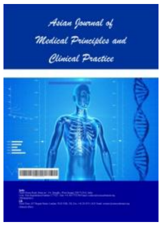

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Checking Consistency among the Four Basic Indicators of Diagnostic Testing in Saudi Medical Journals

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Authors' contributions

This work was carried out in collaboration between the two authors. Author HAMS participated in the literature search, performed the computational work and constructed the table of results. Author AMAR wrote the entire draft of the manuscript, conducted the mathematical and conceptual analyses and managed the literature survey. Both authors read and approved the final manuscript.

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ABSTRACT

We provide a novel method for validating any purported set of the four most prominent indicators of diagnostic testing (Sensitivity, Specificity, Positive Predictive Value, and Negative Predictive Value), by observing that these indicators constitute three rather than four independent quantities. This observation has virtually been unheard of in the open medical literature. We defined two functions, which serve as consistency criteria, since each of them checks consistency for any set of four numerical values claimed to be the four basic diagnostic indicators. Most of the data we came across in various Saudi medical journals met our criteria for consistency, but in a few cases, there were obvious unexplained blunders. We relate our present findings to the more general issue of detection and ramifications of unwelcome flawed data.

Keywords: Diagnostic testing; sensitivity; specificity; positive predictive value; negative predictive value; consistency criterion, flawed data.

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1. INTRODUCTION

Statistical methods are powerful and useful in interpreting experimental data, in general, and in explicating outcomes of medical research, in particular. However, some critics are skeptical about the correctness and validity of these methods, because a significant number of the articles that used statistical methods committed a variety of statistical errors and probabilistic fallacies [1-6]. Despite its effectiveness in handling genuine data, statistics is of limited power in detecting (the not uncommon) false or fabricated data, although a few statistical tools do achieve this purpose, such as the First Digit Law (Benford's law) [7-10].

In this paper, we add yet another method for validating a certain category of bio-statistical data. This method is based on a newly-discovered inter-relation among the four most prominent indicators of diagnostic testing (Sensitivity, Specificity, Positive Predictive Value (PPV), and Negative Predictive Value (NPV)) [11-15]. We developed simple formulas that express any one of these four indicators in terms of the other three. We call a set of four values satisfying these formulas (to within permissible round-off errors) a consistent set. We made extensive testing of sets of the four basic indicators published recently in various Saudi medical journals, to check whether these sets are consistent or not.

The organization of the rest of this paper is as follows. Section 2 reports virtually unknown formulas for inter-dependence among the two predictive values, sensitivity, and specificity. These formulas express any one of these four indicators in terms of the other three, under the assumption that each of the four exists, and no division by zero is encountered. Section 3 applies the new formulas extensively to data available in some Saudi medical journals. Most sets of values of sensitivity, specificity, and predictive values tested agree with our formulas, thereby independently attesting to the correctness of these formulas. However, some reported sets of the four basic indicators experience some appreciable incoherence or inconsistency among their values according to our formulas. Section 6 concludes the paper. The reader is referred to Appendix A for a brief discussion of the related topic of detection of flawed data.

2. VALIDATING FORMULAS

We express each of the four most prominent indicators of diagnostic testing (Sensitivity ($Sens_{ij}$), Specificity ($Spec_{ij}$), Positive Predictive Value (PPV_{ij}), and Negative Predictive Value (NPV_{ij})) solely in terms of the other three (provided each of the four indicators exists, and no division by zero is encountered), namely [14,15]

$$Sens_{ij} = \frac{PPV_{ij} * NPV_{ij}[1 - Spec_{ij}]}{PPV_{ij}NPV_{ij} + Spec_{ij}[1 - PPV_{ij} - NPV_{ij}]} \quad (1)$$

$$Spec_{ij} = \frac{PPV_{ij} * NPV_{ij}[1 - Sens_{ij}]}{PPV_{ij} * NPV_{ij} + Sens_{ij}[1 - PPV_{ij} - NPV_{ij}]} \quad (2)$$

$$PPV_{ij} = \frac{Sens_{ij} * Spec_{ij}\,[1 - NPV_{ij}]}{Sens_{ij} * Spec_{ij} + NPV_{ij}\,[1 - Sens_{ij} - Spec_{ij}]} \quad (3)$$

$$NPV_{ij} = \frac{Sens_{ij} * Spec_{ij}\,[1 - PPV_{ij}]}{Sens_{ij} * Spec_{ij} + PPV_{ij}[1 - Sens_{ij} - Spec_{ij}]} \quad (4)$$

