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ORIGINAL RESEARCH ARTICLE

Ranking and efficiency of the highest-quality biomedical universities

ANNALISA ROSSO[1*], CECILIA ACUTI MARTELLUCCI[2*], GIOVANNI CIONI[3], MARCO TISEO[3], GIOVANNA LETIZIA CALÒ[3], MATTEO FIORE[2], ENRICO ZAULI[4], MARIA ELENA FLACCO[3], LAMBERTO MANZOLI[2,3]

[1]*Department of Public Health and Infectious Diseases, Sapienza University of Rome, Rome, Italy;* [2]*Department of Medical and Surgical Sciences, School of Public Health, University of Bologna, Bologna, Italy;* [3]*Department of Environmental and Prevention Sciences, School of Public Health, University of Ferrara, Ferrara, Italy;* [4]*Department of Translational Medicine, University of Ferrara, Ferrara, Italy.*
*These authors contributed equally to this work

ABSTRACT

Background: Academic rankings may influence student enrolment, faculty recruitment, and funding opportunities, however their methodology is often criticized, primarily because it disregards financial efficiency.
Methods: We analyzed the best 100 biomedical universities in three recognized international rankings (Times Higher Education, Quacquarelli-Symonds, and Shanghai), to investigate the association between expenditure and performance. Times, Q-S and SH overall quality scores, specific sub-scores, operating expenditures, and total students' number were extracted from official websites. A global quality score was computed as weighted mean of the three scores, and a composite efficiency score was calculated dividing the average annual expenditure per student by the global quality score.
Results: Despite a general alignment, the three rankings showed several discrepancies, highlighting the potential role of a composite quality score, which showed high internal validity and reliability. Sixteen of the 20 top academies were located in USA (n=12) or UK, but the median expense per student of USA universities (183,100 USD) was more than five times larger than the European, Australian (both 28,100 USD), or Canadian (25,000 USD) centers, which showed the best efficiency scores. Indeed, greater funding was significantly associated with a higher global quality score, as well as Times, SH, Q-S scores, and most sub-scores.
Discussion and Conclusions: Considering the steep differences in funding that were detected between top-ranking universities and those just below the top 40, the proposed measure of efficiency may serve as a complementary metric to recognize and reward the academies that are able to maximize resources, still delivering high-quality education.

Key words: medical education, university rankings, world universities, academic financial efficiency.

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Correspondence: Lamberto Manzoli, MD, MPH / Department of Medical and Surgical Sciences, School of Public Health, University of Bologna, Bologna, Italy; Department of Environmental and Prevention Sciences, School of Public Health, University of Ferrara, Ferrara, Italy / Via S. Giacomo 12, 40126 Bologna, Italy / E-mail: lmanzoli@post.harvard.edu
ORCID: 0000-0002-8129-9344

Introduction

Although university rankings methodology and potential impact have been questioned (1-5), the academic rankings have increasingly become a relevant measure of institutional prestige, influencing student enrolment, faculty recruitment, and funding opportunities (6-7). Among the factors that contribute to the quality of academic teaching and research, resources availability and financial management may play a pivotal role (8-9). Academic operational expenditure, which encompasses spending on instruction, research, academic support, and library services, is often viewed as a reflection of an institution's commitment to academic excellence (10). However, the extent to which such expenditures correlate with, or influence quality rankings, is debated. Some studies suggest a strong positive correlation, where increased investment improves institutional visibility and performance metrics (11-12), while others emphasize the role of spending efficiency and strategic allocation over expenditure volume (9). We extracted and analyzed the main funding information of the 100 biomedical universities with the best scores in three recognized International rankings, with the following objectives: (i) to assess the degree of consistency among three major international biomedical university rankings; (ii) to explore the use of a composite quality score based on a weighted combination of these rankings; and (iii) to propose and analyze an efficiency metric that relates institutional performance to per-student expenditure.

Methods

To obtain a proxy of the global quality of the biomedical universities, we combined the results of the following three International, widely recognized academic quality rankings, for the year 2024 (the last year available at the time of data extraction): (1) Times Higher Education World University Rankings, subject "Medicine and Dentistry" (Times) (13); (2) Quacquarelli Symonds World University Ranking, subject "Medicine" (Q-S) (14); and (3) Shanghai Ranking – Global Ranking of Academic Subjects, subject "Clinical Medicine" (SH) (15). These are the longest established and most widely cited rankings and were selected for our analysis for ensuring both global representativeness and comparable measures (they all provide rankings mostly based on research criteria) (1, 16). The three international ranking systems included in the analysis assess academic performance across different domains, with a predominant focus on research-related indicators. Specifically, Times evaluates institutions using weighted measures of research output and impact, research environment, teaching-related proxies (such as student-to-staff ratios and reputation surveys), international outlook, and industry engagement. The Q-S ranking primarily relies on academic reputation, citation impact (H-index), and selected internationalization indicators, with limited direct assessment of teaching quality. SH is almost exclusively research-oriented, emphasizing high-impact scientific output, highly cited researchers, and publication performance. The quality of education depends on the rate of alumni and Faculty winning Nobel Prizes and Fields Medals. We focused on biomedical universities because this is our context of research, and extracted all the biomedical academies that were listed among the best 100 in at least one of the three rankings. From the initial list, only the academies that were included in at least two of the rankings, regardless of the position, were included in the final sample.

