

Does Scientific Productivity Influence Athletic Performance? An Analysis of Countries' Performances in Sciences, Sport Sciences and Olympic Games

H. Sotudeh, Ph.D.

Shiraz University, I. R. of Iran

Corresponding Author: sotudeh@shirazu.ac.ir

M. Salehi, Ph.D.

Shiraz University, I. R. of Iran

email: mhsnsls@yahoo.com

F. Didegah, M.Sc.

RICeST, I. R. of Iran

email: fdidgah@gmail.com

B. Bazgir, Ph.D. Student

Baqiatallah Medical University, I. R. of Iran

email: bazgirbehzad@gmail.com

Abstract

Physical Education being applied in nature, the role of scientific research has been widely challenged in this field. Applying a bibliometric analysis method, the present study tries to investigate scientific achievement in sports and exercises and examine its relation to practical performance, using scholarly papers indexed in ISI as substitutes of scientific productivity and medals won in olympic competitions for representations of athletic performance. The results showed that Sport Sciences is a small scientific community with a limited body of literature but a great number of contributing countries. The counts of sports scientific publications revealed to be exponentially increasing, signifying a stable annual growth comparable to that of the global science system. There is also a significant correlation between countries' success in olympic games and their scientific productivity. However, the former is found to have no significant correlation with the counts of sports-specific publications. It implies that though the scientific productivity in sports have no direct effect on athletes' performance in olympic games, the overall development of countries determine their performance in competitions. Consequently, to reach superiority in sports a complete evolution in all aspects of science, sports, economy and human development is necessary.

Keywords: Scientific Performance, Athletic Performance, Medals, Publications, Olympic Games, Sport Sciences.

Introduction

"Does sport-sciences research influence practice?" This was the major theme discussed by expert panelists at the opening congress of the Australian Association for Exercise and Sport Sciences. Reporting the panel discussions, Bishop, Burnett, Farrow, Gabbett & Newton (2006) suggested that scientific research in sports may improve performance by providing

evidences and identifying practices that are safer, more time efficient, and more enjoyable. However, based on Crowley's (2003) findings, they generalized that Sport Sciences dominated by “basic” rather than “applied research” may witness a low transfer rate of basic research into practice. This is despite the fact that sports scientists continue to claim to make a significant contribution to the body of knowledge that influences athletic practice and performance. As a result, while mentioning some research experiences resulting in applied outcomes (see e.g. Burnett et al., 1996; Farrow, 2000; 2003; Gabett, 2002; 2004; Newton, Jones, Kraemer & Wardle, 2002; 1999), they emphasized that there is little experimental evidence to signify the actual influence of research on practice and performance in this field.

Scientometric analysis may help us to find ways to empirically verify the fact by studying some representations of scientific as well as athletic performances. Scholarly papers published in prestigious journals indexed in highly renowned databases especially Thompson Scientific database (formerly ISI), reflect an elite selection of scientific production in every discipline. Athletic performance can be measured based on the distribution of medals among different entities in different international competitions especially at olympic games as one of the most influential, competitive and diverse sports events. Given the fact that athletes are mainly practically rather than scientifically involved in sports, the analysis could not be carried out at individual aggregation level. One may, instead, focus on countries as an entity embodying both scholarly and practical talents.

Searching for some empirical proofs, the present study tries to investigate scientific productivity in sports and exercises as reflected in ISI sports-related papers and then verify whether the contributions in science have any correlation to the athletic performance across countries as reflected by their medals won in olympic games. The study of the correlation may clarify if countries' strength in basic or applied research would improve their applied outcomes.

Review of Literature

Despite searching into a wide range of academic publications, we did not find any previous research specifically directed at the topic of the correlation between scientific and practical achievement in Sport Sciences except for Bishop, Burnett, Farrow, Gabbet & Newton (2006) who discussed the subject in light of their experiences. However, there are some investigations of the factors affecting practice in the

field. For instance, Lui and Suen (2008) showed a relationship between medals won by countries in olympic games and the number of their population as well as their level of income per capita. Before, Bernard and Busse (2004) had found economic resources and population as two important determinants influencing the number of medals gained by countries in the olympic. Johnson and Ali (2004) and Suen (1994) revealed that countries' system of government influences their medal counts.

