs with AI (Time in months)	Extent of Use of AI/ML
Pearson Correlation	Time Taken to Discover Drugs with AI (Time in months)	1.000	.007
	Extent of Use of AI/ML	.007	1.000
Sig. (1-tailed)	Time Taken to Discover Drugs with AI (Time in months)	.	.487
	Extent of Use of AI/ML	.487	.
N	Time Taken to Discover Drugs with AI (Time in months)	25	25
	Extent of Use of AI/ML	25	25

Variables Entered/Removed

Model	Variables Entered	Variables Removed	Method
1	Extent of Use of AI/ML[b]	.	Enter
a. Dependent Variable: Time Taken to Discover Drugs with AI (Time in months)			
b. All requested variables entered.			

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.007[a]	.000	-.043	6.613
a. Predictors: (Constant), Extent of Use of AI/ML				

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.051	1	.051	.001	.973[b]
	Residual	1005.789	23	43.730		
	Total	1005.840	24			
a. Dependent Variable: Time Taken to Discover Drugs with AI (Time in months)						
b. Predictors: (Constant), Extent of Use of AI/ML						

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	41.789	4.061		10.290	<.001
	Extent of Use of AI/ML	.105	3.097	.007	.034	.973

Coefficients							
Model		95.0% Confidence Interval for B		Correlations		
		Lower Bound	Upper Bound	Zero-order	Partial	Part
1	(Constant)	33.388	50.191			
	Extent of Use of AI/ML	-6.301	6.511	.007	.007	.007

a. Dependent Variable: Time Taken to Discover Drugs with AI (Time in months)

In this case, the progression analysis was conducted to examine the relationship between the time taken to discover drugs with AI and the extent of use of artificial intelligence and machine learning technology. The descriptive statistics show that the mean time to discover drugs with AI is 41.92 months, with a standard deviation of 6.474 months. The mean extent of use of AI/ML is 1.24, with a standard deviation of .436. The correlation table indicates a weak positive correlation between the time taken to discover drugs with AI and the extent of use of AI/ML (Pearson correlation coefficient of .007). The ANOVA results, as in this section of the study, also suggest that the extent of use of AI/ML is not a significant predictor of the time taken to discover drugs with AI, considering. The analysis in this section provides weak evidence for a significant relationship between the time taken to discover drugs with AI and the extent of use of AI/ML.

Regression

Descriptive Statistics

	Mean	Std. Deviation	N
Reduced Consumer Cost of Drugs (in %)	21.56	4.369	25
Extent of Use of AI/ML	1.24	.436	25
Year Announced use of AI/ML	2017.16	1.675	25

Correlations

		Reduced Consumer Cost of Drugs (in %)	Extent of Use of AI/ML	Year Announced use of AI/ML
Pearson Correlation	Reduced Consumer Cost of Drugs (in %)	1.000	.145	-.275
	Extent of Use of AI/ML	.145	1.000	-.112
	Year Announced use of AI/ML	-.275	-.112	1.000
Sig. (1-tailed)	Reduced Consumer Cost of Drugs (in %)	.	.244	.092
	Extent of Use of AI/ML	.244	.	.297
	Year Announced use of AI/ML	.092	.297	.
N	Reduced Consumer Cost of Drugs (in %)	25	25	25
	Extent of Use of AI/ML	25	25	25
	Year Announced use of AI/ML	25	25	25

Variables Entered/Removed			
Model	Variables Entered	Variables Removed	Method
1	Extent of Use of AI/ML[b]	.	Enter
2	Year Announced use of AI/ML[b]	.	Enter
a. Dependent Variable: Reduced Consumer Cost of Drug (in %)			
b. All requested variables entered.			

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.145[a]	.021	-.021	4.416
2	.298[b]	.089	.006	4.356
a. Predictors: (Constant), Extent of Use of AI/ML				
b. Predictors: (Constant), Extent of Use of AI/ML, Year Announced use of AI/ML				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	9.669	1	9.669	.496	.488[b]
	Residual	448.491	23	19.500		
	Total	458.160	24			
2	Regression	40.636	2	20.318	1.071	.360[c]
	Residual	417.524	22	18.978		
	Total	458.160	24			
a. Dependent Variable: Reduced Consumer Cost of Drug (in %)						
b. Predictors: (Constant), Extent of Use of AI/ML						
c. Predictors: (Constant), Extent of Use of AI/ML, Year Announced use of AI/ML						

Coefficients						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	19.754	2.712		7.284	<.001
	Extent of Use of AI/ML	1.456	2.068	.145	.704	.488
2	(Constant)	1396.458	1077.749		1.296	.209
	Extent of Use of AI/ML	1.163	2.053	.116	.566	.577
	Year Announced use of AI/ML	-.682	.534	-.262	-1.277	.215