We also define two checking functions of these four values that we call the Diagnostic Checking Difference (DCD) and the Diagnostic Checking Ratio (DCR), that are exactly 0 and 1, respectively, for consistent values. The mathematical definition of the DCD and DCR is [15]

$$DCD_{ij} = Sens_{ij} * Spec_{ij}[PPV_{ij} + NPV_{ij} - 1] - PPV_{ij} * NPV_{ij}[Sens_{ij} + Spec_{ij} - 1] \quad (5)$$

$$DCR_{ij} = \frac{Sens_{ij} * Spec_{ij}[PPV_{ij} + NPV_{ij} - 1]}{PPV_{ij} * NPV_{ij}[Sens_{ij} + Spec_{ij} - 1]}. \quad (6)$$

We use the subscripts ij for all measures and indicators to assert the notion that test i is assessed, judged or measured relative to the reference test or gold standard j.

3. ASSESSMENT OF DATA REPORTED IN SOME SAUDI MEDICAL JOURNALS

The deviation of the DCD and the DCR from 0 and 1, respectively, is a measure of inconsistency for any purported set of the four diagnostic indicators (Sensitivity, Specificity, Positive Predictive Value (PPV), and Negative Predictive Value (NPV)). Table 1 provides our

Table 1. Checking consistency among sets of the four prominent diagnostic indicators published in various Saudi medical Journals. In a dominant majority of cases, the published sets are consistent (uncolored entries), and in a small number of cases, there are sets that are somewhat problematic (highlighted in yellow), or dramatically inconsistent (highlighted in red). A value designated #DIV/0! is a 0/0 that is correct in the limit

#	Original values				Checking values		Computed values				Source
	$Sens_{ij}$	$Spec_{ij}$	PPV_{ij}	NPV_{ij}	DCD_{ij}	DCR_{ij}	$Sens_{ij}$	$Spec_{ij}$	PPV_{ij}	NPV_{ij}	
	Journal of King Abdulaziz University - Medical Sciences										
1	0.8667	0.8000	0.7647	0.8889	0.0000	1.0000	0.8667	0.8000	0.7647	0.8889	Abbas et al., 2016 [16]
	0.7667	0.9250	0.8846	0.8409	0.0000	1.0000	0.7666	0.9250	0.8846	0.8410	
	1.0000	0.9070	0.8710	1.0000	0.0000	1.0000	1.0000	#DIV/0!	#DIV/0!	1.0000	
	0.9273	0.3333	0.8361	0.5556	0.0000	1.0000	0.9273	0.3333	0.8361	0.5556	
	0.6129	0.5385	0.5135	0.6364	0.0000	1.0000	0.6129	0.5385	0.5135	0.6364	
2	0.9158	0.9775	0.9800	0.9062	0.0000	1.0000	0.9159	0.9775	0.9800	0.9060	Mufti & Sawan, 2011 [17]
	0.6666	0.8180	1.0000	0.9000	0.0546	1.1252	1.0000	1.0000	0.4996	0.0000	
	0.9900	0.9800	0.9900	0.8600	-0.0012	0.9986	0.9254	0.8600	0.9987	0.9800	
	0.9700	0.9540	0.9420	0.9760	0.0000	1.0000	0.9696	0.9533	0.9428	0.9764	
	0.9650	0.9390	0.9510	0.9550	-0.0001	0.9999	0.9640	0.9373	0.9524	0.9563	
	0.9210	0.9860	0.9940	0.8210	-0.0001	0.9999	0.9152	0.9849	0.9944	0.8321	
	0.9350	0.9570	0.9350	0.9570	0.0000	1.0000	0.9350	0.9570	0.9350	0.9570	
	0.9840	0.6000	0.9390	0.8570	0.0000	1.0000	0.9840	0.6000	0.9390	0.8570	
	0.9700	0.7800	0.9200	0.9200	0.0007	1.0012	0.9739	0.8035	0.9088	0.9088	
	0.9252	0.8767	0.9588	0.9057	0.0049	1.0070	0.9692	0.9476	0.9015	0.7908	
	0.9065	0.9684	0.9700	0.9019	0.0000	1.0000	0.9065	0.9684	0.9700	0.9019	
3	0.2941	0.6667	0.8333	0.1429	0.0000	0.9997	0.2941	0.6667	0.8333	0.1429	Al-Ghamdi et al., 2013 [18]
	1.0000	0.3333	0.8947	1.0000	0.0000	1.0000	1.0000	#DIV/0!	#DIV/0!	1.0000	
	0.9706	0.5000	0.9167	0.7500	0.0000	1.0000	0.9706	0.5000	0.9167	0.7500	
	Saudi Journal of Medicine and Medical Sciences										
4	0.3870	1.0000	1.0000	0.8510	0.0000	1.0000	#DIV/0!	1.0000	1.0000	#DIV/0!	Amin et al., 2017 [19]
	0.7480	1.0000	1.0000	0.9330	0.0000	1.0000	#DIV/0!	1.0000	1.0000	#DIV/0!	
	0.9910	0.8950	0.7280	0.9970	0.0000	0.9999	0.9905	0.8898	0.7385	0.9972	
	0.9730	0.8870	0.7110	0.9910	-0.0001	0.9998	0.9718	0.8826	0.7198	0.9914	
	0.2830	1.0000	1.0000	0.7610	0.0000	1.0000	#DIV/0!	1.0000	1.0000	0.0000	
	0.5460	1.0000	1.0000	0.8350	0.0000	1.0000	#DIV/0!	1.0000	1.0000	#DIV/0!	