For each university, the following data were extracted:

- Times, Q-S and SH overall quality scores
- sub-scores measuring teaching (Times); research environment (Times); research quality (Times and SH) / H-Index (Q-S); international outlook (Times) / academic reputation (Q-S); and industry engagement (Times);
- total operating expenditures and total number of students (both full time or not), extracted from official websites and/or reports (the exact web pages or documents are available from the authors). As the quality scores of the year 2024 were based on 2022 data, expense and student's data are referred to that year, and all monetary values were converted to USD using the average exchange rate for the year 2022. If the data of the year 2022 were not available, the data of the

following year were extracted. Based on information provided on official university websites, operating expenses encompass staff salaries and expenditures for facilities, infrastructure, supplies, and services necessary to support institutional academic and research functions. A composite global quality score was then computed as a weighted mean of the three overall scores: since the maximum score of both Times and Q-S rankings was 100, while the highest score of the SH ranking was 375.8, we divided SH scores by 3.75, then simply summed the three scores and divided by three (or two, for the universities that were included only in two of the rankings).

The SH and Q-S ranking systems do not attribute an overall score to the universities that are listed below the top 50 and 200, respectively, and proxy scores for both rankings were necessary for the computation of the global quality score. For the universities that were ranked below the 50th position in the SH ranking, we proceeded as follows: to obtain a proxy of the potential score of the universities ranked 51st to 75th, we computed the difference in the scores of the university ranked 26th (204.2) and the one ranked 50th (174.6). This number (29.6) was then split to obtain a proxy of the average difference between a center ranked 25 positions above another. Thus, the universities in the positions 51-75 were assigned the score of the 50th academy (174.6), subtracted by 14.8 (159.8). The same method was applied to the universities that were positioned below, and the academies ranked 76th to 100th were assigned a SH overall score of 145 (resulting from 159.8-14.8). To align with the SH choice of grouping 50 universities after the 100th place, and account for the typical reduction in the score differences in the lower positions of the rankings, we assigned a 14.8 points reduction every 50 academies, as follows:

- the universities classified 101-150 were assigned a score of 130.2 (resulting from 145-14.8);
- those ranked 151-200 were assigned a score of 115.4;
- those ranked 201-300 were assigned a score of 100.6.

For the universities that were ranked below the 200th position in the Q-S ranking, we proceeded as follows: to obtain a proxy of the potential score of the universities ranked 201st to 250th, we computed the difference in the scores of the university ranked 150th (68.54) and the one ranked 200th (66.17). This number (2.4) was then split to obtain a proxy of the average difference between a center ranked 50 positions above another. Thus, the universities in the positions 201-250 were assigned the score of the 200th academy (66.2), subtracted by 1.2 (65.0). The same method was applied to the universities that were positioned below, and the academies ranked 251st to 300th were assigned a Q-S overall score of 63.8 (resulting from 65.0-1.2). To account for the reduction in the score differences in the lower positions of the rankings, we assigned a 1.2 points reduction every 50 academies, as follows:

- the universities classified 301-350 were assigned a score of 62.6 (resulting from 63.8-1.2);
- those ranked 351-400 were assigned a score of 61.4;
- those ranked 401-500 were assigned a score of 60.2.

The composite score of efficiency of each academy was computed dividing the average annual expenditure per student by the global quality score, thus obtaining the amount of money that each university spends to achieve a point of the global mixed quality score, per each student.

The correlations between each quality score or sub-score, and between the global quality score, the efficiency score, and the total number of students were all investigated using Spearman's rank test. All analyses were performed using Stata version 13 (Stata Corp., College Station, Texas, 2013).

Results

Elite academies and correlation among the quality scores

Overall, 147 universities were ranked among the best 100 in at least one of the three selected International biomedical rankings. Only one academy had to be excluded, because it was included in any position in only one of the standings, leaving a final group of 146 universities (Figure 1). The most represented countries were USA (50 universities, 33.6% of the pool), UK (n=19; 12.8%), Germany (n=9), Australia and Canada (n=8 each), and The Netherlands (n=7). The list of the 50 universities with the highest composite global quality score have been reported in Table 1. There was a high degree of consistency across the grading systems, with 58 academies that were in the top 100 in all three rankings (Figure 1), and a high correlation among the three overall quality scores, as well as among the composite global quality score and the specific sub-scores, with the partial exception of the Times industry engagement and Times International outlook scores (Table 2). The degree of agreement among the rankings was highest in the top positions, with 17 universities listed among the best 30 in each of the evaluation systems (Table 3), but there were also several important discrepancies: 7 of the best 50 academies, according to the composite global score, were not even listed in one of the rankings, and 37 centers were listed more than 50 places higher or lower in one ranking vs. another (Table S1). The most notable discrepancies were the University of California, San Francisco and the ETH Zurich, which were in the top 10 overall, but were not listed in one evaluation system. Besides the discrepancies across rankings, a very large variability of the overall scores was observed, with the highest global score being 99.0 (Harvard University), and the lowest score of 146th best academy in the World being as low as 48.3.

