International Journal of Kinesiology & Sports Science
ISSN: 2202-946X
www.ijkss.aiac.org.au

Trends and Developments in Italian Research in Exercise and Sport Sciences: A Bibliometric Analysis

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ARTICLE INFO

Article history
Received: February 11, 2025
Revised: March 20, 2025
Accepted: April 01, 2025
Published: April 30, 2025
Volume: 13 Issue: 2

Conflicts of interest: None.
Funding: None

ABSTRACT

Background of the study: In Italy, the subfield "Exercise and Sport Sciences" (ESS) has been recently redefined due to European Union legislation regulating funding distribution under the Next Generation EU Plan. ESS is now placed exclusively within Clinical Medicine and the Sport Sciences subfield, having been removed from Social Sciences and no longer associated with Education subfield. Previous studies have analysed ESS's scientific productivity and its impact on the international community, assessing overall and specific scientific output (H-Index). **Objective:** The aim is to compile an extensive ranking of scientists, limited to 200 researchers from the Scopus database, focusing on those affiliated with Italian universities and classified within the Group of Academic Scientific Discipline (GoASD) in Exercise and Sport Sciences, further divided into Physical Training (MEDF-01/A) and Sport Sciences (MEDF-01/B) for the period 2017–2022. The rankings include total impact, relative impact in Sport Sciences, total impact weighted by authorship, and relative impact weighted by authorship. **Methodology:** This study adopts a multi-phase, quantitative bibliometric analysis, utilizing data sourced from the Scopus database. First, a keyword-based selection process was applied using six terms (Sport, Physical Education, Physical Training, Exercise, Sports Education, and Sports Science) to identify relevant researchers. The Scopus Researcher Discovery tool was employed to filter Italian authors linked to these keywords. In the second phase, the total h-index for each researcher (2017–2022) was extracted, followed by the calculation of a keyword-specific relative h-index. The study further introduces an authorship-weighted h-index, assigning specific percentage values based on author positions (single author, first author, last author, co-author) to reflect the actual contribution of each scientist. **Results:** The study identified 83 Italian scientists from a pool of 250, with 42 in MEDF-01/A and 41 in MEDF-01/B. It shows that applying a weighting criterion can significantly alter authors' rankings, providing a more accurate measure of their true contribution. By using both weighted and unweighted metrics, the study offers a reliable evaluation of Italian researchers' performance within the ESS, integrating data from Scopus and CINECA. **Conclusions:** This multidimensional approach not only provides a more accurate representation of the Italian scientific community promoting a more sustainable development of ESS in the international context.

Key words: Scientific Production, H-Index, Authorship, Scopus, Subfield, Sport Sciences

INTRODUCTION

Following the reorganization of scientific knowledge through national legislation, Exercise and Sport Sciences (ESS) has been placed within the medical scientific area (Official Gazette, 2024). Consequently, Italy has aligned itself with the demands of the post-Covid-19 European Union Plan, known as Next Generation EU. The previous division of ESS into pedagogical and medical domains in recent years has generated confusion and reduced scientific production related to the subfield of Sports Science (D'Isanto et al., 2023; D'Elia et al., 2023). This division often lacked relevance and coherence with ESS, as there was a drift in the psycho-pedagogical and biomedical aspects concerning the interdisciplinarity of ESS (D'Isanto et al., 2024). Following this alignment, ESS has been placed exclusively in the field of Clinical Medicine, corresponding to the Sport Sciences subfield, and removed from the Social Sciences field, thereby no longer being associated with the subfield of Education. Several studies have investigated scientific productivity and its corresponding impact. They have highlighted that only 32.05% of the categorized Italian scientists produce scientific work in Exercise and Sport Sciences (ESS) according to criteria of scientific, cultural, and educational relevance and affinity (Raiola et al., 2024a), as mandated by the law to align with EU directives (Official Gazette, 2022). In contrast, other categorized scientists direct their investigations toward different scientific

Published by Australian International Academic Centre PTY.LTD.

http://dx.doi.org/10.7575/aiac.ijkss.v.13n.2p.40

domains, often favoring interdisciplinary approaches that frequently evolve into transdisciplinary ones, leading to a definitive shift to other scientific knowledge outside of ESS. These analyses were conducted using the basic classification model for scientific knowledge, currently adopted by the international scientific community, characterized by domains, fields, and subfields from Science-Metrix (Rivest et al., 2021). This classification model has generated the World's Top 2% Scientists, which is the global ranking of scientists with the highest impact of scientific production developed by scientometric researchers at Stanford University (Ioannidis et al., 2019; 2020; 2021; 2022; 2023; 2024) in collaboration with the international publishing company Elsevier and the global scientific research database Scopus. For each scientist, the subfield of scientific production, the corresponding ranking for total citations, and the related h-index have been indicated. The composite index obtained allows for measuring the impact of each scientist and each individual work by applying corrective factors, summarized in a complex mathematical formula that generates the values upon which the ranking is based (Ioannidis, 2025).