Although evaluation or description of the scientific outputs in the field of sports and exercises was the byproduct of a wide range of scientometric studies carried out to investigate the productivity or influence of publications at global or country levels, few ones specifically concentrated on the field. As an earliest instance, Garfield (1997) conducted a citation analysis of sports medicine research at global level using papers published during 1981-1996. In this article, he tried to highlight the productivity and impact of nations, institutions and researchers in the field.

Other studies chose a narrower focus e.g. at journal, subject, or country level. For instance, Tsigilis, Grouios, Tsorbatzoudis & Koidou (2010) conducted a research at journal level to analyze the impact factors of Sport Sciences journals, their relative positions in relation to journals belonging to other scientific fields and their temporal stability. They showed that the journals witnessed an annual growth in their mean impact factors in 2000-2006. The field was found to be placed slightly below the middle for the year 2006 in terms of its overall mean impact factor relative to the other 172 subject categories of the Science Edition of the JCR. The journals' impact factors were revealed to remain relatively stable during the studied years.

Kulinna, Scrabis-Fletcher, Kodish, Phillips & Silverman (2009) chose a subject-specific focus. They analyzed the research literature in physical education pedagogy for a decade from 1995 to 2004. They found that research in this subject was scattered among journals devoted to various disciplines including Physical Education Pedagogy, Kinesiology, Education and Social Science, and Health Education and Medicine. The literature showed an annual growth since 1995. Before, Silverman and his colleagues (Silverman, 1987; Silverman & Manson, 2003; Silverman & Skonie, 1997) had identified, categorized and analyzed the papers and dissertations written on the subject. As another instance, Baker, Robertson-Wilson & Sedwick (2003) studied the distribution of published research papers in the field of Sports Psychology to examine whether it follows the Lotka-Price law of scientific productivity. They found that Sports Psychology is not as elitist as other fields, as it does not indicate good support of the law. They attributed it to an inherent difference between fields that fall under the category of Social Sciences, which unlike those belonging to Physical Sciences have been less supportive of the law. However, according to their findings, the field's productivity is similar to that in other fields of science.

Other researches concentrated on specific countries. For example, Tzormpatzakis and Sleaf (2007) conducted a systematic literature review on the participation of Greece in physical activity and exercise. Li, Lu, Zhao & Zhang (2006), Li (2000), and Liang (1994) analyzed the characteristics of Chinese core periodicals in Sport Sciences.

In sum, review of the previous studies and reports imply that the field of Sport Sciences being relatively small and new has not in scientometrics attracted the serious attention it deserves. The few instances exemplified above confirm that the field manifests some

uncommon characteristics, namely the non-elitism and the dispersion of its outputs among broad disciplines. Moreover, its scientific productivity is found to be improving and flourishing, at least quantitatively. However, many scientific aspects of the field remained uninvestigated especially the successful transfer or applicability of the research outcomes in improving the practice.

Research Objectives

The main aim of the present study is to investigate if there is any correlation between scientific and practical performances in sports at country aggregation level. Before examining the correlation, it is first required to clarify if the research literature in the field is growing at all and if so, how is its growth rate compared to that of the world publications in all disciplines. To this aim, we first analyzed the sports-related scientific publications indexed in ISI during 1999-2008 to examine their growth rate and compare it to the world's over the ten-year period. We then identified and ranked the contributing countries and compared their sport-specific outputs to their total shares of the world publications during the same period. At last, we tested the correlation between the counts of their publications to the total amount of the medals they won in 3 olympic games held from 1999-2008, i.e. 2000, 2004, and 2008 olympic games. The countries medal counts won in olympic were gathered using olympic website¹.

Research hypotheses

In order to achieve the above-mentioned aims, the present study tries to test the following hypotheses:

1. *The Sport Sciences system has been exponentially increasing at an annual growth rate similar to that of the global science system during 1999-2008.*
2. *The counts of publications in the global science system are significantly correlated to the medal counts across countries.*
3. *The counts of publications in the Sport Sciences system are significantly correlated to the medal counts across countries.*

Here, the Global Science System (GSS) means all papers published in all disciplines and indexed in ISI. The Sport Sciences System (SSS) constitutes one of its subsystems, i.e. papers devoted to a given discipline, here those published in sports-related journals.

