

Gender balance in the scientific production of the Atapuerca archaeological and palaeontological research project

Xosé-Pedro Rodríguez-Álvarez^{1,2} & Sergi Lozano^{2,1}

1) Àrea de Prehistòria, Universitat Rovira i Virgili, Av. Catalunya 35, 43002, Tarragona, Spain
e-mail: xprodriguez@iphes.cat

2) Institut Català de Paleoecologia Humana i Evolució Social (IPHES), Zona educacional 4 (Edifici W3), Campus Sescelades URV, 43007, Tarragona, Spain

Introduction

In recent years, many studies have addressed gender balance in science and, more specifically, the role of women in scientific production. The results from these studies reveal differences according to country, time period and, in particular, scientific discipline (Abramo *et al.*, 2009; Larivière *et al.*, 2013; Torres-Salinas *et al.*, 2011; West *et al.*, 2013). Less attention has been paid, however, to gender balance in the scientific production specific to individual research projects. In order to explore this little-known aspect of gender balance, we focus on the Atapuerca archaeo-palaeontological project (Burgos, Spain), a large-scale mission dedicated to the study of human evolution (Lozano *et al.*, 2014). The scientific output generated by this project embraces various disciplines including: anthropology, palaeontology, geosciences, evolutionary biology, and genetics. Although developed in Spain, this project includes researchers from numerous institutions in 21 countries on five continents. The Atapuerca project is one of the most outstanding research programs to study world prehistory in terms of economic investment, relevance of excavated sites, number of scientists engaged, organisational complexity, and volume of scientific production. From 1978 to 2016, more than 1,000 people participated in excavations at the Atapuerca sites. Subsequent research generated publications in highly rated international scientific journals, including 6 papers in *Nature*, 6 in *Science* and 15 in *PNAS*. In addition, the project has generated a significant social impact with a total of 2,349,052 visitors to the facilities related to the project between

2010 and 2015 (the archaeological sites, the archaeological park and the Museum of Human Evolution). Moreover, Atapuerca is a UNESCO's World Heritage Site since 1997.

Our starting point was to record the number of publications related to this project, as indexed by the Web of Science (WOS) (papers and editorials in journals, and book chapters, excluding abstracts), from 1977 (date of the first indexed publication on Atapuerca) to 2013. We thus compiled a list of publications centred on the Atapuerca archeological sites, as well as those in which data from Atapuerca had been used to perform comparative studies or to address different aspects of human evolution. In order to observe changes over time, we subdivided the study period into "time windows" of five years. A longer time window was employed to englobe the first 17 years of the Atapuerca project (from 1977 to 1993) in order to obtain a balanced number of publications across periods. The final result was a database of 299 publications.

The gender of each author in the database was then manually defined and, when possible, we assessed gender balance by performing statistical tests. Specifically, we assumed a null hypothesis based on the actual ratio of male and female authors in the database and applied binomial tests. For example, to determine the statistical significance of finding a total of 13 articles authored exclusively by women, we took into account the total number of articles published, the average number of authors per article and the overall ratio of female/male authors in the database. All tests were performed using

the R package implementation of an Exact Binomial Test.

Observations

Our study focused on gender balance in 5 scientific aspects: Production, Leadership, Collaboration, Impact and completion of PhD theses.

Scientific production

Out of the 309 authors in the dataset, 64.1% are men and 35.9% are women. The percentage of female authors exceeds that reported by West *et al.* (2013) in the field of human origins JSTOR database for the period of 1990-2011 (25.6%). According to West *et al.* (2013), females working in Palaeontology accounted for only 16.6% of the authors for this discipline, compared to 83.4% of male authors. Concerning specialists publishing in fields relating to Pliocene or Pleistocene fauna for the period of 1990-2011, only 21 (11.6%) were females, compared to 166 (88.4%) male authors (West *et al.*, 2013). Another study by Miguel *et al.* (2013) gives data concerning gender for articles published between 1957 and 2011 in the palaeontological journal *Ameghiniana*, found that 28.6% of the authors were female.