Although the Scopus database provides citation data disaggregated by country, no ranking or evaluation has been conducted for each country and individual subfield. Furthermore, the database does not assess the personal contributions that each scientist makes to their field, given that authorship often involves multiple contributors. This limitation affects measures like total citations and the h-index for each individual (Ausloos, 2015). Like all subfields, ESS lacks clarity regarding the extent of individual authors' contributions to research. The World's Top 2% Scientists ranking reveals that only 9 Italian scientists are listed for their entire careers from 2019 to the present, and 13 for the year 2023 (Ioannidis et al., 2024). While this is an important statistic pertaining to the global ranking, it is not related to the total number of researchers investigating this specific subfield. Therefore, it does not provide details about the Italian scientists to reference for the specific development of ESS. It may be more useful and more important to know the exact ranking of researchers who are officially categorized under the Group of Academic Scientific Discipline (GoASD) of ESS (code 06/MEDF-01) within national scientific communities. This is particularly relevant since the two academic scientific disciplines (ASDs) of Physical Training and Methodology (code MEDF-01/A) and Sport Sciences and Methodology (code MEDF-01/B), have been part of the organizational structure of the Ministry of University and Research since 2000 (Official Gazette, 2000) and because the Italian state allocates economic and structural resources for the development of each GoASD. Additionally, the studies by Ioannidis et al. from 2019 to 2024 analyse all subfields in the Science-Metrix classification, evaluating both career achievements and reference years to highlight global research policies. However, these studies do not provide specific data on individual scientist contributions, as they do not distinguish the unique roles of each contributor. This gap exists despite the Scopus database offering detailed authorship data across extended periods for primary authorship roles in aggregated topics with multiple keywords (Ioannidis, 2025). The issue within the scientific community regarding the Sport Sciences subfield related to the GoASD of ESS arises from a lack of precise knowledge about its ranking and evaluation, largely due to the relatively young age of the ESS. The cited studies evaluated the scientific production, its impact on the scientific community, and the aggregated contribution to research in the subfield of Sport Sciences in Italy. Additionally, the h-index of the most productive and cited scientists was assessed, using classifications based on contribution categories, but anonymously, as a sole author, first author, last author, and co-author (Raiola et al., 2024b). A ranking of authors has not yet been established, nor has an evaluation of individual scientific contributions been conducted. However, by applying the same impact assessment method weighted by authorship, it is possible to determine the relative impact of each national scientist. By better utilizing the features of the Scopus database, it is possible to create a national ranking for the Sport Sciences subfield, focused on scientists receiving state economic and structural support. This approach would allow for identifying each scientist's specific contribution to the field according to the four specified categories.

The aim of this analysis is to accurately determine the specific contribution of each Italian scientist involved in scientific production related to ESS subfield by analysing and classifying their impact based on scientific output. The evaluation will consider each scientist's weighted and unweighted contributions to create a comprehensive ranking. This classification will utilize the Scopus database, which allows filtering for up to 200 scientists, and will focus exclusively on those in the ASD of MEDF-01/A and MEDF-01/B for the period 2017-2022.

METHODS

Selection of Keywords and Data Collection

The analysis of the scientific output of Italian researchers, categorized by academic rank (Full professors, Associate professors, and researchers) within the academic scientific disciplines (ASD) of Physical Training and Methodology (MEDF-01/A) and Sport Sciences and Methodology (MEDF-01/B), based on six identified keywords in the subfield, was carried out through several processing stages. The chosen keywords are 'Sport', 'Physical Education', 'Physical Training', 'Exercise', 'Sports Education' and 'Sports Science'. Specific criteria guided the selection process for these six keywords. A qualitative assessment was initially carried out to evaluate the relevance and uniqueness of each keyword, based on their use and applicability in current academic publications. The evaluation considered how well each keyword aligned with ongoing research themes and its significance within the field. Co-occurrence frequencies were also analyzed to identify keywords with minimal conceptual overlap, ensuring that each one represented a distinct research area and avoiding duplication. The Researcher Discovery tool in Scopus supported this process by enabling keyword-based searches and linking directly to related researchers and documents. This same feature was used to

examine six keywords representing a specific subfield. Customized searches were performed to identify only Italian authors associated with each keyword, guaranteeing their inclusion in the analysis. After applying the country filter for Italy, the tool automatically generated a list of up to 200 Italian authors for each keyword. From these results, individuals working in ESS and categorized under one of the two ASD classifications were identified. As of December 31, 2022, the number of such individuals in Italy totaled 250—141 in MEDF-01/A and 118 in MEDF-01/B.

H-Index Extraction and Weighted Analysis

In the second phase of the analysis, after identifying the Italian scientists in ESS through the search for each keyword, the collection of metric values for the period 2017-2022 was carried out, which is also designed to identify articles with varying authorship. The data collection was conducted at the end of 2023. This particular time period was chosen for two primary reasons: first, to examine the latest advancements and patterns in scholarly output within these academic fields, capturing the dynamic progress of the area; and second, to align with the constraints of Scopus Researcher Discovery's capabilities, which allow for a focused analysis of pertinent and up-to-date data up to the year before the study was conducted.

Subsequently, the total h-index from Elsevier's Scopus database for the period 2017-2022 was extracted for each of the ESS scientists distinguished by ASD within the group of 200. The h-index is a metric that quantifies an author's productivity and impact based on their most cited articles. It is defined as the maximum number such that the researcher has published that number of articles that have been cited at least that many times (Hirsh, 2005). Next, the articles of individual Italian scientists attributed to each of the six keywords were identified through the evaluation of each keyword. For each article corresponding to a specific keyword, the number of citations received, and the respective h-index were extracted. The h-index related to each reference keyword was then calculated, thereby creating citation indices "relative" to each keyword. The values for the number of relative citations and the corresponding h-index values (Relative h-index) were then summed for each scholar across the six keywords and divided by the total number of relative h-index values (from 1 to 6, depending on the actual results of the research).

In a similar manner, the weighted total h-index and weighted relative h-index for each keyword were computed for all scientists included in the ESS. To calculate the authorship-weighted h-index, the h-index was determined for various categories of authorship: single author (h-single), first author (h-first), last author (h-last), and co-author (h-coauthor). This was achieved by ranking the publications within each category based on citation count and identifying the point where the number of citations equals or surpasses the number of publications. The h-index values from each category were then incorporated into the weighted h-index formula, where different percentage weights were assigned to each category, reflecting the specific contribution of each author position to the overall scientific output. These weights were determined based on the author's position in each article, as outlined by Scopus Elsevier. They were derived from literature analysis and standard research practices, where the author's role often signals their level of involvement and responsibility in the research. The weights were assigned as follows:

- Single author: 100%, as the author is fully responsible for every aspect of the study, from design to execution.
- First author: 50%, reflecting significant involvement in the study's design and execution phases.
- Last author: 40%, as this role typically includes providing oversight and guiding the research process.
- Co-author: 5%, acknowledging that the level of contribution varies significantly among co-authors, ranging from the second to the penultimate position.