Per-student expenditure and correlation with quality

The mean USD per student available for each of the top 50 academies has been reported in Table 1. The available resources ranged widely: the median amount of money per student of the 20 universities with less resources was more than 30 times lower than the funds available to the 20 wealthiest academies (11,642 USD vs. 375,422 USD, respectively). Within-country variability was large, with academies from the same country spending ≥10 times than others, but the differences were even larger across countries: 19 of the 20 richest academies were located in the USA, and the median expense per student of USA universities was more than twice the median of Asian academies (183,100 USD vs. 68,900 USD, respectively), and ≥4 times larger than

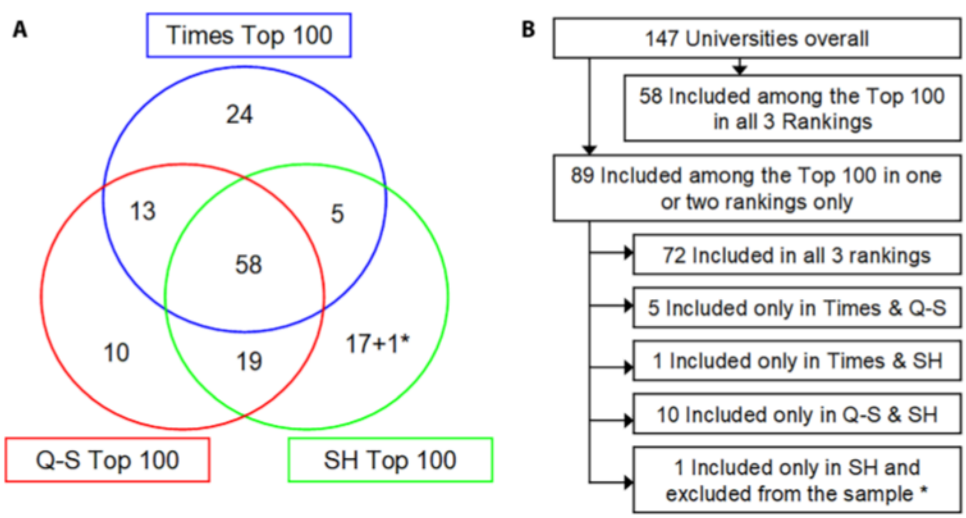

Figure 1. (A-B) Selection process and overlapping of the universities listed among the top 100 in at least one of the three selected University evaluation ranking systems *

* (1) Times Higher Education World University Rankings, subject "Medicine and Dentistry", 2024, overall score (Times); (2) Quacquarelli Symonds World University Ranking, subject "Medicine", 2024, overall score (Q-S); and (3) Shanghai Ranking – Global Ranking of Academic Subjects, subject "Clinical Medicine", 2024, overall score (SH).

Table 1. List of the top 50 universities according to the composite global quality score *.

	University	Country	Global score *	Times	Q-S	SH	USD x student†
1	Harvard University	USA	99.0	97.8	99.1	375.8	177
2	University of Oxford	UK	93.2	98.5	95.4	322.0	123
3	University of California, San Francisco	USA	92.3	N.I.	88.6	361.0	1629
4	University of Pennsylvania	USA	90.9	91.0	87.1	355.8	172
5	Johns Hopkins University	USA	87.9	91.1	92.0	303.3	228
6	University of Cambridge	UK	87.2	97.5	91.6	273.0	114
7	Imperial College London	UK	86.7	95.1	89.6	283.8	75
8	University of California, Los Angeles	USA	85.9	90.1	88.0	299.6	226
9	ETH Zurich	Switzerland	84.9	93.1	76.7	N.I.	79
10	Stanford University	USA	81.9	98.0	92.0	209.6	335
11	Duke University	USA	81.5	83.9	85.2	283.6	249
12	UCL (University College London)	UK	80.5	88.1	89.9	238.1	52
13	University of Toronto	Canada	79.2	88.6	87.6	231.2	26
14	Univ. of Texas M. D. Anderson Cancer Center	USA	78.8	N.I.	76.3	305.2	1,105
15	University of Melbourne	Australia	78.5	79.2	84.0	272.1	37
16	Yale University	USA	78.4	94.2	88.4	197.3	307
17	University of Washington	USA	78.2	85.3	83.7	246.6	111
18	Columbia University	USA	77.5	90.9	87.3	204.2	149
19	Massachusetts Institute of Technology	USA	75.7	N.I.	88.3	237.5	319
20	The Chinese University of Hong Kong	Hong Kong	74.9	75.4	82.1	252.5	53
21	University of Michigan-Ann Arbor	USA	74.8	87.4	82.8	203.9	84
22	Heidelberg University	Germany	74.4	76.7	81.4	245.2	16
23	University of California, San Diego	USA	74.3	81.0	83.1	220.7	174
24	University of Chicago	USA	73.8	92.1	81.0	181.7	309
25	King's College London	UK	73.8	79.0	87.9	204.7	48
26	Cornell University	USA	73.3	89.5	81.4	183.8	189
27	Emory University	USA	73.0	66.1	78.7	279.1	538
28	Karolinska Institute	Sweden	72.0	75.9	89.7	189.1	118
29	National University of Singapore	Singapore	70.9	90.0	84.0	145.0	62
30	Northwestern University	USA	70.5	83.2	78.6	187.3	119
31	University of Edinburgh	UK	69.5	82.5	83.5	159.8	29
32	KU Leuven	Belgium	69.2	77.0	81.3	185.5	20
33	Peking University	China	69.1	91.8	80.8	130.2	76
34	New York University	USA	69.0	83.5	81.0	159.8	64
35	University of Sydney	Australia	68.9	73.8	82.6	189.5	26
36	University of Amsterdam	Netherlands	68.9	73.6	82.0	192.4	23
37	University of Pittsburgh	USA	68.3	62.5	76.9	246.3	77
38	University of British Columbia	Canada	67.6	78.0	82.3	159.8	27
39	McGill University	Canada	67.5	76.0	84.0	159.8	18