Research Methodology

The present study applies a bibliometric analysis research method. To collect data, we first identified 72 sports journals using JCR 2008. It should be mentioned that sports-specific scholarly outputs are scattered among a wide range of journals belonging to different disciplines (Baker, Robertson-Wilson & Sedgwick, 2003; Kulinna, Scrabis-Fletcher, Kodish,

Phillips & Silverman, 2009). It is, thus, very difficult if not impossible to conduct a comprehensive identification. Consequently, we restricted our search in JCR to the journals clearly devoted to "Sport Sciences" based on their subject category.

In order to extract the bibliographic information of the papers published in the journals, a search was carried out in expanded version of Web of Science in early 2010, using the search formulation: "SO= [journal title]". The search was limited to years 1999-2008. A total of 66487 documents were retrieved and downloaded in a tab-delimited format and then transmitted to Excel for further refinement and analysis.

To analyze data, we used descriptive statistics (including frequency and percentage) as well as analytical statistics (regression analysis) to calculate the productions and determine their growth rate and correlation to the medals respectively.

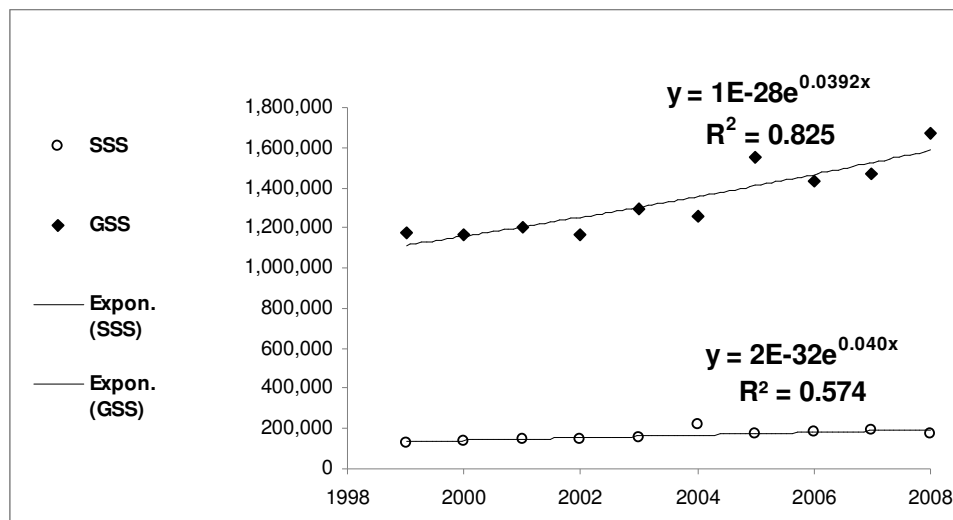


Figure 1: Exponential growth of publications in SSS and GSS during 1999-2008

Results

Scholarly productivity of SSS

The total number of scientific productions in the SSS amounts to 66,487 items accounting for just 0.5 percent of the GSS publications (13,397,911 items).

The annual growth of the two science systems was studied using regression analysis of papers versus years. The results illustrated in Figure 1 reveal that the two science systems have been exponentially growing in terms of their amounts of scientific productions during the studied years. The exponents of the equations yielded for the two systems are approximately equal (0.04 for SSS and 0.039 for the GSS).

Countries' contribution to SSS

Totally, 113 nations were revealed to (co) author 72599 scientific items in sports. It should be mentioned that the sum of the contributions exceeds the total number of papers identified, due to international collaboration of countries in multi-authored papers. Table 1

summarizes the countries contributions to GSS and SSS. It is ordered by countries' share in SSS (column 4). Top countries exhibiting the best performance in each system (including GSS, SSS or olympic games) are highlighted.

The "Other" group categorizes those countries with a relatively weak presence in sports, whether in science or practice. These include those contributing less than 5 papers during the 10-year period accounting for 32 countries or those with more than 5 contributions in Sport Sciences but no medals in at least one of the studied olympic games (These include Ireland, Iceland, Serbia, Egypt and Venezuela).