The overall authorship-weighted h-index for an author was calculated by multiplying the h-index for each authorship category by its respective weight and summing the results for all the author's publications from 2017 to 2022. Similarly, the h-index values for each authorship category related to the six keywords were summed for each scientist. The h-index quotient, relating to the six keywords and multiplied by their corresponding weights, was then calculated for all the author's publications. The computation of the numerical quotient for the h-index provides several methodological benefits. Primarily, it allows the normalization of relative h-index values against the total number of keywords considered, thus minimizing the potential bias caused by variations in the number of publications and citations across different fields. This method results in a weighted h-index that accurately reflects the author's scientific impact over time. Furthermore, the straightforward interpretation of the numerical quotient makes it an effective and easily understandable tool for evaluating an author's performance, facilitating comparisons between authors and offering a more comprehensive view of their scientific contributions over time.

RESULTS

The ranking of the metrics is reported below. Table 1 shows the ranking of Italian authors by total h-index, including the entire scientific production. Table 2 concerns the ranking of authors by h-index relative to the subfield sport sciences. Tables 3 and 4 concern the ranking of total and relative h-index weighted by authorship.

Figure 1 compares different h-index metrics (Total h-index, Relative h-index, Total weighted h-index, and Relative weighted h-index) for ASD in ESS between 2017 and 2022, analysing two categories: MEDF-01/A and MEDF-01/B. The comparison shows that the Total h-index is the highest metric for both categories, indicating a high overall productivity. However, the Relative h-index is significantly lower, suggesting that the ratio between publications and the relative context is less relevant. The weighted metrics show similar values, with slight differences between MEDF-01/A and MEDF-01/B. MEDF-01/A tends to have a slightly higher Total h-index, suggesting greater absolute productivity. However, for

Table 1. Ranking of the total h-index, of all scientific production, of Italian scientists in the GoASD of ESS

ASD	Surname and Name	Total h-index 2017-2022
MEDF-01/A	1. Musumeci Giuseppe	28
MEDF-01/B	2. Venturelli Massimo	28
MEDF-01/A	3. Bianco Antonino	26
MEDF-01/A	4. D'Ascenzi Flavio	26
MEDF-01/B	5. Schena Federico	26
MEDF-01/B	6. La Torre Antonio	25
MEDF-01/A	7. Paoli Antonio	25
MEDF-01/B	8. Mazzeo Filomena	24
MEDF-01/B	9. Padulo Johnny	23
MEDF-01/A	10. Raiola Gaetano	23
MEDF-01/B	11. Campa Francesco	21
MEDF-01/B	12. Coratella Giuseppe	21
MEDF-01/B	13. Esposito Fabio	20
MEDF-01/A	14. Pesce Caterina	20
MEDF-01/B	15. Altavilla Gaetano	19
MEDF-01/B	16. Capranica Laura	19
MEDF-01/A	17. Palma Antonio	19
MEDF-01/A	18. Perrone Marco	19
MEDF-01/A	19. Sacchetti Massimo	19
MEDF-01/B	20. Castagna Carlo	18
MEDF-01/B	21. Cortis Cristina	18
MEDF-01/B	22. Bertollo Maurizio	17
MEDF-01/B	23. Codella Roberto	17
MEDF-01/B	24. Brustio Paolo Riccardo	16
MEDF-01/A	25. D'Elia Francesca	16
MEDF-01/A	26. Robazza Claudio	16
MEDF-01/B	27. Trecroci Athos	16
MEDF-01/B	28. Zago Matteo	16
MEDF-01/B	29. Battaglia Giuseppe	15
MEDF-01/B	30. Lupo Corrado	15
MEDF-01/A	31. Roveda Eliana	15
MEDF-01/B	32. Tessitore Antonio	15
MEDF-01/B	33. Condello Giancarlo	14
MEDF-01/A	34. Di Fronso Selenia	14
MEDF-01/B	35. Fischetti Francesco	14
MEDF-01/B	36. Fusco Andrea	14
MEDF-01/B	37. Greco Gianpiero	14
MEDF-01/A	38. Izzicupo Pascal	14
MEDF-01/B	39. Mascherini Gabriele	14
MEDF-01/A	40. Messina Giuseppe	14
MEDF-01/B	41. Milanese Chiara	14
MEDF-01/A	42. Thomas Ewan	14
MEDF-01/A	43. Ascione Antonio	13
MEDF-01/B	44. Formenti Damiano	13
MEDF-01/A	45. Lazzer Stefano	13
MEDF-01/B	46. Vandoni Matteo	13
MEDF-01/B	47. Baldari Carlo	12
MEDF-01/A	48. Bergamin Marco	12
MEDF-01/A	49. Di Blasio Andrea	12
MEDF-01/A	50. Guidetti Laura	12
MEDF-01/A	51. Lucini Daniela	12
MEDF-01/B	52. Zaccagni Luciana	12
MEDF-01/B	53. Bellafiore Marianna	11
MEDF-01/A	54. Ceciliani Andrea	11
MEDF-01/A	55. Di Corrado Donatella	11
MEDF-01/A	56. Emerenziani Gianpietro	11
MEDF-01/B	57. Iona Teresa	11
MEDF-01/B	58. Izzo Riccardo	11
MEDF-01/B	59. Lovecchio Nicola	11
MEDF-01/A	60. Mazzoni Gianni	11
MEDF-01/A	61. Belfiore Patrizia	10
MEDF-01/A	62. Grazzi Giovanni	10
MEDF-01/A	63. Muscella Antonella	10
MEDF-01/A	64. Neunhaeuserer Daniel	10
MEDF-01/A	65. Petrigna Luca	10
MEDF-01/A	66. Scurati Raffaele	10
MEDF-01/B	67. Sgrò Francesco Lucio	10
MEDF-01/A	68. Carraro Attilio	9
MEDF-01/A	69. Gobbi Erica	9
MEDF-01/A	70. Grazioli Elisa	9
MEDF-01/B	71. Guidotti Flavia	9
MEDF-01/A	72. Maietta Pasqualino	9
MEDF-01/A	73. Parisi Attilio	9
MEDF-01/B	74. Puce Luca	9
MEDF-01/A	75. Federici Ario	8
MEDF-01/B	76. Invernizzi Pietro Luigi	8
MEDF-01/B	77. Lipoma Mario	8
MEDF-01/A	78. Lucertini Francesco	8
MEDF-01/A	79. Mandini Simona	8
MEDF-01/B	80. Bonavolontà Valerio	7
MEDF-01/A	81. Colella Dario	7
MEDF-01/A	82. Tortella Patrizia	7
MEDF-01/B	83. Masala Daniele	5