Table 1 (*Continued*)

	University	Country	Global score *	Times	Q-S	SH	USD x student†
40	Washington University in St Louis	USA	67.3	72.3	79.6	188.0	240
41	University of Munich - LMU	Germany	67.3	79.0	80.3	159.8	16
42	Korea Advanced Institute of Science & Tech	S. Korea	67.1	69.2	65.0	N.I.	65
43	Lomonosov Moscow State University	Russian Fed.	66.0	67.0	65.0	N.I.	16
44	Monash University	Australia	66.0	75.2	80.2	159.8	28
45	University of North Carolina at Chapel Hill	USA	65.7	71.2	79.3	174.6	105
46	Purdue University West Lafayette	USA	65.6	68.5	62.6	N.I.	43
47	Tsinghua University	China	65.3	92.4	76.7	100.6	95
48	University of Manchester	UK	65.2	75.6	81.5	145.0	33
49	University of Hong Kong	Hong Kong	65.2	80.3	80.7	130.2	44
50	Seoul National University	S. Korea	65.0	73.4	79.2	159.8	121

*The global quality score is the weighted average of the three quality scores: (1) Times Higher Education World University Rankings, subject "Medicine and Dentistry", 2024, overall score (Times); (2) Quacquarelli Symonds World University Ranking, subject "Medicine", 2024, overall score (Q-S); and (3) Shanghai Ranking – Global Ranking of Academic Subjects, subject "Clinical Medicine", 2024, overall score (SH). Higher scores correspond to higher quality. N.I.: Not included in the ranking. † Values must be multiplied by 1000, and correspond to the ratio between year 2022 operating expenses and the overall number of students. All currencies have been converted to USD (see text for details).

Table 2. Correlation (Spearman's rho) matrix of the global quality score and overall and sub-scores of the selected three university evaluation ranking systems *.

	Global score	Times overall	Q-S overall	SH overall	Times - Teaching	Times - Res. env. [A]	Times -Res. qual. [B]	Times - Ind. eng. [C]	Times - Int. outl. [D]	Q-S - Acad. rep. [E]	Q-S - H index
Times overall	0.79										
Q-S overall	0.78	0.65									
SH overall	0.72	0.26	0.54								
Times – Teaching	0.68	0.89	0.51	0.18							
Times - Res. env. [A]	0.69	0.94	0.57	0.14*	0.91						
Times - Res. qual. [B]	0.60	0.46	0.57	0.57	0.21	0.26					
Times - Ind. eng. [C]	0.31	0.38	0.15	0.01*	0.31	0.40	-0.06*				
Times - Int. outl. [D]	0.37	0.30	0.36	0.25	-0.01*	0.17	0.49	-0.01*			
Q-S - Acad. rep. [E]	0.74	0.66	0.94	0.45	0.57	0.62	0.49	0.24	0.27		
Q-S - H index	0.67	0.44	0.74	0.76	0.32	0.31	0.56	0.02*	0.21	0.55	
SH - Res. qual. [F]	0.66	0.40	0.62	0.68	0.33	0.31	0.43	0.16	0.04*	0.55	0.79

* The global quality score is the weighted average of the three quality scores: (1) Times Higher Education World University Rankings, subject "Medicine and Dentistry", 2024, overall score (Times); (2) Quacquarelli Symonds World University Ranking, subject "Medicine", 2024, overall score (Q-S); and (3) Shanghai Ranking – Global Ranking of Academic Subjects, subject "Clinical Medicine", 2024, overall score (SH). Higher scores correspond to higher quality. [A] Times Research Environment sub-score; [B] Times Research quality sub-score; [C] Times Industry engagement sub-score; [D] Times International outlook sub-score; [E] Q-S Academic Reputation sub-score; [F] SH High quality research output sub-score; * p-value>0.05.

all other countries or continents (Figure 2). Although the median global quality score did not differ substantially by continent, a significant, positive correlation was found between per-student expenditure and the composite global quality score, as well as Times overall and most sub-scores, SH scores, and Q-S sub-scores (Table 4). Indeed, among the 17 universities that were rated best in all rankings, only the University of Toronto and the University of Melbourne were able to achieve this level of excellence spending less than 50,000 USD per student (Table 3).

Efficiency and size

Given the wide variability of resources available, and that more resources could provide a substantial advantage in achieving a higher quality, it would be important to develop a proxy of the ability of each academy to obtain quality points using less resources per student. An efficiency score was thus created, dividing the mean expense per student by the global quality score of each university, and the list of the 50 most efficient academies has been reported in Table 5. Of these centers, which were able to achieve a point of the global score using less than 500 USD per student, 33 were located in Europe, and 7 (each) were located in Germany and The Netherlands; 6 (each) in Australia and Canada, and none in USA. Similar to the expense per student, the efficiency score varied widely by country: the median of USA universities was 2,586 USD, much higher than the UK (646 USD), Australian (439 USD), other European (397 USD) or Canadian (356 USD) academies. Of the 17 universities with the highest global quality score (Table 3), only four were able to obtain a point of the global quality score spending less than 1,000 USD per student (the Universities of Toronto and Melbourne, and the University College and Imperial College of London). The number of students largely differed across the selected academies, ranging from less than 5,000 students, up to more than 100,000. The three largest universities were among the most efficient ones: Sapienza University of Rome (n=117,000), the University of Bologna (n=93,800) and the University of Sao Paulo (n=97,200). However, size was not significantly correlated with any of the quality scores, with the exception of the overall SH score and the Times Research Quality sub-score (Table 4). In both cases, a larger number of students was associated with a lower quality (both p<0.001).