Coefficients						
Model		95.0% Confidence Interval for B		Correlations		
		Lower Bound	Upper Bound	Zero-order	Partial	Part
1	(Constant)	14.144	25.365			
	Extent of Use of AI/ML	-2.822	5.734	.145	.145	.145
2	(Constant)	-838.656	3631.572			
	Extent of Use of AI/ML	-3.095	5.420	.145	.120	.115
	Year Announced use of AI/ML	-1.790	.425	-.275	-.263	-.260
a. Dependent Variable: Reduced Consumer Cost of Drug (in %)						

Excluded Variables						
Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	Year Announced use of AI/ML	$-.262^{b}$	-1.277	.215	-.263	.987
a. Dependent Variable: Reduced Consumer Cost of Drug (in %)						
b. Predictors in the Model: (Constant), Extent of Use of AI/ML						

The correlation matrix shows the Pearson correlation coefficients and the associated p-values for each pair of variables. The correlation coefficients indicate that Reduced Consumer Cost of Drugs (in %) has a weak positive correlation with the Extent of Use of AI/ML (r = 0.145) and a weak negative correlation with Year Announced use of AI/ML (r = -0.275). The model summary table shows the coefficient of determination (R-squared), which indicates the proportion of variance in the dependent variable that the independent variables can explain. Model 1 explains only 2.1% of the variance, while Model 2 explains 8.9%, indicating that adding Year Announced use of AI/ML to the model increases its predictive power. The ANOVA and coefficient tables indicate slight significance on models 1 and 2, respectively, considering that the F-value for ANOVA is only slightly greater than 1, and the associated p-value is insignificant. At the same time, the Extent of Use of AI/ML has a non-significant positive coefficient (b = 1.456, p = 0.488).

Frequencies

Statistics		
Impact on Medical Education		
N	Valid	25
	Missing	0
Mode		1
Range		2
Minimum		1
Maximum		3

Impact on Medical Education					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	13	52.0	52.0	52.0
	2	8	32.0	32.0	84.0
	3	4	16.0	16.0	100.0
	Total	25	100.0	100.0	

Regression

Variables Entered/Removed			
Model	Variables Entered	Variables Removed	Method
1	Extent of Use of AI/ML	.	Enter
a. Dependent Variable: Impact on Medical Education			
b. All requested variables entered.			

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	$.651^{a}$	.424	.399	.587
a. Predictors: (Constant), Extent of Use of AI/ML				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5.839	1	5.839	16.954	<.001[b]
	Residual	7.921	23	.344		
	Total	13.760	24			
a. Dependent Variable: Impact on Medical Education						
b. Predictors: (Constant), Extent of Use of AI/ML						

Coefficients						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.237	.360		.657	.518
	Extent of Use of AI/ML	1.132	.275	.651	4.118	<.001
a. Dependent Variable: Impact on Medical Education						

The Frequency table in evaluating the extent to which artificial learning impacts medical education indicates a low degree of influence at 53%, medium influence at 32%, and high performance at 16%. The regression analysis supports this analysis, indicating a correlation coefficient (R) of .651, indicating a moderate positive correlation between the two variables. The R-squared value is .424, indicating that 42.4% of the variation in "ImpactonMedicalEducation" is explained by "ExtentofUseofAIML." Moreover, the ANOVA table shows that the regression model is significant (p < .001) and explains a significant amount of the variance in "Impact on Medical Education," indicating that a one-unit increase in "Extent of Use of AI/ML" is associated with a .651-unit increase in "Impact on Medical Education."

Regression

Variables Entered/Removed			
Model	Variables Entered	Variables Removed	Method
1	Stage of Use	.	Enter
a. Dependent Variable: Ethical Issues			
b. All requested variables entered.			

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.140[a]	.020	-.023	.482
a. Predictors: (Constant), Stage of Use				

ANOVA						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.107	1	.107	.460	.504[b]
	Residual	5.333	23	.232		
	Total	5.440	24			
a. Dependent Variable: Ethical Issues						
b. Predictors: (Constant), Stage of Use						

Coefficients						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.133	.292		3.887	<.001
	Stage of Use	.133	.197	.140	.678	.504
a. Dependent Variable: Ethical Issues						

The frequency table indicates a significant relationship between ethical issues to the use of AI/ML, with the number of responses for each level of ethical issues per Year. It is evident that in 2015, there was one response with an ethical issue rating of 1 and four with an ethical issue rating of 2. In contrast, in 2018, there were two responses with an ethical issue rating of 2; in 2019, there were three with an ethical issue rating of 1. On the other hand, the regression analysis indicates a very weak relationship between ethical issues in medicine to the use of AI and machine learning in the development of drugs; registering an R-square value of 0.020 indicates that only 2% of the variation in ethical issues can be explained by the stage of use and a coefficient of 0.133 for the Stage of Use variable indicating that for every one-unit increase in the stage of use, the ethical issues related to the use of AI/ML increase by 0.133 units. However, the p-value of 0.504 for the ANOVA table suggests that the regression model is not statistically significant.