the weighted and relative metrics, MEDF-01/B approaches the values of MEDF-01/A, indicating that the two categories are more balanced when considering the context and impact of publications. This suggests that while MEDF-01/A may have a higher volume of publications, MEDF-01/B could be more balanced regarding relative impact. Table 5 below shows the comparative table of the four *Top 10* rankings.

Regarding the top 10, in the total index ranking, there are five scientists from MEDF-01/A and five from MEDF-01/B.

Table 2. Ranking of the relative h-index, of ESS subfield, of Italian scientists in the GoASD of ESS

ASD	Surname and Name	Relative h-index 2017-2022
MEDF-01/A	1. Raiola Gaetano	4,9
MEDF-01/A	2. D'Ascenzi Flavio	4,8
MEDF-01/B	3. Coratella Giuseppe	4,3
MEDF-01/B	4. Capranica Laura	4,2
MEDF-01/B	5. Campa Francesco	4,2
MEDF-01/B	6. Schena Federico	4,0
MEDF-01/B	7. La Torre Antonio	3,9
MEDF-01/B	8. Codella Roberto	3,9
MEDF-01/B	9. Castagna Carlo	3,7
MEDF-01/B	10. Cortis Cristina	3,6
MEDF-01/B	11. Lupo Corrado	3,5
MEDF-01/B	12. Tessitore Antonio	3,5
MEDF-01/B	13. Mazzeo Filomena	3,3
MEDF-01/B	14. Fischetti Francesco	3,2
MEDF-01/A	15. D'Elia Francesca	3,2
MEDF-01/B	16. Altavilla Gaetano	3,1
MEDF-01/B	17. Brustio Paolo Riccardo	3,0
MEDF-01/A	18. Di Fronso Selenia	3,0
MEDF-01/A	19. Perrone Marco	3,0
MEDF-01/A	20. Sacchetti Massimo	3,0
MEDF-01/A	21. Bergamin Marco	2,9
MEDF-01/B	22. Padulo Johnny	2,9
MEDF-01/B	23. Venturelli Massimo	2,8
MEDF-01/A	24. Bianco Antonino	2,7
MEDF-01/A	25. Neunhaeuserer Daniel	2,7
MEDF-01/A	26. Pesce Caterina	2,7
MEDF-01/A	27. Paoli Antonio	2,7
MEDF-01/B	28. Condello Giancarlo	2,6
MEDF-01/A	29. Robazza Claudio	2,5
MEDF-01/A	30. Di Corrado Donatella	2,5
MEDF-01/B	31. Esposito Fabio	2,5
MEDF-01/B	32. Invernizzi Pietro Luigi	2,5
MEDF-01/B	33. Izzo Riccardo	2,5
MEDF-01/B	34. Trecroci Athos	2,4
MEDF-01/A	35. Musumeci Giuseppe	2,4
MEDF-01/A	36. Muscella Antonella	2,4
MEDF-01/B	37. Vandoni Matteo	2,4
MEDF-01/B	38. Baldari Carlo	2,4
MEDF-01/A	39. Carraro Attilio	2,4
MEDF-01/A	40. Di Blasio Andrea	2,4
MEDF-01/A	41. Grazioli Elisa	2,4
MEDF-01/B	42. Zago Matteo	2,4
MEDF-01/A	43. Messina Giuseppe	2,3
MEDF-01/B	44. Zaccagni Luciana	2,3
MEDF-01/B	45. Bonavolontà Valerio	2,3
MEDF-01/B	46. Fusco Andrea	2,2
MEDF-01/A	47. Ascione Antonio	2,2
MEDF-01/B	48. Greco Gianpiero	2,2
MEDF-01/A	49. Izzicupo Pascal	2,2
MEDF-01/B	50. Sgro' Francesco Lucio	2,2
MEDF-01/B	51. Bertollo Maurizio	2,2
MEDF-01/A	52. Palma Antonio	2,2
MEDF-01/B	53. Guidotti Flavia	2,1
MEDF-01/A	54. Guidetti Laura	2,0
MEDF-01/B	55. Mascherini Gabriele	2,0
MEDF-01/B	56. Battaglia Giuseppe	2,0
MEDF-01/A	57. Emerenziani Gianpietro	2,0
MEDF-01/A	58. Grazzi Giovanni	2,0
MEDF-01/A	59. Mandini Simona	2,0
MEDF-01/A	60. Lazzer Stefano	1,9
MEDF-01/A	61. Parisi Attilio	1,9
MEDF-01/B	62. Lovecchio Nicola	1,8
MEDF-01/A	63. Tortella Patrizia	1,8
MEDF-01/B	64. Formenti Damiano	1,8
MEDF-01/A	65. Maietta Pasqualino	1,8
MEDF-01/A	66. Thomas Ewan	1,8
MEDF-01/A	67. Belfiore Patrizia	1,7
MEDF-01/B	68. Bellafiore Marianna	1,7
MEDF-01/A	69. Gobbi Erica	1,7
MEDF-01/B	70. Lipoma Mario	1,6
MEDF-01/A	71. Ceciliani Andrea	1,5
MEDF-01/A	72. Lucini Daniela	1,5
MEDF-01/A	73. Federici Ario	1,5
MEDF-01/A	74. Lucertini Francesco	1,5
MEDF-01/A	75. Mazzoni Gianni	1,5
MEDF-01/B	76. Milanese Chiara	1,5
MEDF-01/A	77. Colella Dario	1,4
MEDF-01/B	78. Puce Luca	1,4
MEDF-01/A	79. Petrigna Luca	1,3
MEDF-01/A	80. Scurati Raffaele	1,2
MEDF-01/B	81. Iona Teresa	1,0
MEDF-01/A	82. Roveda Eliana	1,0
MEDF-01/B	83. Masala Daniele	1,0

(Contd...)