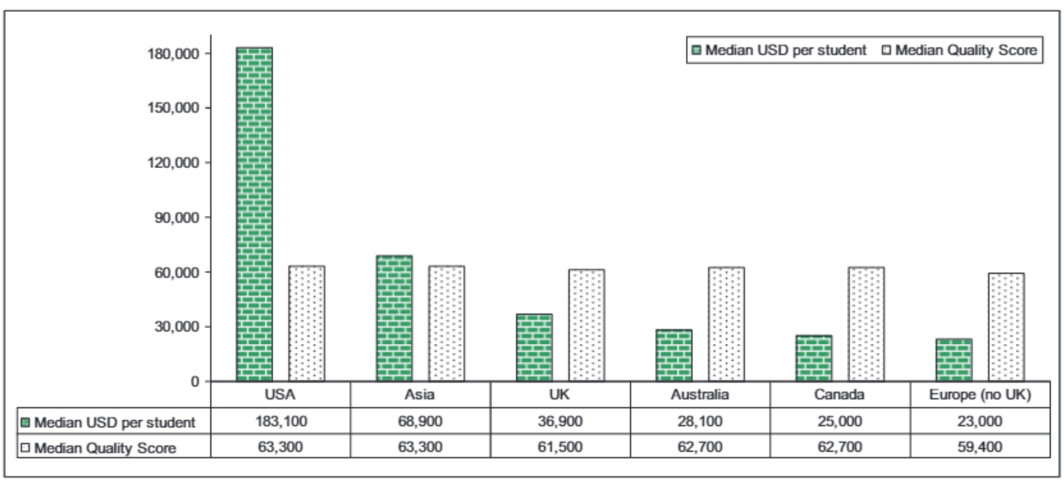

Figure 2. Median resources available per student (USD) and median global quality score *, by site. For graphical purposes, all quality scores have been multiplied by 1000.

* The global quality score is the weighted average of the following three quality scores: (1) Times Higher Education World University Rankings, subject "Medicine and Dentistry", 2024, overall score (Times); (2) Quacquarelli Symonds World University Ranking, subject "Medicine", 2024, overall score (Q-S); and (3) Shanghai Ranking – Global Ranking of Academic Subjects, subject "Clinical Medicine", 2024, overall score (SH). Higher scores correspond to higher quality.

Table 3. List of the 17 Universities ranked in the top 30 positions across all of the three selected evaluation systems *.

	University	Country	Global score *	Times	Q-S	SH	USD x student**	Efficiency Score†
1	Harvard University	USA	99.0	97.8	99.1	375.8	177	1791
2	University of Oxford	UK	93.2	98.5	95.4	322.0	123	1318
4	University of Pennsylvania	USA	90.9	91.0	87.1	355.8	172	1897
5	Johns Hopkins University	USA	87.9	91.1	92.0	303.3	228	2595
6	University of Cambridge	UK	87.2	97.5	91.6	273.0	114	1310
7	Imperial College London	UK	86.7	95.1	89.6	283.8	75	865
8	University of California, Los Angeles	USA	85.9	90.1	88.0	299.6	226	2631
10	Stanford University	USA	81.9	98.0	92.0	209.6	335	4093
11	Duke University	USA	81.5	83.9	85.2	283.6	249	3060
12	UCL (University College London)	UK	80.5	88.1	89.9	238.1	52	646
13	University of Toronto	Canada	79.2	88.6	87.6	231.2	26	333
15	University of Melbourne	Australia	78.5	79.2	84.0	272.1	37	475
16	Yale University	USA	78.4	94.2	88.4	197.3	307	3921
17	University of Washington	USA	78.2	85.3	83.7	246.6	111	1423
18	Columbia University	USA	77.5	90.9	87.3	204.2	149	1928
21	University of Michigan-Ann Arbor	USA	74.8	87.4	82.8	203.9	84	1128
23	University of California, San Diego	USA	74.3	81.0	83.1	220.7	174	2354

* The global quality score is the weighted average of the following three quality scores: (1) Times Higher Education World University Rankings, subject "Medicine and Dentistry", 2024, overall score (Times); (2) Quacquarelli Symonds World University Ranking, subject "Medicine", 2024, overall score (Q-S); and (3) Shanghai Ranking – Global Ranking of Academic Subjects, subject "Clinical Medicine", 2024, overall score (SH). Higher scores correspond to higher quality.

** Values must be multiplied by 1000 and correspond to the ratio between year 2022 operating expenses and the overall number of students. All currencies have been converted to USD (see text for details).

† The Efficiency score was computed as the ratio between the expenditure per-student (converted to U.S.D. using the average exchange rate for the year 2022) and the global mixed quality score. It reflects the amount of money the universities spend to obtain a point of the global mixed quality score, per student. A lower score corresponds to higher efficiency.