In terms of co-authorship, with an average number of authors per article of 4.94, 74.3% included female contributors, while 95.6% of them were male (Tab. 1). Averages for male and female author contributions per paper were, respectively, 3.42 and 1.52. Moreover, most papers (71.9%) had a majority of male authors, while 16.1% of the articles had the same number of authors of both genders, and only 13% had more female than male authors. The longitudinal view of the data shows a steady increase in the percentage of female participation and average number of women who authored papers (see Tabs. 1 and 2). Nevertheless, the frequency of female authors in this study is lower than that of women who have been part of the Atapuerca research project from the beginning to 2013 (35.9% *vs* 45.4%). It is also well below the percentage of women who have participated in

archeological excavations at the Atapuerca sites (58% of women between 1992 and 2011).

Article leadership

When assessing the leadership of articles, it is common to select either the first author or the corresponding author. In our publications list there are only 10 cases where the first author does not match the corresponding author. We therefore chose to always consider the first author as leader of the article.

In our database, 34.8% of the papers were written by a female first author; a proportion that is very similar to that reported by Larivière *et al.* (2013) for general scientific production in the WOS databases between 2008 and 2012. However, this percentage is higher than those reported in other studies. For example, West *et al.* (2013) show that almost 26% of articles on human origins had female first authors. Moreover, in a study on the gender of authors who published in five North- American Archaeology journals between 1990 and 2013, Bardolph (2014) indicated that 28.6% of the articles were led by women. In our study, the percentage of papers about Atapuerca with female first authors tended to increase over time between 2004 and 2013, to the point where female-male parity was almost reached (see Tab. 3).

If we exclude all publications led by the three male co-directors of the Atapuerca project from 1991 up to the present (20.1% of the total and 30.8% of the articles led by men), the overall percentage of publications led by women is 43.5% (compared to 34.8% when the co-directors are included) and the percentage of male-researcher-led publications drops to 56.5% (65.2% when the co-directors are included).

We also analysed the stage of women's careers who have led publications in our database. In 31.7% of cases, the first author had not yet presented her PhD thesis or had presented it in the same year. In addition, 25% of women-led articles were published between 1 and 3 years after the defence of the author's doctoral thesis and 43.3% were published more than 3 years after the defence of the thesis.

Tab. 1 - Scientific production (publications indexed by the WOS) related to the Atapuerca sites and male / female authorship.

PERIOD	NUMBER OF PAPERS	PAPERS WITH FEMALE PARTICIPATION		PAPERS AUTHORED ONLY BY MEN		PAPERS WITH MALE PARTICIPATION		PAPERS AUTHORED ONLY BY WOMEN	
1977-1993	20	11	55%	9	45%	18	90%	2	10%
1994-1998	33	22	66.7%	11	33.3%	29	93.6%	2	6.4%
1999-2003	65	41	63.1%	24	36.9%	63	96.9%	2	3.1%
2004-2008	58	44	75.9%	14	24.1%	54	93.1%	4	6.9%
2009-2013	123	104	84.6%	19	15.4%	122	99.2%	1	0.8%
TOTAL	299	222	74.3% ***	77	25.7%	286	95.6%	13	4.5%***

Aggregated results on female participation are higher than expected (taking into account the average number of authors per article and the total ratio of female authors) and statistically significant (***) for $p < 0.01$.

Scientific collaboration

Scientific collaboration has a positive effect on production, particularly for international collaborations (Abramo & D'Angelo, 2015). In our study, the percentage of single-author papers shows gender differences, with only 6.7% of the papers led by women having a single author, compared to 12.8% of papers led by a male author. According to our data, in general, both genders tend to publish with a similar number of co-authors (4.89 in papers led by women and 4.97 in papers led by men). Looking to collaborative publications between institutions, we found that 55.8% of articles led by women involved three or more scientific institutions, while in papers led by men the percentage was 42.6%.

Regarding international collaborations, 39.5% of the articles involved more than one country, while 11.7% included institutions from three or more countries. If we analyse the data in terms of first author's gender, 36.4% of the papers led by men included institutions from more than one country, while for those led by women this percentage rose to 45.2%. Similarly, 9.7% of the papers led by men included institutions from three or more countries, compared with 15.4% led by women. This contrasts with results reported

by other studies showing that women are less involved in international collaborations than men (Abramo *et al.*, 2013; Larivière *et al.*, 2013).