Table 2. *(Continued)*

Table 3. Total h-index ranking weighted by authorship, i.e., by the specific position in the author string, of Italian scientists in the GoASD of ESS

ASD	Surname and Name	Total weighted h-index 2017-2022
MEDF-01/A	1. Musumeci Giuseppe	44,2
MEDF-01/A	2. Raiola Gaetano	35,6
MEDF-01/A	3. Bianco Antonino	30,1
MEDF-01/A	4. D'Elia Francesca	28,8
MEDF-01/A	5. Paoli Antonio	27,6
MEDF-01/A	6. D'Ascenzi Flavio	25,6
MEDF-01/B	7. Padulo Johnny	25,6
MEDF-01/B	8. Schena Federico	25
MEDF-01/B	9. Esposito Fabio	24,1
MEDF-01/B	10. Coratella Giuseppe	23,1
MEDF-01/B	11. Altavilla Gaetano	22,8
MEDF-01/B	12. Fischetti Francesco	21,6
MEDF-01/B	13. Brustio Paolo Riccardo	20,4
MEDF-01/B	14. Zago Matteo	20,1
MEDF-01/B	15. Venturelli Massimo	19,2
MEDF-01/B	16. Campa Francesco	19
MEDF-01/B	17. Codella Roberto	18
MEDF-01/A	18. Perrone Marco	16,9
MEDF-01/B	19. Greco Gianpiero	15,9
MEDF-01/A	20. Lazzer Stefano	15,6
MEDF-01/B	21. Izzo Riccardo	15,2
MEDF-01/B	22. Bertollo Maurizio	14,9
MEDF-01/A	23. Messina Giuseppe	13,8
MEDF-01/B	24. Lupo Corrado	13,7
MEDF-01/B	25. Mazzeo Filomena	13,6
MEDF-01/A	26. Ascione Antonio	13,3
MEDF-01/A	27. Lucini Daniela	13,3
MEDF-01/B	28. Mascherini Gabriele	13
MEDF-01/A	29. Thomas Ewan	12,6
MEDF-01/B	30. Trecroci Athos	12,6
MEDF-01/B	31. Castagna Carlo	12,5
MEDF-01/A	32. Sacchetti Massimo	12,1
MEDF-01/A	33. Belfiore Patrizia	11,9
MEDF-01/A	34. Robazza Claudio	11,8
MEDF-01/B	35. La Torre Antonio	11,2
MEDF-01/A	36. Pesce Caterina	11,2
MEDF-01/A	37. Palma Antonio	11,1
MEDF-01/A	38. Muscella Antonella	10,7
MEDF-01/B	39. Condello Giancarlo	10,3
MEDF-01/B	40. Vandoni Matteo	10,3
MEDF-01/A	41. Di Corrado Donatella	10,1
MEDF-01/B	42. Lovecchio Nicola	9,8
MEDF-01/B	43. Cortis Cristina	9,6
MEDF-01/A	44. Bergamin Marco	9,3
MEDF-01/B	45. Tessitore Antonio	9,1
MEDF-01/A	46. Grazzi Giovanni	9
MEDF-01/B	47. Bellafiore Marianna	8,8
MEDF-01/B	48. Milanese Chiara	8,7
MEDF-01/B	49. Zaccagni Luciana	8,7
MEDF-01/A	50. Petrigna Luca	8,6
MEDF-01/B	51. Sgrò Francesco Lucio	8,4
MEDF-01/B	52. Invernizzi Pietro Luigi	8,4
MEDF-01/B	53. Baldari Carlo	8,2
MEDF-01/A	54. Federici Ario	8,2
MEDF-01/B	55. Puce Luca	8,2
MEDF-01/B	56. Capranica Laura	7,9
MEDF-01/A	57. Emerenziani Gianpietro	7,9
MEDF-01/B	58. Battaglia Giuseppe	7,7
MEDF-01/A	59. Di Fronso Selenia	7,7
MEDF-01/A	60. Guidetti Laura	7,7
MEDF-01/A	61. Ceciliani Andrea	7,5
MEDF-01/A	62. Di Blasio Andrea	7,5
MEDF-01/B	63. Formenti Damiano	7,4
MEDF-01/B	64. Lipoma Mario	7,2
MEDF-01/B	65. Fusco Andrea	7
MEDF-01/A	66. Carraro Attilio	6,7
MEDF-01/A	67. Mandini Simona	6,7
MEDF-01/A	68. Mazzoni Gianni	6,6
MEDF-01/A	69. Roveda Eliana	6,6
MEDF-01/A	70. Izzicupo Pascal	6,3
MEDF-01/A	71. Neunhaeuserer Daniel	6,3
MEDF-01/A	72. Parisi Attilio	6,3
MEDF-01/A	73. Grazioli Elisa	6,2
MEDF-01/A	74. Scurati Raffaele	5,9
MEDF-01/A	75. Tortella Patrizia	5,4
MEDF-01/B	76. Bonavolontà Valerio	5,3
MEDF-01/A	77. Gobbi Erica	5
MEDF-01/B	78. Iona Teresa	4,9
MEDF-01/A	79. Lucertini Francesco	4,7
MEDF-01/A	80. Colella Dario	3,5
MEDF-01/A	81. Maietta Pasqualino	3,2
MEDF-01/B	82. Masala Daniele	3,2
MEDF-01/B	83. Guidotti Flavia	1,9

(Contd...)