Table 4. Correlation (Spearman's rho) between per-student expenditure, number of students and: global quality score; Times, Q-S, and SH overall and sub-scores *.

		Per-student expenditure		N. of students	
Variables	N. of Universities**	rho	p	rho	P
A. Global mixed quality score	146	0.27	<0.001	-0.05	0.590
B. Times overall score	136	0.34	<0.001	0.05	0.575
Sub-scores:					
• Teaching		0.38	<0.001	0.09	0.281
• Research environment		0.25	0.003	0.17	0.049

		Per-student expenditure		N. of students	
Variables	N. of Universities**	rho	p	rho	P
• Research quality		0.29	<0.001	-0.30	<0.001
• Industry engagement		0.08	0.379	-0.02	0.834
• International outlook		-0.18	0.036	-0.10	0.243
C. Q-S overall score	145	0.14	0.090	0.02	0.816
Sub-scores:					
• Academic reputation		0.20	0.018	-0.07	0.396
• H-Index citations		0.27	0.001	-0.00	0.992
D. SH overall score	141	0.28	<0.001	-0.18	0.030
Sub-score:					
• High quality research output		0.28	<0.001	-0.02	0.788

* The global quality score is the weighted average of the following three quality scores: (1) Times Higher Education World University Rankings, subject "Medicine and Dentistry", 2024, overall score (Times); (2) Quacquarelli Symonds World University Ranking, subject "Medicine", 2024, overall score (Q-S); and (3) Shanghai Ranking – Global Ranking of Academic Subjects, subject "Clinical Medicine", 2024, overall score (SH). Higher scores correspond to higher quality.
** The numbers vary because a few universities were included only in two of the three rankings.

Table 5. List of the top 50 universities according to the efficiency score (expressed in USD per each quality point per student).

	University	Country	Efficiency score [A]	Global quality score [B]
1	Sapienza University of Rome	Italy	128	56.0
2	University of Barcelona	Spain	134	61.1
3	Yonsei University (Seoul campus)	S. Korea	150	60.1
4	Université Grenoble Alpes	France	159	55.0
5	University of Bologna	Italy	169	56.7
6	University of Milan	Italy	171	55.8
7	University of Montréal	Canada	172	59.9
8	Paris-Saclay University	France	194	63.1
9	Université Paris Cité	France	196	59.2
10	RWTH Aachen University	Germany	208	53.7
11	Heidelberg University	Germany	215	74.4
12	University of São Paulo	Brazil	215	58.4
13	Queen Mary University of London	UK	230	60.9
14	Lomonosov Moscow State University	Russian Fed.	236	66.0

Table 5 (*Continued*)

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	University	Country	Efficiency score [A]	Global quality score [B]
15	University of Munich - LMU	Germany	238	67.3
16	Pontifical Catholic University of Chile	Chile	238	49.2
17	Uppsala University	Sweden	244	56.7
18	McGill University	Canada	271	67.5
19	University of Tuebingen	Germany	278	57.4
20	University of Cape Town	South Africa	282	56.3
21	KU Leuven	Belgium	290	69.2
22	University of Toronto	Canada	333	79.2
23	University of Amsterdam	Netherlands	334	68.9
24	University of Ottawa	Canada	343	58.0
25	McMaster University	Canada	364	64.7
26	Vrije Universiteit Amsterdam	Netherlands	366	59.0
27	Un. Bonn (Rheinische Friedrich-Wilhelms)	Germany	369	60.5
28	University of Goettingen	Germany	380	53.6
29	University of Hamburg	Germany	381	57.5
30	University of Sydney	Australia	382	68.9
31	Vita-Salute San Raffaele University	Italy	394	52.6
32	Leiden University	Netherlands	398	63.1
33	Maastricht University	Netherlands	398	58.9
34	University of British Columbia	Canada	399	67.6
35	Trinity College Dublin, University of Dublin	Ireland	401	56.3
36	Erasmus University Rotterdam	Netherlands	403	63.1
37	University of Adelaide	Australia	403	57.0
38	University of Leicester	UK	410	60.3
39	Univ. of New South Wales (UNSW Sydney)	Australia	415	63.1
40	Monash University	Australia	418	66.0
41	University of Edinburgh	UK	418	69.5
42	University of Groningen	Netherlands	420	62.3
43	University of Queensland	Australia	459	62.3
44	Newcastle University	UK	470	56.6
45	Utrecht University	Netherlands	474	59.8
46	University of Melbourne	Australia	475	78.5
47	University of Birmingham	UK	478	60.3
48	University of Helsinki	Finland	479	57.2
49	University of Nottingham	UK	486	61.9
50	University of Manchester	UK	506	65.2

[A] The Efficiency score was computed as the ratio between the expenditure per-student (converted to U.S.D. using the average exchange rate for the year 2022) and the global mixed quality score. It reflects the amount of money the universities spend to obtain a point of the global mixed quality score, per student. A lower score corresponds to higher efficiency.
[B] The global quality score is the weighted average of the following three quality scores: (1) Times Higher Education World University Rankings, subject "Medicine and Dentistry", 2024, overall score (Times); (2) Quacquarelli Symonds World University Ranking, subject "Medicine", 2024, overall score (Q-S); and (3) Shanghai Ranking – Global Ranking of Academic Subjects, subject "Clinical Medicine", 2024, overall score (SH). Higher scores correspond to higher quality.