Scientific impact

The 299 publications analysed in this study received 9,279 citations up to 31 December 2015 (according to WOS). Consequently, each article was cited 31.03 times on average. Overall, the articles led by men and women were cited an average of 35.50 and 22.66 times, respectively. The largest difference across genders corresponded to the period 1994-1998. This is probably due to the relatively small number of papers published in this period, which made the average number of citations very sensitive to the effect of highly-cited articles (most often led by Atapuerca's male directors). From a longitudinal perspective, this data shows that the scientific impact of publications led by women is increasingly similar to those led by men (see Tab. 3). In this sense, citation averages of articles led by men and by women throughout the period of 2009-2013 are very similar (16.28 *vs.* 14.33). It is noteworthy that previous studies have already documented this trend (Barrios *et al.*, 2013; Borrego *et al.*, 2010; Symonds *et al.*, 2006; Torres-Salinas *et al.*, 2011).

Tab. 2- Average and standard deviation of the number of authors per article by gender, ratio between men/women per paper (total author counting and Fractional counts of publications). SD= standard deviation ANA = Average of number of authors per article; AMA (A) = Average male authors per article; AFA (B)= Average female authors per article; M/F= Male/ Female author ratio per article.

PERIOD	ANA (SD)	AMA (A) (SD)	AFA (B) (SD)	M/F (A/B)	FRACTIONAL COUNTS OF PUBLICATIONS		
					BY MALE (A)	BY FEMALE (B)	M/F (A/B)
1977-1993	3.05 (3.30)	2.20 (2.33)	0.85 (1.18)	2.59	14.8	5.2	2.85
1994-1998	3.12 (2.12)	2.33 (1.88)	0.79 (0.70)	2.95	22.7	10.3	2.21
1999-2003	4.15 (2.87)	3.15 (2.46)	1.00 (1.09)	3.15	49.6	15.4	3.21
2004-2008	5.09 (4.78)	3.33 (3.55)	1.76 (1.75)	1.89	37.6	20.4	1.84
2009-2013	6.09 (3.61)	4.11 (2.66)	1.98 (1.83)	2.08	84.2	38.8	2.17
TOTAL	4.94 (3.73)	3.42*** (2.79)	1.52*** (1.61)	2.25	208.8	90.2	2.32

Aggregated results show a B value higher than expected (taking into account the average number of authors per article and the total ratio of female authors) and statistically significant (***) for $p < 0.01$.

PhD theses

PhD thesis writing is another interesting aspect of scientific production in research projects. Between 1977 and 2013, 67 doctoral theses dealing specifically with Atapuerca, or in which findings from Atapuerca played an essential role, were defended. Parity is reached in this case, since female candidates defended 34 PhD theses compared with 33 by males.

From a chronological perspective, one can distinguish three phases. Firstly, from 1977 to 1998, PhD theses were defended mostly by male students. Then, over the following ten years (1999-2008), the number of PhD theses defended by men and women was balanced. Finally, in the most recent period (2009-2013), the trend has been reversed, with a higher frequency of PhDs being defended by female *vs* male students (62.5% of the total) (Tab. 4). This trend resembles that reported by Bardolph for the United States (2014), where, in 1972, only 32% of PhD theses in Anthropology were defended by women. This percentage then reached 59%

in 1995, and finally 65% of theses completed in 2012-2013.

Interestingly, this evolution of PhD thesis defences affected gender balance in scientific leadership. For example, the period with the lowest percentage of articles led by women (i.e. 1999-2003) was preceded by one with the lowest number of PhD theses defended by women and, therefore, there were few female junior postdoctoral students (one of the most productive stages of a scientific career). On the contrary, the increase in female scientific production in the Atapuerca project since 2004 could be linked to the corresponding increase of PhD theses written by women from 1999 onwards. In fact, 46.2% of the papers led by women during 2004-2008 corresponds with researchers who presented their thesis during this period, and 19.2% were by women who presented their thesis between 1999 and 2003.