Table 3. *(Continued)*

Table 4. Relative h-index ranking weighted by authorship, i.e., by the specific position in the author string, of Italian scientists in the GoASD of ESS

ASD	Surname and Name	Relative weighted h-index 2017-2022
MEDF-01/A	1. Raiola Gaetano	66,9
MEDF-01/A	2. D'Elia Francesca	56,1
MEDF-01/B	3. Fischetti Francesco	44,7
MEDF-01/A	4. Bianco Antonino	32,2
MEDF-01/B	5. Altavilla Gaetano	30,8
MEDF-01/A	6. D'Ascenzi Flavio	27,3
MEDF-01/A	7. Musumeci Giuseppe	25,3
MEDF-01/B	8. Greco Gianpiero	24,7
MEDF-01/B	9. Schena Federico	21,9
MEDF-01/A	10. Paoli Antonio	21,5
MEDF-01/B	11. Padulo Johnny	20,6
MEDF-01/A	12. Pesce Caterina	20,3
MEDF-01/B	13. Codella Roberto	20,1
MEDF-01/B	14. Izzo Riccardo	19,7
MEDF-01/A	15. Ascione Antonio	18,4
MEDF-01/B	16. Bertollo Maurizio	17,5
MEDF-01/B	17. Trecroci Athos	16,7
MEDF-01/B	18. Castagna Carlo	16,6
MEDF-01/B	19. Mascherini Gabriele	16,6
MEDF-01/B	20. Campa Francesco	16,4
MEDF-01/B	21. Brustio Paolo Riccardo	15,9
MEDF-01/B	22. Lupo Corrado	15
MEDF-01/B	23. Sgrò Francesco Lucio	15
MEDF-01/A	24. Parisi Attilio	13,6
MEDF-01/A	25. Belfiore Patrizia	13,6
MEDF-01/B	26. Coratella Giuseppe	12,8
MEDF-01/B	27. Vandoni Matteo	12,4
MEDF-01/A	28. Lucini Daniela	11,8
MEDF-01/A	29. Palma Antonio	11,5
MEDF-01/A	30. Ceciliani Andrea	11
MEDF-01/B	31. Lipoma Mario	10,9
MEDF-01/B	32. Cortis Cristina	10,9
MEDF-01/B	33. Bonavolontà Valerio	10
MEDF-01/B	34. La Torre Antonio	10
MEDF-01/A	35. Muscella Antonella	9,8
MEDF-01/B	36. Zaccagni Luciana	9,8
MEDF-01/A	37. Robazza Claudio	9,7
MEDF-01/A	38. Scurati Raffaele	9,7
MEDF-01/B	39. Tessitore Antonio	9,7
MEDF-01/B	40. Milanese Chiara	9,6
MEDF-01/B	41. Capranica Laura	9,5
MEDF-01/A	42. Federici Ario	9,5
MEDF-01/A	43. Di Blasio Andrea	9,1
MEDF-01/A	44. Grazioli Elisa	9
MEDF-01/A	45. Sacchetti Massimo	8,8
MEDF-01/B	46. Mazzeo Filomena	8,6
MEDF-01/A	47. Gobbi Erica	8,4
MEDF-01/B	48. Battaglia Giuseppe	8,3
MEDF-01/B	49. Formenti Damiano	8,2
MEDF-01/B	50. Esposito Fabio	8,1
MEDF-01/A	51. Izzicupo Pascal	7,6
MEDF-01/B	52. Puce Luca	7,5
MEDF-01/B	53. Fusco Andrea	6,8
MEDF-01/A	54. Di Fronso Selenia	6,8
MEDF-01/A	55. Guidetti Laura	6,7
MEDF-01/B	56. Lovecchio Nicola	6,6
MEDF-01/B	57. Invernizzi Pietro Luigi	6,5
MEDF-01/A	58. Neunhaeuserer Daniel	6,4
MEDF-01/A	59. Carraro Attilio	6,4
MEDF-01/A	60. Perrone Marco	6,3
MEDF-01/B	61. Condello Giancarlo	6,1
MEDF-01/A	62. Lazzer Stefano	6,1
MEDF-01/A	63. Petrigna Luca	6,1
MEDF-01/A	64. Tortella Patrizia	6
MEDF-01/A	65. Emerenziani Gianpietro	5,9
MEDF-01/A	66. Thomas Ewan	5,9
MEDF-01/A	67. Messina Giuseppe	5,6
MEDF-01/A	68. Bergamin Marco	5,4
MEDF-01/A	69. Di Corrado Donatella	5,4
MEDF-01/B	70. Zago Matteo	5,3
MEDF-01/B	71. Bellafiore Marianna	5,2
MEDF-01/B	72. Iona Teresa	5,1
MEDF-01/B	73. Baldari Carlo	5
MEDF-01/A	74. Grazzi Giovanni	4,9
MEDF-01/B	75. Venturelli Massimo	4,5
MEDF-01/A	76. Colella Dario	4,5
MEDF-01/A	77. Maietta Pasqualino	3,8
MEDF-01/A	78. Lucertini Francesco	3,7
MEDF-01/A	79. Mandini Simona	2,6
MEDF-01/B	80. Guidotti Flavia	2,3
MEDF-01/A	81. Mazzoni Gianni	2,2
MEDF-01/B	82. Masala Daniele	2,1
MEDF-01/A	83. Roveda Eliana	1,8

(Contd...)