As it is seen in Table 1, USA contributing to about half of all SSS publications (42.59 percent) ranks the first among the world countries as regards its absolute amount of sports-related papers. It is followed by Great Britain, Canada, Australia and Japan. However, if the share of Sport Sciences in total publication of each country is considered, the top-ranked country is Guadeloupe with 6.37 percent of its total outputs. Turkey with a share amounting to 3.77 percent ranks the second. These, together with USA, Nepal and Estonia constitute the top five countries as regards devoting a higher percentage of their total outputs to sports and exercises.

Countries' achievement in olympic games

Table 1 also summarizes the countries achievement in olympic games during the studied years. The sums of gold, silver and bronze medals won by the countries are provided in the last column. It is noteworthy that there were some other winner countries with no scientific participation in the field, which were not listed in the table (including Armenia, Azerbaijan, Bahamas, Cuba, Dominican Republic, Georgia, Jamaica, Kyrgyzstan, Moldova, Mongolia, North Korea, Uzbekistan, and Zimbabwe).

The top ten countries regarding the total amount of medals won are USA, Russia, China, Australia, Germany, France, Great Britain, Italy, South Korea and Japan. As expected, the world's scientific and economic leaders including USA, Great Britain, Australia and Germany are situated among the top winner countries. The presence of newly emerging economic and scientific powers like China and South Korea are also noticeable.

Is there any relationship between countries' scientific productions and their success in olympic games? To answer the question, we analyzed the correlation between the total amounts of countries' scientific papers and their total counts of medals. The results are depicted in Figure 2. As seen, there is a significant strong correlation between the two variables ($R^2=0.62$). Situated far from other countries of the world, USA seems to act as an outlier and misleadingly increase the coefficient of determination. In order to control the effect, we repeat the analysis, excluding the outlier from the data. As seen in the inset of Figure 2, the two variables are still strongly correlated ($R^2=0.462$).

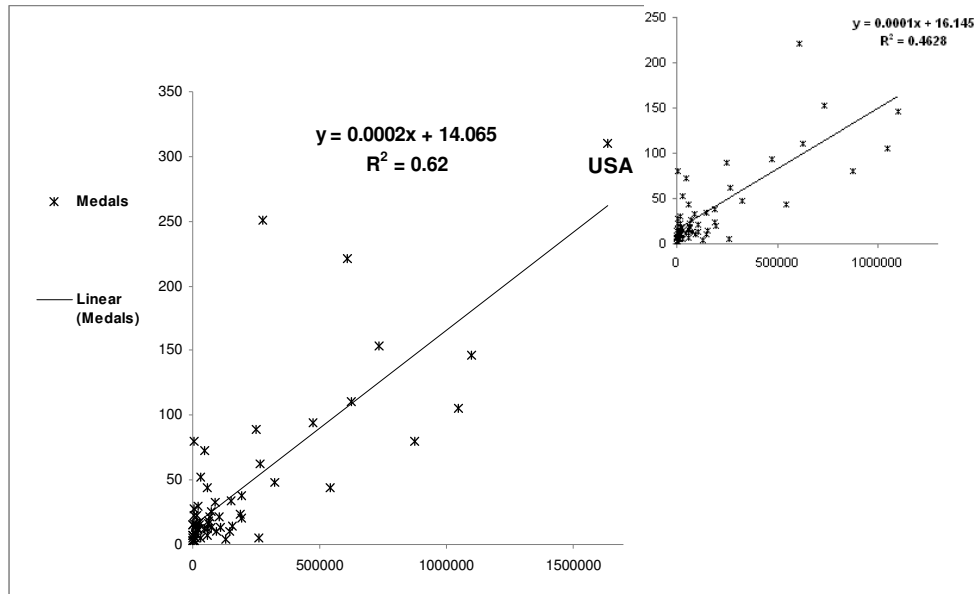


Figure 1: The correlation between total scientific outputs and medal counts across countries

The correlation between the amount of SSS publications and the counts of medals across countries

Figure 3 plots the medal counts versus the amount of sports scholarly papers across countries. As it is seen, the two variables seem to be significantly correlated ($R^2 = 0.417$). However, USA with 30919 papers in SSS is situated very far from the other countries of the world. This probably affects the correlation and fallaciously increases the coefficient of determination. To check the effect, we excluded data related to the country and repeated the analysis. As seen in the inset of the Figure 3, the coefficient of determination reduces to a non-significant level ($R^2 = 0.171$), signifying the existence of no significant correlation between the two variables.