Discussion

We extracted the rankings of the best 100 biomedical universities according to three of the most influential International university ranking systems, in order to (1) determine the level of agreement between these ranking systems and explore the potential of a composite score; (2) evaluate the relationship between university quality and expenditure, investigating whether top-quality performance can be achieved exclusively with large resources, and eventually proposing a score to estimate (and reward) academics efficiency in addition to effectiveness; finally (3) explore the potential correlation between university quality and size (in terms of number of students). The analysis was exploratory and aimed to provide complementary descriptive insights alongside existing causal and efficiency-modelling approaches. Despite differing methodologies, the selected International rankings capture similar dimensions of academic performance, especially related to research output (1, 11, 17). Expectedly, the degree of alignment among the three rankings was high, particularly at the top of the distribution, with many biomedical academies listed among the elite centers in each of three systems. Notably, however, discrepancies were also common, and several academies, including top universities, were not even listed in one of the three rankings. These inconsistencies highlight the limitations of relying on any single ranking as a definitive measure of institutional quality and could be addressed by the use of a simple composite quality score, which showed a high internal validity and reliability, being highly correlated with almost all specific quality sub-scores. The composite score may effectively solve some of the vulnerabilities identified by Johnes and others (1-5); it should be interpreted as a pragmatic synthesis of existing ranking systems, designed to reduce ranking-specific variability rather than to replace individual rankings or claim superior validity. Notably, the three international ranking systems examined primarily reflect research-oriented metrics, such as scientific output, citation impact, and academic reputation, while providing limited insight into teaching quality, clinical excellence, or broader societal missions. Accordingly, these classifications should not be interpreted as comprehensive evaluations of universities, but rather as comparative tools focused on research-intensive biomedical performance. This distinction is particularly relevant for institutional comparability. The biomedical universities included differ substantially in institutional mission, governance, size, clinical integration, and national higher-education contexts. By emphasizing research performance and privileging élite, research-intensive institutions and international rankings may disadvantage universities with a stronger focus on teaching and community engagement, with downstream effects on institutional diversity and student choice (1). Consistent with the literature (18-19), we observed a very large variation in the average amount of resources available per student across institutions, but the vast majority of the top universities had very large funds. Indeed, there was a significant, positive correlation between per-student expenditure and institutional quality, confirming previous analyses that documented an association between funding levels and improved research capacity, student outcomes, and academic prestige (8, 12). In fact, several authors have argued that global rankings essentially measure levels of wealth and investment in higher education (6, 17), with Benito et al, stressing that public funding explains about 51% of the variance in Q-S World Ranking positions for the top 300 universities (8). Also, most of the top-ranking Institutions across all systems are based in the USA, reflecting the fact that well-funded U.S. institutions produce more publications and citations than typically less-funded European ones (20). Given the association between quality and available resources, it is problematic to directly compare the performance of centers that can spend 20 times more than others, with no adjustment, and it would be valuable to recognize, and eventually reward, the academies that were able to most efficiently manage the available resources. Although the overall quality – the effectiveness – remains the primary outcome, it is important to evaluate also how the academies are managed, and whether some are able to deliver high-quality education even when the available resources are scarce (1). A simple efficiency score, adjusted for the institutional size, allowed the identification of the most efficient centers, and may serve as a complementary metric that can inform funding decisions, strategic planning, and policy evaluation, particularly in contexts with limited resources, where the evaluation of quality, based only on scientific and academic outputs, is inevitably restrictive (12). The efficiency score is intended to describe the relationship between overall institutional resources, size, and ranking-based performance, and should not be interpreted as a measure of resources allocated to individual students. It should not be interpreted as a direct measure of management quality or institutional merit, but as a comparative indicator that makes visible the scale of resource disparities underlying apparently similar ranking positions. Clearly, the recognition of the most efficient centers cannot replace nor diminish the exceptional value of the executive work needed to achieve top quality scores. As an example, many of the very élite universities were located in the USA, but USA academies overall did not show a higher quality than the rest of the World, in spite of a far higher average of resources available, highlighting the complexity of achieving élite performance even for wealthy centers, and implying that regardless of the funding available, the very best centers, both in the USA and worldwide, are outstandingly administered. As suggested previously, a small number of students may help a university to maintain a focused academic strategy and excel in research-intensive, reputation-based metrics (21). Although we did not observe an association between student population size and biomedical university quality rankings, with some very large academies that were still able to achieve high scores, further research is definitely required to confirm this finding, since most of the élite centers have relatively small student bodies, and the lack of correlation may reflect the fact that many indicators used in global rankings are size-independent (21), rather than a true absence of effect of size. We found that not all ranking components contributed equally to the composite score: the Times International Outlook sub-score, in particular, displayed the weakest associations with the global mixed quality score and with nearly all other overall sub-scores. This finding is in line with previous criticisms towards indicators measuring International staff or student ratios – which typically drive the International Outlook score – as they may reflect geopolitical or linguistic advantages, rather than true academic excellence (1-2). This study has some limitations that must be considered in interpreting the results. First, funding may be proportional to a country's Gross National Income (GNI), and also to the cost of living in specific cities, therefore the academies located in nations with high price levels may require more resources just to afford higher salaries and maintenance costs. In fact, most of the countries hosting the universities included in this analysis presented a fairly similar per capita GNI (compared in Purchasing Power Parity in year 2022) (22). However, the extremely good results of some academies from Mediterranean countries, which hosted seven of the ten most efficient centers, should be interpreted with caution, as the per capita GNI of these nations is substantially lower than most of the other countries that host top universities (23). Second, the analysis relies on publicly available data from university websites and official reports, which may vary in accuracy and completeness across institutions. This is especially important when considering the funding data: standardized estimates of university financing are only available as nationally-aggregated figures (24). Indeed, the ranking systems, including and beyond those examined in this paper, compute numerous indicators consistently across universities, except for funding, outlining the need for a standardized assessment of this crucial aspect of higher education. In any case, besides the fact that these are published, official data, we tried to contact all the listed academies, requesting for confirmation or, eventually, revision of our data. Unfortunately, we received a response only from 20 centers, 15 of which confirmed our data, and four made minor corrections (±5%). As per expenditure data, differences in national accounting frameworks may affect the comparability and should be considered when interpreting the efficiency score. Third, the cross-sectional design limits the ability to draw causal inferences between expenditure, size, and performance; longitudinal studies would be necessary to examine temporal trends and causal mechanisms. Fourth, while the composite global quality score provides a broader picture than any single ranking, it is still dependent on the inherent flaws of the ranking systems: these include an overemphasis on research output, the reliance on "reputation surveys" as a proxy for teaching quality, and the limited set of indicators – some of which are chosen primarily for their availability rather than their relevance or validity (2, 25). Finally, we opted to compute the composite quality score assigning an equal weight to the three rankings, while alternative weighting strategies might have explored, for example by assigning weights based on domain relevance or external validation criteria. However, in the absence of a gold-standard, or external criteria to justify differential weighting across ranking systems, assigning equal weight, reduces the degree of subjectivity and allows the composite score to represent a balanced synthesis of three widely recognized and independent evaluations, without privileging any single methodological approach; however, such approaches would require normative assumptions that go beyond the scope of the present study. In conclusion, despite a high degree of alignment among three of the major International University rankings, there were some relevant discrepancies that could be reduced by the use of a composite quality score, which may provide a more balanced and reliable estimate of academic performance. As we found a significant, positive correlation between per-student expenditure and institutional quality, with most of the top biomedical universities spending 5 to 10 times more than most of the academies ranked below the top 40, the addition of a measure of universities efficiency could be very valuable. A simple score was computed, that may serve as a complementary metric that can help recognize and reward the academies that are able to maximize the available resources, still delivering high-quality education. Finally, further research is needed to confirm the lack of association between the number of students and the overall quality.