The gender parity of PhD students highlighted above is not reproduced by the gender profile of their supervisors, since only 22.2% of

Tab. 3- Leadership of papers by gender (first author) and citations received by articles, as a function of the time period and gender of the first author (male/female). SD= standard deviation; A SD= Average number of citations per article led by male authors; B SD= Average number of citations per article led by female authors; A-B= Differences between the citations to articles led by male and female authors.

PERIOD	% OF PAPERS LED BY MEN	% OF PAPERS LED BY WOMEN	AVERAGE (AND MEDIAN) OF CITATIONS PER ARTICLE				A SD	B SD	A-B
			ALL FIRST AUTHORS	SD	WITHOUT DIRECTORS	SD			
1977-1993	75%	25%	35.5 (16.5)	43.13	31.14 (14)	47.17	34.27 (40.59)	39.20 (55.18)	-4.93
1994-1998	72.7%	27.3%	61.91 (42)	62.23	48.9 (43)	32.16	71.75 (69.96)	35.67 (18.77)	36.08
1999-2003	80%	20%*	39.66 (31)	38.96	40.13 (30)	43.03	42.60 (40.72)	27.92 (29.35)	14.68
2004-2008	55.2%	44.8%**	35.26 (21.5)	43.72	31.66 (21)	32.77	40.59 (53.35)	28.69 (27.36)	11.90
2009-2013	58.5%	41.5%***	15.47 (12)	15.55	15.38 (11,5)	15.97	16.28 (16.57)	14.33 (14.06)	1.95
Total	65.2%	34.8%**	31.03 (19)	39.39	26.49 (16)	26.95	35.50 (44.81)	22.66 (24.47)	12.84

The ratio of articles led by female authors is close to 50% in recent periods, which is remarkable when taking into account the gender ratio of authors. The final column shows the differences between gender averages (statistical significance was marked using a standard notation (i.e. */**/** for $p < 0.1/p < 0.05/p < 0.001$, respectively).

them were women (Tab. 4). A total of 18 PhD theses (26.9%) were supervised by at least one woman while the remaining 49 theses were supervised only by men. These percentages are close to those published by Villarroja *et al.* (2008) who analysed a sample of 1,054 doctoral theses presented in Spain between 1990 and 2004 and found that most thesis supervisors were men (78.2% vs. 13.9%, and mixed in 8% of theses). As expected, these figures are heavily influenced by the role of the directors of the Atapuerca's project, since they supervised half of the PhD theses.

Perspectives

In sum, our results suggest that gender differences are starting to disappear among younger researchers (van Arensbergen *et al.*, 2012).

This trend has been significantly marked in the Atapuerca project by two factors, namely; the role of the three (male) directors in scientific production and the increasing percentage of PhD theses completed by female researchers. Nevertheless, this encouraging fact may be conditioned by the possibility that promising early female scientific careers may be complicated later on when trying to access more stable positions in Academia and Research Agencies (van den Besselaar & Sandström, 2016; Abramo *et al.*, 2016; van den Brink *et al.*, 2010). In Spain, researchers' professional stability is usually reached through a position at a university or at the Spanish Council for Scientific Research (CSIC - Consejo Superior de Investigaciones Científicas). The CSIC is the main government research agency in Spain, and 34% of the publications related to the Atapuerca project have at least one author from this institute. While in general the quantity of women in stable positions in the Spanish

Tab. 4- Doctoral theses related to Atapuerca, as a function of authors' and supervisors' gender. Note that some theses involved two or even three supervisors. NT=Number of Thesis, MS=Male supervisors, FS =Female supervisors.