#	Original values				Checking values		Computed values				Source
	$Sens_{ij}$	$Spec_{ij}$	PPV_{ij}	NPV_{ij}	DCD_{ij}	DCR_{ij}	$Sens_{ij}$	$Spec_{ij}$	PPV_{ij}	NPV_{ij}	
	0.9930	1.0000	1.0000	0.9970	0.0000	1.0000	#DIV/0!	1.0000	1.0000	#DIV/0!	
5	0.8550	0.9910	0.9920	0.8440	0.0000	1.0000	0.8590	0.9913	0.9917	0.8396	Zarif et al., 2018 [20]
	0.8890	0.7560	0.7970	0.8440	-0.0031	0.9929	0.8727	0.7262	0.8210	0.8634	
6	0.4290	1.0000	1.0000	0.8960	0.0000	1.0000	#DIV/0!	1.0000	1.0000	0.0000	Udoh et al., 2020 [21]
	0.2290	0.9940	0.8890	0.8640	0.0001	1.0007	0.2350	0.9942	0.8857	0.8600	
7	0.1175	0.9900	0.6660	0.8800	0.0005	1.0081	0.1287	0.9910	0.6425	0.8686	Saeed et al., 2017 [22]
	0.2180	0.9920	0.8750	0.8330	0.0000	1.0003	0.2197	0.9921	0.8739	0.8316	
	0.1830	0.9910	0.8180	0.8540	0.0003	1.0026	0.1927	0.9916	0.8083	0.8459	
8	0.491	0.8450	0.6050	0.7750	0.0001	1.0007	0.4918	0.8454	0.6042	0.7744	Moradan et al., 2017 [23]
	Saudi Medical Journal										
9	0.8160	0.9005	0.6667	0.9526	0.0000	1.0000	0.8162	0.9006	0.6663	0.9525	Mehmood et al., 2017 [24]
10	1.0000	0.3150	0.1050	1.0000	0.0000	1.0000	1.0000	0.0000	#DIV/0!	1.0000	Raffa et al., 2020 [25]
11	0.9733	0.5333	0.7766	0.9231	0.0000	1.0000	0.9733	0.5337	0.7763	0.9230	Sudheer, 2018 [26]
	Journal of King Saud University										
12	0.8685	0.8750	0.9335	0.7774	0.0007	1.0013	0.8751	0.8813	0.9298	0.7671	Nugroho et al., 2019 [27]
	0.8413	0.8725	0.8042	0.9042	0.0009	1.0018	0.8500	0.8797	0.7935	0.8983	
	0.9535	0.9091	0.9762	0.8333	0.0000	1.0000	0.9535	0.9091	0.9762	0.8333	
	1.0000	0.9545	0.9583	1.0000	0.0000	1.0000	1.0000	#DIV/0!	#DIV/0!	1.0000	
13	0.9500	0.9500	0.9500	0.9500	0.0000	1.0000	0.9500	0.9500	0.9500	0.9500	Al Jahdali et al., 2013 [28]
	0.9500	0.9500	0.9500	0.9500	0.0000	1.0000	0.9500	0.9500	0.9500	0.9500	
	Saudi Journal of Biological Sciences										
14	0.2960	0.8180	0.8000	0.3210	0.0000	1.0008	0.2961	0.8181	0.7999	0.3209	Nour-Neamatollahi et al., 2018 [29]
	1.0000	0.6370	0.8710	1.0000	0.0000	1.0000	1.0000	#DIV/0!	#DIV/0!	1.0000	
	0.6300	0.7270	0.8500	0.4440	-0.0001	0.9994	0.6295	0.7266	0.8503	0.4445	
	0.8810	1.0000	1.0000	0.9480	0.0000	1.0000	#DIV/0!	1.0000	1.0000	#DIV/0!	
	1.0000	0.9130	0.8430	1.0000	0.0000	1.0000	1.0000	#DIV/0!	#DIV/0!	1.0000	
	0.8610	0.9940	0.9850	0.9390	0.0000	1.0000	0.8592	0.9939	0.9852	0.9399	
	0.9740	0.9290	0.8650	0.9870	0.0000	1.0000	0.9738	0.9285	0.8659	0.9871	
15	0.1700	0.8600	0.3300	0.7100	-0.0012	0.8320	0.1641	0.8548	0.3395	0.7187	Alghamdi et al., 2019 [30]
	0.7500	1.0000	1.0000	0.8600	0.0000	1.0000	#DIV/0!	1.0000	1.0000	#DIV/0!	
	1.0000	0.6400	0.5500	1.0000	0.0000	1.0000	1.0000	#DIV/0!	#DIV/0!	1.0000	
	0.9340	0.7710	0.8980	0.8440	0.0000	1.0000	0.9340	0.7709	0.8980	0.8440	
	0.0110	0.9960	0.2500	0.9000	0.0001	1.0434	0.0119	0.9963	0.2353	0.8926	