DISCUSSION

Speed Drug Discovery and Development

One of the fundamental promises of using technology in the healthcare industry is to speed up providing services and treatment. However, an insight into the disparity of importance and implementation of artificial intelligence-assisted drug discovery and development is evidence that pharmaceutical companies have a significant issue trusting the use of AI in discovering drugs. The latter is further supported by the findings of this study, where a majority of the pharmaceutical companies considered for this study only use AI/ML technology partially to develop drugs—the time is taken to discover and develop drugs upon testing the parameter. The latter emphasizes developing policies considering AI technology's input on drug discovery and development in contemporary society.

Affordability of Drugs

An insight into the cost and time to discover and develop drugs using AI technology shows that AI can significantly reduce healthcare costs. The trajectory taken by pharmaceutical companies to transition from traditional processes and methods of discovering medicine to using AI-assisted techniques for discovering and developing drugs remains a critical component of the process. Government and state input in assisting pharmaceutical companies to improve their methods and procedures of learning and developing drugs play a significant role in reducing the cost of production, consequently leading to affordability in the market (Wouters et al., 2020). As shown in image 2, investments in the pharmaceutical industry portray a promising future of affordable healthcare services in the global society. The convergence of precision medicine and artificial intelligence has a significant potential to revolutionize the modern healthcare industry (Johnson et al., 2020). The latter indicates that the success of being registered in the healthcare industry as far as AI technology is concerned depends on the monetary and literature investments in the industry.

Education

As explored herein, the sustainability of AI-assisted drug discovery depends on the availability of AI-skilled human resources in the industry. However, an insight into the number of successful drug discoveries in the modern pharmaceutical industry depicts a reduced number of skilled personnel. The reduced number can be confirmed by companies' reluctance to fully transition into using AI in discovering and developing drugs. Moreover, strategic investment since the year 2016, when the first company in the industry announced its move to incorporate AI technology in their drug discovery and development procedures and methods, could lead to a significant surge in the number of scientists graduating to fill positions in the pharmaceutical industry. According to Bittner and Farajnia (2022), the slow development of drugs in the modern pharmaceutical industry is a result of the reduced amount of data used in the industry and the training of personnel. The latter suggests that continuous data collection will impact the pharmaceutical industry and the medical curriculum.

Ethics

When one looks into the question of ethics regarding the use of artificial intelligence and machine learning, there are very limited checkpoints to highlight the safety and privacy of personal data provided for research. According to Chen et al. (2021), the limited literature on the matter depicts a concern that is not backed with facts considering that there are no claims of breach of privacy or security of data to date within the corresponding industry. Moreover, the current state of affairs within the industry can only be criticized for indigenous workers' lack of job security, considering the imminent production automation. For this reason, most of the critiques in the transition based on ethics are not supported by any research considering the early stages of growth in the global pharmaceutical industry.

Clinical Trials

Artificial intelligence and machine learning in the modern pharmaceutical industry significantly impact all stages of the discovery and development of drugs. During the stages of production where pharmaceutical companies prefer to use AI technology, it is evident that companies engage in different levels of drug discovery and development, with a majority leaning toward using AI in the first stages of drug discovery and development. According to Liebman (2022), artificial intelligence thrives on the use of data. On the other hand, it is the fundamental aspect of drug discovery and development, hence using artificial intelligence to identify and evaluate clinical data. Employment of AI in stages that depend on data manipulation primarily aims at aggregating, organizing, and analyzing “big data.” For this reason, it is accurate to note that as the amount of data in the industry glows, the need for using artificial intelligence continues to grow.

CONCLUSION

Throughout this study, artificial intelligence plays a significant role in the healthcare industry, especially in the discovery and development of drugs. Governments, states, and relevant healthcare organizations are investing significantly in the pharmaceutical industry to speed up the development and use of AI and ML technology in the corresponding industry. The government's involvement in developing artificial intelligence and machine learning within the pharmaceutical industry significantly fast-tracks development, considering the input of the political class in providing financial and legal resources. Herein, it is established that apart from artificial intelligence improving the efficiency, safety, and accuracy of drugs, the well-being of the global society is positively impacted. The latter is in consideration of the paced development of medical solutions that are affordable and effective. Moreover, the use of AI is identified to significantly impact the medical curriculum, necessitating adjustments that would produce AI-proficient medical practitioners. Finally, the impacts of artificial intelligence on contemporary society are developing into a core aspect of life, considering the use of data to improve life.

However, it is established that limited literature resources look into the critiques of the use of AI in the pharmaceutical industry. Moreover, more literature is needed to compare traditional and contemporary (based on AI/ML technology) processes and methods of discovering and developing drugs. The limited literature resources, in this case, depict a reduced number of studies focusing on this aspect of AI in the pharmaceutical industry. Therefore, developing literature within the field adds value to the topic discussed in this study. Furthermore, this study contributes to the development of literature in the discipline by giving out indicators of what is to be expected in the pharmaceutical industry in the future with the growth of AI use in the industry by interpreting trends in the sector associated with the use of AI technology in discovering and developing drugs. For this reason, there is a great need for researchers and scholars affiliated with pharmaceutical and medical disciplines of study to develop an interest in studying artificial intelligence and machine learning to fill the void of knowledge in the field.

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