PERIOD	MALE PHD CANDIDATES			FEMALE PHD CANDIDATES			OVERALL PHD THESES							
	NT	MS	FS	NT	MS	FS	MS	FS						
1977-1993	5	3	60%	2	40%	4	4	66.7%	2	33.3%	7	63.6%	4	36.4%
1994-1998	6	6	100%	0	0%	1	2	100%	0	0%	8	100%	0	0%
1999-2003	4	5	83.3%	1	16.7%	4	3	60.0%	2	40.0%	8	72.7%	3	27.3%
2004-2008	9	12	85.7%	2	14.3%	10	14	87.5%	2	12.5%	26	86.7%	4	13.3%
2009-2013	9	13	76.5%	4	23.5%	15	22	71.0%	9	29.0%	35	72.9%	13	27.1%
TOTAL	33	39	81.3%	9	18.8%	34	45	75.0%	15	25.0%	84	77.8%	24	22.2%

Research System has been increasing slowly but steadily, this trend is not observable for the scientific areas most-closely related to our study, particularly when considering women occupying senior positions (full and research professors). While in Palaeontology there has been a general upward trend in terms of tenured women at universities, this tendency is reversed if looking only to data on full professors (the highest position) (Fig. 1). In Prehistory, the situation is even worse, because in recent years there has been a decrease in the overall percentage of women, especially if we consider full professorships. When comparing data from CSIC from 2001 and 2013, there is a clear decline in the percentage of women research professors in the area of Natural Resources (from 21.6% to 15.4%). In Humanities and Social Sciences, the percentage of research professors increased (from 20% to 26.8%). However, if we analyse this increase in more detail, the data shows that after reaching a peak in 2004 (34.2%), the trend reversed and dropped continuously from 2005 to 2013 (Fig. 1).

Consequently, looking to the future, the consolidation of the observed trend towards gender balance in the Atapuerca project's scientific production seems to depend on 3 factors: a) A moderated influence of the male project directors in the leadership of papers; b) The continuation of

female supremacy regarding PhD thesis writing; and c) The consolidation of the scientific career of young female researchers through job stabilization at universities or research institutions. If this is achieved, young female researchers will be able to maintain the high level of production, international collaboration and leadership that they have displayed during the early stages of their scientific career.

Our results cannot be directly extrapolated to projects in other disciplines. However, applying studies like this to other research projects could provide information on how research strategies designed by project leaders, and the subsequent development of such projects, may influence gender balance in scientific production.

Acknowledgments

This work has been supported by the Spanish MINECO/FEDER Project CGL2015-65387-C03-1-P and the Generalitat de Catalunya projects 2017SGR1040 (with URV project 2016PFR-URV-B2-17) and 2017SGR836. Fieldwork at Atapuerca is supported by Junta de Castilla y León and Fundación Atapuerca. We thank Déborah Barsky for the revision of English language.

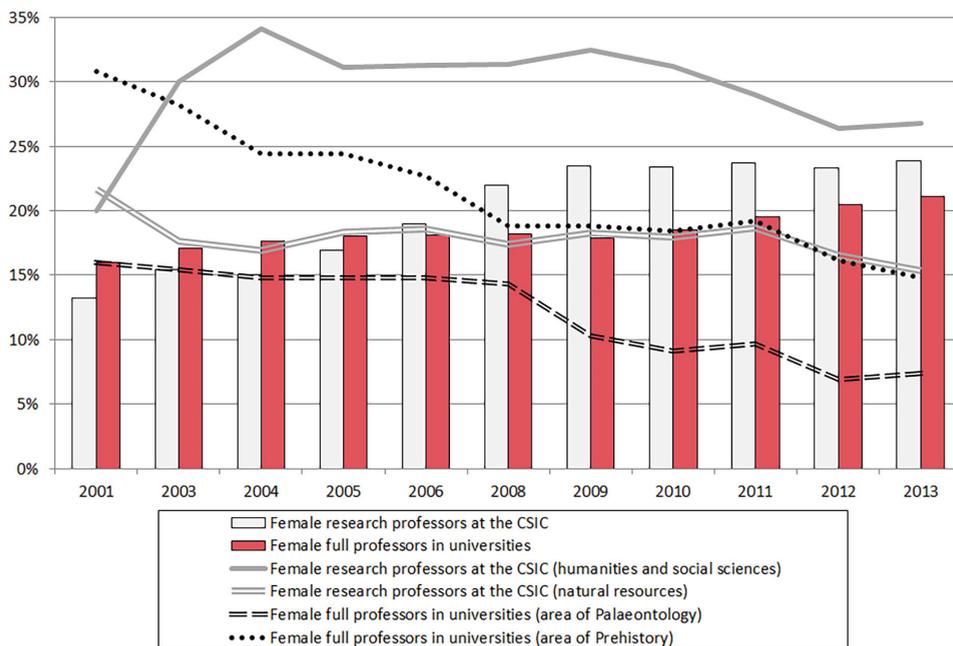


Fig.1 - Percentage of women occupying senior positions in the Spanish research System. Female full professors of Palaeontology and Prehistory (in Spanish public universities), and female research professors in the areas of humanities and social sciences, and natural resources (at the CSIC, the main government research agency in Spain). The colour version of this figure is available at the JASs website.