#	Original values				Checking values		Computed values				Source
	$Sens_{ij}$	$Spec_{ij}$	PPV_{ij}	NPV_{ij}	DCD_{ij}	DCR_{ij}	$Sens_{ij}$	$Spec_{ij}$	PPV_{ij}	NPV_{ij}	
	0.8840	0.8800	0.6710	0.9650	0.0001	1.0001	0.8846	0.8807	0.6696	0.9648	
16	0.8107	0.7936	0.6976	0.8771	0.0000	1.0000	0.8107	0.7936	0.6976	0.8771	Zhang et al., 2019 [31]
	0.7837	0.7777	0.6743	0.8595	0.0000	0.9999	0.7836	0.7776	0.6745	0.8596	
	0.7296	0.7459	0.6278	0.8245	0.0000	1.0001	0.7297	0.7460	0.6277	0.8244	
	0.9458	0.8729	0.8139	0.9448	-0.0032	0.9949	0.9160	0.8110	0.8750	0.9648	
	0.0630	0.0342	0.0388	0.0584	0.0001	0.9511	0.0660	0.0359	0.0369	0.0557	
	0.0010	0.0033	0.0027	0.0012	0.0000	0.9850	0.0010	0.0034	0.0027	0.0012	
	Journal of Nature and Science of Medicine - King Saud University										
17	0.5556	0.8873	0.6522	0.8400	0.0000	1.0000	0.5556	0.8873	0.6522	0.8400	Al-Bahkaly et al., 2020 [32]
	Saudi Journal of Gastroenterology										
18	1.0000	0.9300	0.9200	1.0000	0.0000	1.0000	1.0000	#DIV/0!	#DIV/0!	1.0000	Senok et al., 2017 [33]
19	0.3120	0.9640	0.9410	0.2970	-0.0056	0.9280	0.2010	0.9369	0.9664	0.4323	Zhang et al., 2019 [34]
	0.4090	0.9280	0.9410	0.3210	-0.0024	0.9769	0.3691	0.9159	0.9497	0.3587	
	0.5270	0.8930	0.9410	0.3620	-0.0005	0.9967	0.5202	0.8904	0.9425	0.3683	
	0.6670	0.8570	0.9120	0.4360	-0.0094	0.9547	0.5721	0.8000	0.9395	0.5367	
	0.7850	0.8210	0.9020	0.5350	-0.0108	0.9631	0.6978	0.7436	0.9357	0.6453	
	0.7960	0.8210	0.8970	0.5480	-0.0125	0.9589	0.6972	0.7302	0.9366	0.6727	
	0.8170	0.7860	0.8890	0.5640	-0.0114	0.9622	0.7383	0.6988	0.9269	0.6719	
20	1.0000	0.8889	0.9412	1.0000	0.0000	1.0000	1.0000	#DIV/0!	#DIV/0!	1.0000	Mahmoud et al., 2012 [35]
	1.0000	0.9444	0.9697	1.0000	0.0000	1.0000	1.0000	#DIV/0!	#DIV/0!	1.0000	
	1.0000	0.8485	0.7727	1.0000	0.0000	1.0000	1.0000	#DIV/0!	#DIV/0!	1.0000	
	0.8820	0.8182	0.7143	0.9310	0.0000	1.0001	0.8823	0.8186	0.7137	0.9308	
	1.0000	0.9394	0.8947	1.0000	0.0000	1.0000	1.0000	#DIV/0!	#DIV/0!	1.0000	
	0.9770	1.0000	1.0000	0.8571	0.0000	1.0000	#DIV/0!	1.0000	1.0000	#DIV/0!	
	0.8330	0.9091	0.5556	0.9756	0.0000	1.0000	0.8333	0.9093	0.5551	0.9756	
	0.9770	1.0000	1.0000	0.8571	0.0000	1.0000	#DIV/0!	1.0000	1.0000	#DIV/0!	
21	0.9090	0.9090	0.2860	0.9960	0.0000	1.0000	0.9090	0.9090	0.2861	0.9960	Khayyat, 2012 [36]
22	0.5000	0.6500	0.1500	0.9100	-0.0010	0.9524	0.4900	0.6408	0.1552	0.9132	Abu-Eshy et al., 2008 [37]
	0.3800	0.8800	0.2700	0.9200	-0.0010	0.9838	0.3671	0.8741	0.2810	0.9240	
	0.1300	0.9500	0.2500	0.9000	0.0005	1.0292	0.1364	0.9526	0.2398	0.8949	
	1.0000	0.1500	0.1700	1.0000	0.0000	1.0000	1.0000	0.0000	#DIV/0!	1.0000	
	0.2500	0.6900	0.1000	0.8800	0.0018	0.6534	0.2680	0.7097	0.0919	0.8697	