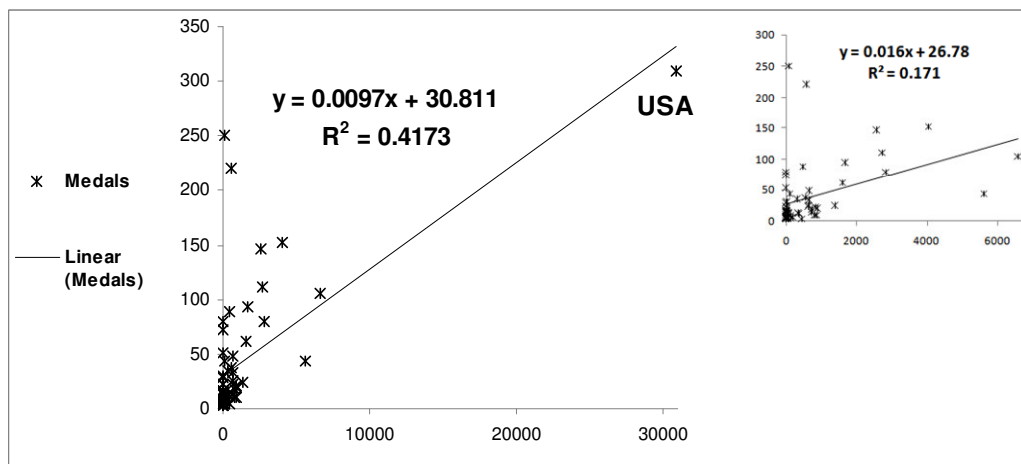


Figure 2: The correlation between sports scientific outputs and medal counts across countries

Discussion

Hypothesis 1: *The Sport Sciences system has been exponentially increasing at an annual growth rate similar to that of the global science system during 1999-2008.*

The stability of a science system is guaranteed if its share of the total production in the GSS steadily grows on an annual basis. The results of the regression analysis revealed that the SSS is increasingly growing on an exponential basis. The magnitude of the exponents yielded being approximately equal to that of the GSS implies that the SSS keeps pace with the GSS in terms of the annual rise in its publications. The finding is in accordance with kulina et al. (2009) confirming a growth in the scientific literature of Physical Education Pedagogy since 1995 and also with Baker, Robertson-Wilson & Sedgwick (2003) reporting a similarity between Sport Sciences and other scientific fields in terms of their productivity.

Hypothesis 2: *The counts of publications in the global science system are significantly correlated to the medal counts across countries.*

The results of the regression analysis signify that countries' contributions to GSS significantly correlate to their performance in olympics. In other words, the number of publications in GSS can predict the athletic performance to some extent. Notwithstanding the fact, it seems that it is not just the amount of the scientific publications but the overall development of the countries that matters. Because scientifically developed block mainly consists of the world's economic leaders (Wagner, Brahmakulam, Jackson, Wong & Yoda, 2001) and those with a high degree of human development², the superiority in science production is a tangible outcome of their overall development. Consequently, a brilliant participation in international sport championships may not be simplistically inferred as a direct result of the increase in the scientific development. Neither a superficial rise in the quantity of the scientific publications ensures a scientific development nor could be the research outcomes directly transferred into applied results without improving the required infrastructures e.g. in science, economic, human development etc. This reasoning is in accordance with the results of the previous studies confirming the effects of economic conditions and government systems on the athletic performance (see Lui and Suen, 2008; Bernard and Busse, 2004; Johnson and Ali, 2004 and Suen, 1994).

Hypothesis 3: *The counts of publications in the Sport Sciences system are significantly correlated to the medal counts across countries.*

A large number of the world countries are revealed to be active in scientific production in SSS. As expected, the top countries contributing to sport whether in science or practice are the economic leaders or the newly emerging powers. However, the results of the regression analysis, showing no significant correlation between the publication counts in SSS and the olympic medals across countries, reject the hypothesis.