References

- Abramo G., D'Angelo C.A. & Caprasecca A. 2009. Gender differences in research productivity: A bibliometric analysis of the Italian academic system. *Scientometrics*, 79: 517-39.
- Abramo G., D'Angelo C.A. & Murgia G. 2013. Gender differences in research collaboration. *J. Informetr.*, 7: 811-22.
- Abramo G. & D'Angelo C.A. 2015. The relationship between the number of authors of a publication, its citations and the impact factor of the publishing journal: Evidence from Italy. *J. Informetr.*, 9: 746-61.
- Abramo G., D'Angelo C.A. & Rosati F. 2016. Gender bias in academic recruitment. *Scientometrics*, 106: 119-41.
- Bardolph D. 2014. A Critical Evaluation of Recent Gendered Publishing Trends in American Archaeology. *Am. Ant.*, 79: 522-40.
- Barrios M., Villarroya A. & Borrego Á. 2013. Scientific production in psychology: A gender analysis. *Scientometrics*, 95: 15-23.
- Borrego A., Barrios M., Villarroya A. & Ollé C. 2010. Scientific output and impact of postdoctoral scientists: A gender perspective. *Scientometrics*, 83: 93-101.
- Larivière V., Ni C., Gingras Y., Cronin B. & Sugimoto C.R. 2013. Global gender disparities in science. *Nature*, 504: 211-13.
- Lozano S., Rodríguez X.-P. & Arenas A. 2014. Atapuerca: evolution of scientific collaboration in an emergent large-scale research infrastructure. *Scientometrics*, 98: 1505-20.
- Miguel S., Hidalgo M., Stubbs E., Posadas P. & Ortiz Jaureguizar E. 2013. Estudio bibliométrico de género en la paleontología de vertebrados. El caso de la revista argentina *Ameghiniana* (1957-2011). *Investigación Bibliotecnológica*, 27: 133-55.

- Symonds M.R.E., Gemmell N.J., Braisher T.L., Gorringe K.L. & Elgar A. 2006. Gender Differences in Publication Output: Towards an Unbiased Metric of Research Performance. *PLoS One*, 1: e127.
- Torres-Salinas D., Muñoz-Muñoz A.M. & Jiménez-Contreras E. 2011. Análisis bibliométrico de la situación de las mujeres investigadoras de Ciencias Sociales y Jurídicas en España. *Rev. Esp. Doc. Cient.*, 34: 11-28.
- van Arensbergen P., van der Weijden I. & van den Besselaar P. 2012. Gender differences in scientific productivity: A persisting phenomenon? *Scientometrics*, 93: 857-68.
- van den Besselaar P. & Sandström U. 2016. Gender differences in research performance and its impact on careers: a longitudinal case study. *Scientometrics*, 106: 143-62.
- van den Brink M., Benschop Y. & Jansen W. 2010. Transparency in Academic Recruitment: A Problematic Tool for Gender Equality? *Organization Studies*, 31: 1459-83.
- Villarroya A., Barrios M., Borrego A. & Frías A. 2008. PhD theses in Spain: A gender study covering the years 1990–2004. *Scientometrics*, 77: 469-83.
- West J.D., Jacquet J., King M.M., Correll S.J. & Bergstrom C.T. 2013. The Role of Gender in Scholarly Authorship. *PLoS One*, 8: e66212.

Associate Editor, Markus Bastir



This work is distributed under the terms of a Creative Commons Attribution-NonCommercial 4.0 Unported License <http://creativecommons.org/licenses/by-nc/4.0/>