#	Original values				Checking values		Computed values				Source
	$Sens_{ij}$	$Spec_{ij}$	PPV_{ij}	NPV_{ij}	DCD_{ij}	DCR_{ij}	$Sens_{ij}$	$Spec_{ij}$	PPV_{ij}	NPV_{ij}	
	0.2500	0.6800	0.1000	0.8600	-0.0008	1.1296	0.2431	0.6719	0.1034	0.8644	
	0.2900	0.9200	0.3300	0.9100	0.0010	1.0154	0.3022	0.9242	0.3172	0.9051	
	0.5700	0.8300	0.3600	0.9200	0.0000	0.9999	0.5699	0.8299	0.3601	0.9200	
	0.6300	0.7200	0.3300	0.9000	0.0004	1.0036	0.6329	0.7225	0.3273	0.8989	
	0.1300	0.9500	0.2500	0.9000	0.0005	1.0292	0.1364	0.9526	0.2398	0.8949	
	0.6300	0.7200	0.2200	0.9400	0.0002	1.0027	0.6321	0.7218	0.2184	0.9395	
	0.2900	0.9200	0.3300	0.9100	0.0010	1.0154	0.3022	0.9242	0.3172	0.9051	
	0.5700	0.8300	0.3100	0.9400	0.0017	1.0147	0.5904	0.8415	0.2923	0.9351	
	0.5700	0.8300	0.3600	0.9200	0.0000	0.9999	0.5699	0.8299	0.3601	0.9200	
	0.5700	0.8300	0.3600	0.9200	0.0000	0.9999	0.5699	0.8299	0.3601	0.9200	
	0.6300	0.7200	0.3300	0.9000	0.0004	1.0036	0.6329	0.7225	0.3273	0.8989	
	0.6300	0.8300	0.4500	0.9100	-0.0001	0.9993	0.6289	0.8293	0.4512	0.9104	
	0.8800	0.6200	0.2200	0.9800	0.0013	1.0122	0.8944	0.6533	0.1963	0.9770	
	0.8800	0.8200	0.4100	0.9800	0.0002	1.0006	0.8820	0.8228	0.4054	0.9796	
23	0.8060	0.5000	0.7246	0.6129	0.0001	1.0009	0.8064	0.5007	0.7241	0.6123	Alboraie et al., 2014 [38]
	0.7580	0.6842	0.7966	0.6341	0.0000	1.0000	0.7580	0.6842	0.7966	0.6341	
	0.7260	0.6842	0.7895	0.6047	0.0000	0.9999	0.7259	0.6841	0.7896	0.6048	
	0.9167	0.7763	0.5641	0.9672	0.0000	1.0000	0.9166	0.7762	0.5643	0.9672	
	0.8750	0.7763	0.5526	0.9516	0.0000	1.0000	0.8750	0.7762	0.5527	0.9516	
	1.0000	0.5658	0.4211	1.0000	0.0000	1.0000	1.0000	0.0000	#DIV/0!	1.0000	
	0.9583	0.5921	0.4259	0.9783	0.0000	1.0001	0.9584	0.5927	0.4253	0.9782	
	0.8182	0.7978	0.3333	0.9726	0.0000	1.0000	0.8181	0.7977	0.3334	0.9726	
	0.8182	0.8652	0.4286	0.9747	0.0000	1.0000	0.8183	0.8652	0.4285	0.9747	
	Annals of Saudi Medicine										
24	0.5500	0.5400	0.1900	0.8700	0.0029	1.1978	0.5721	0.5622	0.1765	0.8595	Almajwal et al., 2009 [39]
	0.5800	0.6100	0.2500	0.8600	-0.0019	0.9527	0.5669	0.5972	0.2601	0.8663	
	0.5900	0.5800	0.1800	0.9100	0.0030	1.1060	0.6165	0.6067	0.1643	0.9005	
	0.6000	0.6200	0.2500	0.8700	-0.0032	0.9329	0.5776	0.5979	0.2678	0.8801	
	0.5800	0.5600	0.1300	0.9200	-0.0005	0.9699	0.5745	0.5544	0.1326	0.9216	
	0.6300	0.5800	0.1700	0.9200	0.0000	1.0013	0.6304	0.5804	0.1698	0.9199	
	0.5500	0.6200	0.0800	0.9600	0.0006	1.0447	0.5612	0.6307	0.0767	0.9582	
	0.6100	0.5900	0.1200	0.9400	-0.0010	0.9572	0.5975	0.5773	0.1256	0.9429	
	0.9800	0.0600	0.1600	0.9400	-0.0001	0.9774	0.9791	0.0574	0.1664	0.9426	