Table 4. *(Continued)*

Table 5. Comparative table of the Top 10 for the four impact rankings

Total h-index 2017-2022	Relative h-index 2017-2022	Total weighted h-index 2017-2022	Relative weighted h-index 2017-2022
1. Musumeci Giuseppe	1. Raiola Gaetano	1. Musumeci Giuseppe	1. Raiola Gaetano
2. Venturelli Massimo	2. D'Ascenzi Flavio	2. Raiola Gaetano	2. D'elia Francesca
3. Bianco Antonino	3. Coratella Giuseppe	3. Bianco Antonino	3. Fischetti Francesco
4. D'Ascenzi Flavio	4. Capranica Laura	4. D'Elia Francesca	4. Bianco Antonino
5. Schena Federico	5. Campa Francesco	5. Paoli Antonio	5. Altavilla Gaetano
6. La Torre Antonio	6. Schena Federico	6. D'Ascenzi Flavio	6. D'Ascenzi Flavio
7. Paoli Antonio	7. La Torre Antonio	7. Padulo Johnny	7. Musumeci Giuseppe
8. Mazzeo Filomena	8. Codella Roberto	8. Schena Federico	8. Greco Gianpiero
9. Padulo Johnny	9. Castagna Carlo	9. Esposito Fabio	9. Schena Federico
10. Raiola Gaetano	10. Cortis Cristina	10. Coratella Giuseppe	10. Paoli Antonio

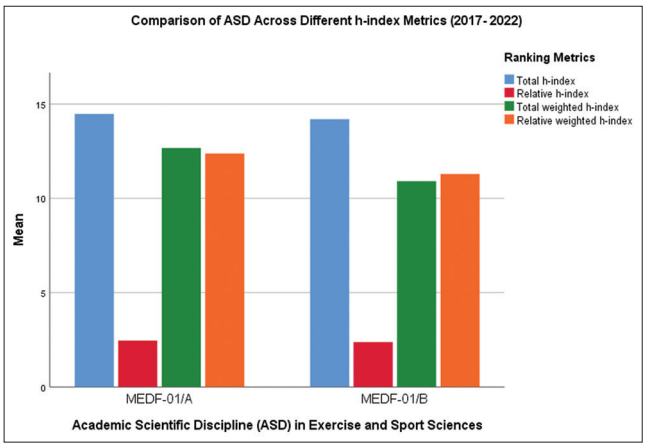

Figure 1. Comparison of ASD across different h-index metrics

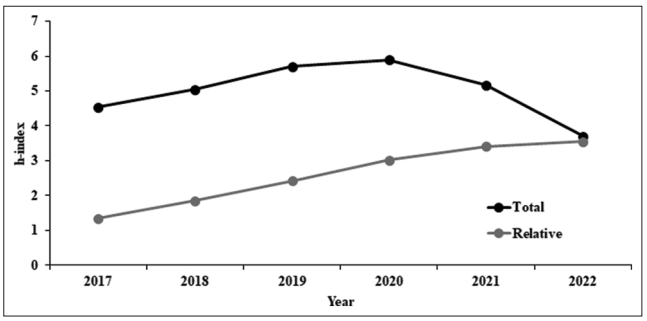

Figure 2. Trends in h-Index metrics for the Sport Sciences subfield from 2017-2022

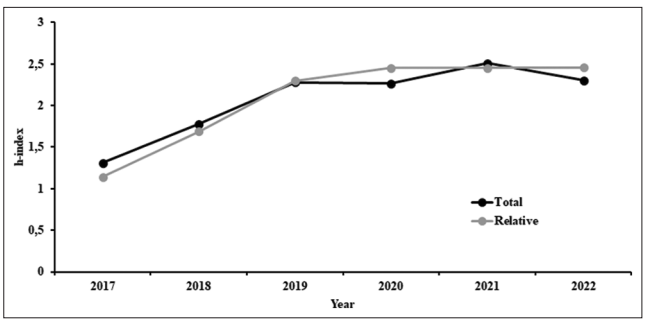

Figure 3. Trends in h-Index metrics weighted by authorship for the Sport Sciences subfield from 2017-2022

In ranking the relative h-index specific to the six keywords, the top 10 includes two scientists from MEDF-01/A and 8 from MEDF-01/B. Finally, in the top 10 of the weighted total h-index ranking and in the weighted relative ranking for the keywords, there are six scientists from MEDF-01/A and four from MEDF-01/B.

Figures 2 and 3 show the trend of four different h-index metrics from 2017 to 2022, highlighting the variations between the Total h-index, the Relative h-index referring to the six keywords of the subfield 'sport sciences,' and their weighted versions based on authorship (single author, first author, co-author, last author).

- The Total h-index (black line) exhibits a consistent increase from 2017 to 2020, reaching a peak of approximately 6 in 2020, followed by a gradual decline in subsequent years, resulting in a value close to 4.5 in 2022. This trend suggests an initial phase of expansion in research output or the overall number of citations, followed by a contraction or stabilization in the more recent period. This pattern indicates that the decrease in overall impact, which overlaps in the later period (2022) with that of the relative h-index for the subfield of Sport Sciences, is attributed to the shift in the scientific production of the 83 ranked researchers, whose output is specifically focused on this area and is recognized by the relevant scientific community.
- In contrast, the Relative h-index (grey line), which reflects the significance of publications specific to the keywords of the subfield of Sport Sciences, demonstrates continuous and linear growth throughout the entire period under consideration, increasing from a value of less than 2 in 2017 to approximately 4 in 2022. This suggests that, despite the decrease in the overall value of the Total h-index, publications pertaining to the specific field have correspondingly gained in impact over time, resulting in a consistent enhancement of the relative indicator.

The two weighted rankings based on authorship provide a less pronounced perspective than that previously observed. The total weighted h-index (black line), which accounts for the weight of the author's position (single author, first author,

co-author, last author), exhibits modest growth from 2017 to 2020, stabilizing around a value of 2.5 after 2020. This stability following 2020 suggests that, while the overall impact of the Total h-index has diminished, the weighted influence based on authorship has remained constant, indicating that the distribution of authorship has not led to increased visibility or impact for more recent publications.

Furthermore, the relative weighted h-index (grey line), which measures relevance specific to the keywords of the subfield of Sport Sciences while incorporating authorship weight, also displays consistent growth, albeit with a shallower slope compared to the Relative h-index. Beginning with a value of approximately 1 in 2017, it reaches just above 2 in 2022, confirming an improvement in the impact of publications within the subfield of Sport Sciences, though this improvement is less pronounced than that observed for the unweighted Relative h-index.