This may be partly due to the predominance of a scholarly communication system in Sport Sciences community which is traditionally different from other scientific fields, as reflected in the related research literature. As the literature specifies, there is a gap between information seeking and publication behavior in Sport Sciences. Sport practitioners mainly tend to get their information through an informal unmediated process; i.e. personal contacts (Reade, Rodgers & Hall, 2008; Gould, Giannini, Krane & Hodge, 1990; Irwin, Hanton & Kerwin, 2004). Some reasons include the time required to find and read scientific journals, lack of direct access to sport scientists, while having direct access to other practitioners within their own institution (Reade, Rogers & Hall, 2008). That is why, for instance, coaches even university-based high performance ones prefer to consult other coaches to get information. That is in spite of the fact that sports scientists are forced to disseminate their research results via formal media especially scholarly journals to ensure their tenure, promotion and research grants. Consequently, the field witnesses a divergence between publication outlets preferred by the scientists and the sources of information referred to by the practitioners. This results in a low transfer rate of basic research into practice (Bishop, Burnett, Farrow, Gabbett & Newton, 2006). As Cushion, Armour & Jones (2003) point out, this informal knowledge transfer system could reproduce existing practice at the expense of innovation and/or critical analysis.

Another fact is that papers published in scholarly journals especially those indexed in ISI just partly reflect the scientific achievement of academics and scholars. This is especially true for Sport Sciences where sport-specific newsletters and newspapers rather than scholarly journals are considered to be the dominant media to circulate the information. Besides, the sports-related papers being distributed among highly diverse disciplines (Baker, Robertson-Wilson & Sedgwick, 2003; Kulinna, Scrabis-Fletcher, Kodish, Phillips & Silverman, 2009), the present data collection consists a limited though the most prestigious subset of the total production in the field.

Conclusion

Although Sport Sciences is a small and young scientific community with a limited body of literature, the large number of contributing countries implies that the scientific production in sports is of concern all over the world. Besides, the field is found to be increasingly improving its scholarly outputs at a growth rate comparable to that of the global science system. This implies that the discipline reached stability as regards scientific productivity. Given the fact that the field is rather dominated by basic than applied research (Bishop, Burnett, Farrow, Gabbett & Newton, 2006), the findings may implicitly signify that the former is receiving more and more importance.

For such a discipline, applied in nature, this might be inferred as an increasing influence of the research efforts whether basic or applied on the practical achievement of its

practitioners. However, the regression analysis carried out across countries revealed no significant correlations between the sport-specific literature and the medals.

Though the scientific development in sports scholarly productions is revealed to have no direct effect on athletes' performance in olympic games, the significant correlation between total scientific outputs and medals across countries empirically reinforce an already known fact: the world's economic giants govern the sports world, too. On this basis, one may infer that to reach superiority in sports an entire evolution in all aspects of science, sports, economy and human development is necessary.

Research Limitations and Propositions for Further Research

The present research encountered some limitations seemingly affecting the non-significant correlation between scientific papers and medals. First, the discrepancy between publication and reference preferences among scientists and practitioners results in a widespread reliance on personal circulation of knowledge and a relative isolation of research outputs. Second, the sports information is found to be widely mediated by newsletters and newspapers rather than scholarly journals. Furthermore, the scattering of the sports-related articles among a wide range of disciplines results in a non-comprehensive identification of articles in the present study. All these give rise to the question whether the target community feels inapplicability of research outcomes or inconsistency of research priorities in relation to their information needs. Further research is required to re-examine the hypothesis by controlling the effect of these features.