#	Original values				Checking values		Computed values				Source
	$Sens_{ij}$	$Spec_{ij}$	PPV_{ij}	NPV_{ij}	DCD_{ij}	DCR_{ij}	$Sens_{ij}$	$Spec_{ij}$	PPV_{ij}	NPV_{ij}	
	0.9800	0.0800	0.2000	0.9500	0.0004	1.0316	0.9820	0.0884	0.1832	0.9446	
	0.9500	0.1300	0.1400	0.9500	0.0005	1.0446	0.9539	0.1400	0.1300	0.9458	
	0.9600	0.1200	0.1900	0.9300	-0.0003	0.9779	0.9581	0.1149	0.1976	0.9331	
	0.9800	0.0600	0.1100	0.9600	-0.0001	0.9744	0.9789	0.0571	0.1153	0.9620	
	0.9700	0.0900	0.1300	0.9500	-0.0004	0.9425	0.9663	0.0807	0.1441	0.9554	
	0.9600	0.1200	0.0600	0.9800	-0.0001	0.9796	0.9582	0.1153	0.0626	0.9809	
	0.9700	0.1100	0.0900	0.9800	0.0004	1.0585	0.9751	0.1303	0.0754	0.9758	
	Saudi Journal of Anaesthesia										
25	0.8737	0.1463	0.9330	0.0780	0.0000	0.9660	0.8730	0.1455	0.9334	0.0785	Safavi et al., 2011 [40]
	0.6601	0.7317	0.9710	0.1360	-0.0001	0.9989	0.6590	0.7307	0.9711	0.1366	
	0.7562	0.5854	0.9620	0.1490	0.0002	1.0035	0.7584	0.5883	0.9616	0.1475	
	0.9930	0.0732	0.9360	0.4290	-0.0001	0.9981	0.9929	0.0719	0.9372	0.4338	
	0.2651	0.8050	0.9490	0.0740	0.0000	0.9971	0.2648	0.8048	0.9491	0.0741	
	0.9911	0.0488	0.9350	0.2860	0.0000	1.0018	0.9912	0.0492	0.9345	0.2843	
	0.9964	0.0244	0.9330	0.3330	0.0000	1.0007	0.9964	0.0245	0.9327	0.3320	
26	0.8831	0.7447	0.8500	0.8000	0.0006	1.0013	0.8860	0.7500	0.8464	0.7954	Terkawi et al., 2017 [41]
	1.0000	0.1100	0.6500	1.0000	0.0000	1.0000	1.0000	#DIV/0!	#DIV/0!	1.0000	
	1.0000	0.2800	0.6900	1.0000	0.0000	1.0000	1.0000	#DIV/0!	#DIV/0!	1.0000	
	0.9220	0.5300	0.7600	0.8100	0.0003	1.0010	0.9229	0.5332	0.7577	0.8080	
	0.8830	0.7400	0.8500	0.8000	0.0011	1.0026	0.8884	0.7502	0.8430	0.7913	
	0.7270	0.8700	0.9000	0.6600	-0.0004	0.9988	0.7230	0.8677	0.9018	0.6645	
	0.5450	0.9400	0.9300	0.5600	-0.0016	0.9938	0.5191	0.9338	0.9365	0.5855	
	0.3120	0.9800	0.9600	0.4600	-0.0005	0.9959	0.2944	0.9783	0.9631	0.4808	
	0.1950	1.0000	1.0000	0.4300	0.0000	1.0000	#DIV/0!	1.0000	1.0000	0.0000	
	0.0650	1.0000	1.0000	0.4000	0.0000	1.0000	#DIV/0!	1.0000	1.0000	0.0000	
	Saudi Journal for Health Sciences										
27	0.6660	0.5760	0.3260	0.8490	0.0002	1.0023	0.6669	0.5770	0.3251	0.8485	Vasudevan et al., 2016 [42]
	0.8333	0.7820	0.5450	0.9380	0.0002	1.0006	0.8348	0.7838	0.5424	0.9374	
	0.7910	0.7564	0.5000	0.9218	0.0001	1.0003	0.7915	0.7570	0.4992	0.9216	
	0.8333	0.8846	0.6896	0.9452	0.0000	1.0000	0.8333	0.8846	0.6896	0.9452	
	0.8125	0.8450	0.7222	0.9032	0.0005	1.0012	0.8165	0.8484	0.7169	0.9009	
	Saudi Journal of Kidney Diseases and Transplantation										