Ethic Approval: not required, since only publicly available, aggregated data, were used and no human subjects were involved

Conflict of Interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

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Annex

Table S1. List of the 37 universities with at least one large discrepancy (±50 positions or more; or absence in one ranking) among the selected three international rankings *.

University	Country	Times	Q-S	SH
University of California, San Francisco	USA	N.I.	9	2
ETH Zurich	Switzerland	7	61	N.I.
Univ. of Texas M. D. Anderson Cancer Center	USA	N.I.	66	5
Massachusetts Institute of Technology	USA	N.I.	11	19
Emory University	USA	87	50	10
University of Pittsburgh	USA	111	59	16
Korea Advanced Institute of Science & Tech	S. Korea	68	133	N.I.
Lomonosov Moscow State University	Russian Fed.	78	138	N.I.
Purdue University West Lafayette	USA	71	145	N.I.
City University of Hong Kong	Hong Kong	67	147	N.I.
Mayo Clinic College of Medicine and Science	USA	N.I.	71	30
Icahn School of Medicine at Mount Sinai	USA	N.I.	93	28
Ohio State University (Main Campus)	USA	81	102	45
Oregon Health and Science University	USA	133	137	13
University of Nottingham	UK	103	90	42
University of Barcelona	Spain	113	48	56
University of Western Australia	Australia	110	119	34
London School of Hygiene & Tropical Medicine	UK	N.I.	24	100
Univ. of Bonn (Rheinische Friedrich-Wilhelms)	Germany	74	127	51
University of Leicester	UK	129	140	22
Utrecht University	Netherlands	N.I.	58	53
Université Paris Cité	France	112	N.I.	23
University of Rochester	USA	104	139	44
Medical University of Vienna	Austria	128	60	71
Rockefeller University	USA	N.I.	124	38
University of São Paulo	Brazil	126	53	82
University of Ottawa	Canada	121	112	60
University of Virginia	USA	117	132	49
University of Calgary	Canada	125	101	69
Univ. Texas Southwestern Med. Center Dallas	USA	N.I.	106	54
University of Utah	USA	124	144	39
University of Milan	Italy	134	80	76
Université Grenoble Alpes	France	132	143	40
Baylor College of Medicine	USA	139	44	58
Univ. Texas Health Science Center at Houston	USA	N.I.	128	98
University	Italy	130	141	80
University of Alabama, Birmingham	USA	138	129	84

* (1) Times Higher Education World University Rankings, subject "Medicine and Dentistry", 2024, overall score (Times); (2) Quacquarelli Symonds World University Ranking, subject "Medicine", 2024, overall score (Q-S); and (3) Shanghai Ranking – Global Ranking of Academic Subjects, subject "Clinical Medicine", 2024, overall score (SH). The numbers in the table are referred to the positions in the rankings, where 1 is the best (first one) and 146 is the last. N.I.: Not included in the ranking.