The present study focused on the most elite representations of scientific as well as practical performance. This gives rise to the question whether shifting our focus from the elite set of indicators to a more general one would get different results. Thus, it is also suggested to repeat the study using a broad set of indicators to discover any possible relationship between these two types of achievements. For instance, the number of sports academic staffs, researchers, students and academic departments as well as the number of papers, journals, books, and websites devoted to Sport Sciences may give a more inclusive image of a country's scientific achievement in sports. Similarly, olympic games are just one of the sports events, though the most competitive one. Consequently, the inclusion of the number of medals and records won or set in other international competitions and championships may bring on a more complete representation of performance in the field. Besides, the number of (high-performance) athletes and coaches in general and those directly involved in both science and practice in particular may help to have a relatively comprehensive set of indicators to build our judgment on. Also, the indicators could be studied at other aggregation levels, e.g. across practitioners and scientists' affiliations including sports clubs, groups, societies and bodies on the one hand and universities and research institutions on the other hand.

Table 1

The World Countries' Achievements in Olympic and in Science (in GSS and SSS)

Country	Number of Papers		Sports share		Medals
	The GSS	The SSS	of the SSS	of the country's total publication	
USA	1638125	30919	42.59	1.89	310
UK	1047188	6581	9.06	0.63	105
Canada	543200	5609	7.73	1.03	44
Australia	734190	4035	5.56	0.55	153
Japan	876469	2846	3.92	0.32	80
France	626839	2746	3.78	0.44	111
Germany	1100002	2582	3.56	0.23	146
Italy	472507	1693	2.33	0.36	94
Netherlands	267096	1601	2.21	0.60	62
Sweden	190259	1394	1.92	0.73	24
Switzerland	192789	897	1.24	0.47	20
Belgium	148304	872	1.20	0.59	10
Denmark	105533	856	1.18	0.81	21
Finland	95262	826	1.14	0.87	10
New Zealand	62891	739	1.02	1.18	18
Taiwan	154667	707	0.97	0.46	14
Spain	323211	677	0.93	0.21	48
Greece	87572	674	0.93	0.77	33
Turkey	16864	636	0.88	3.77	23
Norway	73561	634	0.87	0.86	26
China	608608	597	0.82	0.10	221
Brazil	191742	571	0.79	0.30	38
South Korea	249983	476	0.66	0.19	89
Israel	129110	463	0.64	0.36	4
Austria	108117	377	0.52	0.35	13
South Africa	57333	354	0.49	0.62	12
Poland	149232	325	0.45	0.22	34
Portugal	58713	184	0.25	0.31	7
Estonia	8380	153	0.21	1.83	8
India	261923	131	0.18	0.05	5
Hungary	56479	108	0.15	0.19	44

Country	Number of Papers		Sports share		Medals
	The GSS	The SSS	of the SSS	of the country's total publication	
Slovenia	21907	97	0.13	0.44	11
Iran	49283	95	0.13	0.19	12
Russia	278226	92	0.13	0.03	251
Croatia	20396	63	0.09	0.31	12
Guadeloupe	832	53	0.07	6.37	3
Argentina	60506	44	0.06	0.07	16
Czech	66985	43	0.06	0.06	22
Mexico	75233	34	0.05	0.05	13
Thailand	27168	31	0.04	0.11	15
Chile	31673	27	0.04	0.09	5
Lithuania	10681	27	0.04	0.25	13
Hong Kong	4587	23	0.03	0.50	16
Colombia	10856	17	0.02	0.16	5
Kuwait	6384	16	0.02	0.25	23
Luxembourg	2107	16	0.02	0.76	5
Nigeria	11939	14	0.02	0.12	9
Costa Rica	3252	12	0.02	0.37	6
Botswana	1576	12	0.02	0.76	15
Slovakia	24944	10	0.01	0.04	17
Cyprus	3332	10	0.01	0.30	80
Libya	801	10	0.01	1.25	3
Cameroon	3387	9	0.01	0.27	3
Lebanon	5678	8	0.01	0.14	3
Ukraine	44679	7	0.01	0.02	73
Romania	30476	6	0.01	0.02	52
Kenya	7594	6	0.01	0.08	28
Bolivia	1407	6	0.01	0.43	7
Monaco	668	5	0.01	0.75	15
Other	*1917326	427	0.59	0.02	170
Total	13397911	72599	100.00	0.54	2782

* The number includes the publication of the rest of the world, with or without scientific contribution to sports.

End Notes

1. <http://www.olympic.it/english/medal>
2. See <http://hdr.undp.org/en/statistics/>

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