#	Original values				Checking values		Computed values				Source
	$Sens_{ij}$	$Spec_{ij}$	PPV_{ij}	NPV_{ij}	DCD_{ij}	DCR_{ij}	$Sens_{ij}$	$Spec_{ij}$	PPV_{ij}	NPV_{ij}	
28	0.7620	0.9720	0.8000	0.9660	0.0001		0.7660	0.9726	0.7964	0.9653	Rathore et al., 2017 [43]
	0.9050	0.9860	0.9500	0.9860	0.0006	1.0007	0.9500	0.9929	0.9050	0.9725	
	0.5240	0.9860	0.8460	0.9340	0.0000	1.0000	0.5247	0.9860	0.8456	0.9338	
	0.9520	0.9520	0.7410	0.9930	0.0001	1.0001	0.9534	0.9534	0.7350	0.9928	
29	0.8000	0.3200	0.4800	0.6700	-0.0002	0.9950	0.7993	0.3190	0.4811	0.6710	Chandra et al., 2020 [44]
	0.7000	0.5000	0.5300	0.6800	0.0014	1.0197	0.7056	0.5067	0.5234	0.6742	
	0.6500	0.6200	0.5800	0.6900	0.0008	1.0070	0.6532	0.6234	0.5765	0.6869	
	0.5500	0.7200	0.6100	0.6700	0.0005	1.0048	0.5526	0.7221	0.6075	0.6677	
	0.9250	0.2200	0.4900	0.7900	0.0009	1.0152	0.9276	0.2266	0.4804	0.7836	
	0.9000	0.3000	0.5100	0.7900	0.0004	1.0052	0.9013	0.3032	0.5063	0.7875	
	0.8000	0.5000	0.5600	0.7600	0.0003	1.0025	0.8012	0.5019	0.5581	0.7586	
	0.6000	0.7600	0.6700	0.7000	-0.0001	0.9993	0.5994	0.7595	0.6706	0.7006	
	Saudi Journal of Internal Medicine										
30	0.8460	0.8330	0.9880	0.2560	0.0002	1.0012	0.8503	0.8376	0.9876	0.2497	Alashari et al., 2019 [45]

	RED	ORANGE		YELLOW		WHITE		YELLOW		ORANGE		RED
DCR=1	<0.9400	0.9400	0.9599	0.9600	0.9799	0.9800	1.0199	1.0200	1.0399	1.0400	1.0599	>=1.06
DCD=0	<0.0600	-0.0600	-0.0410	-0.0400	-0.021	-0.0200	0.0199	0.0200	0.0399	0.0400	0.0599	>=0.06
Others ,%	<=6%	<4% to 5.999%		<2.0% to 3.999%		±2%		>2% to 3.999%		>4% to 5.999%		>=6%

validation of some published sets of these four basic indicators. We check whether the sets considered are consistent or not. For each published set of $\{Sens_{ij}, Spec_{ij}, PPV_{ij}, NPV_{ij}\}$ the table computes the checking difference DCD_{ij} via (5), and the checking ratio DCR_{ij} via (6). It also uses equations (1-4) to compute a new value for each of the four prominent indicators in terms of the old values of the other three indicators. Most sets of values of sensitivity, specificity, and predictive values tested agree with our formulas, thereby independently attesting to the correctness of these formulas. However, some reported sets of the four basic indicators experience some appreciable incoherence among their values according to our formulas. It is not clear (and it is worth further investigation) why errors exist occasionally within some of the purported sets.

4. CONCLUSIONS

We provide a novel method for validating any purported set of the four most prominent indicators of diagnostic testing (Sensitivity, Specificity, Positive Predictive Value, and Negative Predictive Value), by observing that these indicators constitute three rather than four independent quantities. This observation has virtually been unheard of in the open medical literature. We defined two functions that check consistency for any set of four numerical values claimed to be the four basic diagnostic indicators. Most of the data we came across met our criterion for consistency, but in a few cases, there were obvious unexplained blunders. The results obtained herein for data in diverse Saudi medical journals resemble (and generally are not inferior to) results obtained in [15] for data in prominent international journals of high impact factors.