The disparity between the weighted and unweighted indices highlights the moderate impact of authorship positions during the period from 2017 to 2022, contributing to a steady enhancement in the relative quality of specific publications, even amid a decline in the overall value of the Total h-index, which, following this trend, would overlap for the 83 researchers within the subfield of Sport Sciences.

DISCUSSION

The complexity of classifying the impact of Italian scientists categorized within the ESS is now known. It consists of the absolute impact, the same weighted for personal contributions, the impact related solely to the subfield of Sport Sciences, and the impact related to the subfield of Sport Sciences weighted for personal contributions. It emerges that all four rankings include only 83 scientists categorized within the ESS out of 250 scientists present in the CINECA database as of December 31, 2023, which is the official site of the Ministry of University and Research, working at Italian universities. Moreover, the analysis of the impact of the scientific production of Italian scholars within the ESS has highlighted significant differences between unweighted and weighted data based on authorship, suggesting the importance of evaluating both approaches to obtain a comprehensive and detailed understanding of the impact of research.

The unweighted impact, which is simply based on the total number of citations, provides a preliminary indication of a researcher's scientific productivity. However, this assessment can be misleading as it does not account for the quality of participation in research and the importance of each author's contribution within a multi-author product. Consequently, a researcher might appear at the top of the ranking due to the number of publications, without this reflecting a genuine contribution to the research results because they do not hold a prominent role: sole author, first author, or last author. In contrast, the analysis weighted by authorship offers a more nuanced and precise view of an author's impact. Assigning different weights based on each author's position within the publication allows for a more accurate assessment of their actual influence and relevance in the scientific community globally.

The results highlight that authors who occupy the top positions in the unweighted ranking, thanks to their high number of publications, may experience a substantial change in their position when applying the weighting criterion, as evidenced in Table 4. This variation in the ranking underscores the importance of considering the real contribution of each author and the value difference between the various ratings, as shown in Table 4. However, it is also important to emphasize that this role-based approach, as evident on the homepage of each author in the Scopus database, is intrinsically limited because it does not also recognize the role of the second author, which in some scientific communities is weighted as a substitute principal investigator, and the role of the corresponding author, which is seen as an expert in article writing. Another limitation of this study is that it relies solely on Scopus databases, which, while comprehensive, may not capture the full scope of scientific contributions, particularly those outside indexed journals or in interdisciplinary research areas. Additionally, it is important to note that since the data from Scopus was crystallized as of December 31, 2022, those relating to CINECA were instead crystallized as of December 31, 2023, because the data were collected throughout 2023. Given the time required for Scopus to integrate all of them, this ensures that the analysis conducted is consistent and up to date for the period considered. Finally, it is important to note that the distribution of scientists across the four rankings does not suggest any explanation, as it is random. It is only useful to verify how many and which scientists are in each or in part of the four rankings, keeping in mind that for specifics, the fourth-ranking presents greater rigor compared to the other three because it exclusively reflects the subfield of Sport Sciences and the specific contribution of scientists.

The strengths of this study lie in its systematic approach to evaluating scientific impact through multiple weighted and unweighted measures, offering a more holistic view of research contributions. Additionally, by integrating both Scopus and CINECA data, the study provides a more reliable and detailed evaluation of Italian researchers' performance within the ESS. The practical implications of this study include guiding policymakers and academic institutions in refining evaluation criteria for research impact, ensuring a fairer and more accurate assessment of scientific contributions.

CONCLUSION

Comparative analysis of unweighted and authorship-weighted data reveals significant differences in the ranking of scientists and emphasizes the necessity of a critical and analytical approach in evaluating scientific productivity, thereby extending the discussion to the aspect of rating. Weighting allows for the recognition of the true impact and quality of personal contributions to research. This multidimensional approach not only provides a more accurate representation of the scientific community but also aids in guiding future decisions within academic and financial contexts, promoting a more sustainable and innovative development of the ESS. This study strengthens its reliability by integrating both

Scopus and CINECA data, offering a more comprehensive assessment of Italian researchers in the ESS. Its systematic approach, combining weighted and unweighted measures, provides a fairer evaluation of scientific impact and offers practical insights for refining research assessment criteria. The ranking/rating can be updated annually as soon as the Scopus data becomes available. Such frequent updates enable timely reflection of changes in researchers' scientific productivity, offering a current and dynamic assessment of their performance. For the practical applications of this study, it is important to note that funding agencies can benefit from utilizing weighted metrics to determine which projects to fund that involve engaged scientists. Acknowledging the individual contributions of scholars beyond their total productivity, ensures a more effective and targeted use of available resources, thereby enhancing the impact of research. In summary, there is only a limited representation of scientists among those predominantly conducting research within the GoASD of ESS, with a notable and perplexing heterogeneity observed in the top 10 of the four rankings/ratings. The differences between total and relative impact can be attributed to the relatively young age of the ESS within the Italian academic landscape, while the comparison between Sport Sciences and the authorship-weighted impact indicates that some scientists, despite having a lower relative impact in Sport Sciences, make substantially greater contributions. Naturally, other scientists appear in the top 10 of both rankings. This suggests a need for greater emphasis on scientific productivity weighted by authorship in comparison to total productivity, and particularly in relation to Sport Sciences, as it more accurately reflects the genuine impact and true quality of research.

DATA AVAILABILITY

All data generated or analyzed during this study are included within the manuscript.

AUTHOR CONTRIBUTION

Conceptualization, G.R. and G.E.; methodology, S.A.; software, R.C.; validation, G.G. and R.C.; formal analysis, S.A.; investigation, G.E.; resources, G.E.; data curation, S.A.; writing—original draft preparation, G.E.; writing—review and editing, G.R.; visualization, G.G.; supervision, G.R. All authors have read and agreed to the published version of the manuscript.

ETHICAL APPROVAL

Ethical approval was not required for this study, as it is a documentary research project with no associated risks. The study utilized Elsevier's Scopus database, which provides tools to track, analyze, and visualize research trends, citations, and scientific impact.

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