There are very few (mainly statistical) methods that are available for detecting incorrect, fraudulent, dishonest, false, or fatally-flawed data. The checking method developed herein is not a statistical one, and it is just a modest and specialized tool that supplements the already existing tools. We observe that the research field handling the detection of flawed data is still in its infancy, and hope that this field will reach maturity very soon. We reassert that we are still unaware of the causes of the errors caught by our method. We refrain from criticizing or placing unnecessary blame on the authors of the papers identified to have errors, and we definitely do not accuse these authors explicitly or implicitly of fraud, falsification, or even incompetence.

The fact that the enter-relationships (1)-(4) were almost unknown in the open literature might be a somewhat valid excuse for authors to fall into the trap of reporting inconsistent sets of diagnostic indicators. The implicit appearance of these relations in [4-6,11-13], and their explicit appearance in [14,15] (as well as in the present paper) make such an excuse totally unacceptable for forthcoming papers. In fact, future publications on the four prominent diagnostic indicators should check the consistency of reported sets of these indicators, and must refrain from reporting obviously inconsistent sets. A necessary word of caution is declared herein, namely that the inconsistencies studied in this paper do not exhaust all types of problematic data, but are just one particular manifestation of flawed data. Further discussion of the topic of flawed data and their detection is delegated to Appendix A.

This paper sets the stage for many potential directions for fruitful future work. Comparative analysis (across scientific disciplines, academic journals, and geographical regions) is warranted for the spread, seriousness and ramifications of the errors identified herein. It is also necessary to identify the real causes for the errors caught by our method, and hence propose effective remedies to mitigate them. An intriguing question is why the highly acclaimed peer-review system of academic journals failed to detect such errors and inconsistencies when they existed.

In a forthcoming sequel of this paper, we explore the same consistency problem for diagnostic data published in 2020 concerning the ongoing Covid-19 pandemic. Our purpose is to assess and judge an alarming widespread belief that victims of the novel coronavirus include the quality and accuracy of scientific publications about it. Our initial results suggest that this belief cannot be readily ignored, denied or refuted, since some genuine supporting evidence can be forwarded for it.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

The authors have declared that no competing interests exist.

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APPENDIX

Appendix A. On the Detection of Fabricated, False, Flawed and Wrong Medical Data

Steen [46] hypothesizes that error and fraud are the main sources of misinformation and that error is more common than fraud. He further asserts that misinformation can arise without malicious intent, and that authors of incorrect papers are owed a presumption of incompetence, not malice. This latter assertion of Steen is of utmost importance here, since we point out certain errors in a few publications. We are simply still unaware of the causes of these errors, and we do not want to criticize or place unnecessary blame on the authors of these papers, and definitely do not accuse them of fraud, falsification, or even incompetence. In a sequel paper, Steen [47] investigates the possibility that medical research so flawed as to be retracted may put patients at risk by influencing treatments administered to them. He concludes that if one is to minimize risk to patients, the appropriate focus should be placed on clinical trials, since these trials form the foundation of evidence-based medicine, and their integrity must be protected. Unfortunately, highly publicized cases of fabrication or falsification of data in clinical trials have occurred in recent years and it is likely that there are many other cases that went undetected or, at least, unreported [48].

The role of gatekeepers of science is the collective responsibility of scientists in general. It is also an implicit assignment for the editors, reviewers, and readers of scientific journals [49]. These could be doing much more to spot mistakes or errors in scientific publications, particularly those concerning medical data, since errors in medical data can be a matter of life and death sometimes [50]. Concerned that many medical studies contain false data, Carlisle [51] analyzed the baseline summary data of some randomized controlled trials submitted to the well-known journal *Anaesthesia*, and revealed false and fatally-flawed data in 44% of the studies he reviewed, which is an unacceptably very high ratio, indeed. He concluded that “journals should assume that all submitted papers are potentially flawed and editors should review individual patient data before publishing randomized controlled trials.” The findings of Carlisle have major implications and ramifications for medical science and its publication systems [52]. The (mainly statistical) methods available for detecting false data, which are devised by Carlisle and others [53-61], have become rather visible and advanced during the past decade. Rushdi and Rushdi [4] have recently suggested a non-statistical method based on the premise that flawed data might be detected via the excessive inconsistencies it causes in a variant of Boolean Analysis called Qualitative Comparative Analysis (QCA) [62-65]. The checking method developed herein is also a non-statistical one, and it is just a modest and specialized tool that supplements the already existing tools.

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