Consumption of anabolic steroids in sport, physical activity and as a drug of abuse: an analysis of the scientific literature and areas of research

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CONSUMPTION OF ANABOLIC STEROIDS IN SPORT, PHYSICAL ACTIVITY AND AS A DRUG OF ABUSE: AN ANALYSIS OF THE SCIENTIFIC LITERATURE AND AREAS OF RESEARCH

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ABSTRACT

Objective: The consumption of anabolic steroids (AS) has been growing continuously in recent years. It has gone beyond the sports world; AS are now widely used as drugs of abuse in connection with bodybuilding. This study sets out to assess the state of scientific research in the area.

Design: Bibliometrics were employed to evaluate the literature retrieved from the principal relevant bibliographic databases, viz. MEDLINE, SportDiscus, Science Citation Index Expanded™ and Social Sciences Citation Index®. The core journals were identified along with the leading authors and research groups and their institutional affiliations. Techniques based on social network analysis were applied in order to build up a concept map of research.

Results: The documents retrieved numbered 1,325. They were produced by 3,131 different researchers giving a Collaboration Index of 3.32. The institutions with the most productive authors were Ball State University (Muncie, IN, USA), the École Nationale Vétérinaire de Nantes (ENVN), the Institut Municipal d´Investigació Mèdica (IMIM) (Barcelona, Spain), the Institute of Biochemistry of the German Sport University Cologne (DSHS), Iowa State University, Maastricht University and the University of Iowa.

Conclusions: It was concluded that there has been an upward trend in the number of research projects. The sources used complemented one another, since 78.04% of the documents retrieved were unique to one source. The productivity ranking was headed by Sports Medicine journals, followed by journals of Chemistry, Physiology, Endocrinology and Substance Abuse. Besides sporting activities, the most important research clusters were those connected with bodybuilding and with youth groups.

Keywords:
Anabolic Steroids
Sports
Drugs of abuse
Bibliometric Research
Network analysis

INTRODUCTION

Steroids are synthetic substances that mimic the effects of the natural male hormone testosterone. Their effects are both anabolic (muscle-building) and androgenic (they increase masculine characteristics); which of the two is paramount depends on the chemical composition of the steroid. They are used in sport to increase muscle mass, strength and resistance to fatigue;[1, 2] but according to some researchers, the greatest benefit from taking them is their effect on the central nervous system, which makes athletes more aggressive in training and in competition.[3]

Consumption of this class of substances has increased considerably during the last few decades. Various studies have pointed to increases both in the quantities taken and in the range of new substances. Use by top sportsmen and athletes constantly makes headlines in the media. The sports where consumption is highest include bodybuilding, baseball, athletics, wrestling, American football, weightlifting, swimming, soccer and cycling.[3-6]

It is in this context that steroid consumption is approached in sports science as an area of knowledge related to the systematic acquiring and evaluating of information about sport, embracing any discipline that uses the scientific method and which relies on observed data, not biased perceptions or vague statements, to explain and predict the sporting phenomenon.[7]

However, AS taking has gone beyond the sports environment and become similar to consumption patterns associated with recreational use – among a population that, furthermore, has a low risk perception of AS -. This makes it necessary to undertake the study of AS in a broader perspective.[8, 9]

Bibliometric analysis of quantitative data about scientific literature enables very precise determination of the state of research in a given branch or subject area.[10] It proceeds by identifying the principal bibliographic databases for the field, the distribution of the source journals in which the research is published, and the agents mainly responsible for scientific activities.

The purpose of the present study was to analyse the current state of research into the taking of AS in professional sport and as a drug of abuse, and to do so by applying bibliometric techniques. The contribution of the main databases was assessed and the core journals, leading authors, research groups and institutional affiliations were identified. In addition, a terminological analysis has been conducted in order to build up a conceptual map of the relationships that exist between the main research subject areas.

Undertaking the present study was justified by the interest that this type of investigation has for professionals in the field in question, and by the small number of such studies in this and other related areas.[11, 12]

METHODS

The procedure comprised the following steps:

a) Selecting the databases and composing a search profile

The databases selected were *MEDLINE, SportDiscus, Science Citation Index Expanded* and *Social Sciences Citation Index.*

The MEDLINE database is produced by the National Center for Biotechnology Information (NCBI) of the United States National Library of Medicine (NLM)

(http://www.nlm.nih.gov). Accessible free of charge through the *Pubmed* platform, its coverage and volume make it the main world database specialising in medicine and health sciences, as it contains roughly 14 million entries of 4,800 biomedical journals from all over the world. For indexing the documents it uses the *Medical Subject Headings* (MESH) thesaurus, a controlled vocabulary giving 23,800 headings apart from 83 subheadings or "qualifiers" whose purpose is to narrow down or specify the standpoint of the aspects covered.

Sport Discus is a database specialising in the sports field which covers all aspects to do with this activity, such as health, fitness and sports medicine, amongst many others. Produced by Canada's Sport Information Resource Center (SIRC) (http://www.sirc.ca), in cooperation with other bodies belonging to the International Sports Information Association (IASI), it covers over 2000 journals in the area using the documents of the sport thesaurus for assigning descriptors.

Finally, *Science Citation Index Expanded* (SCI-expanded) and *Social Sciences Citation Index* (SSCI) are two multidisciplinary databases distributed by Thomson Scientific over the web of knowledge platform (http://www.isinet.com) conceived with the aim of compiling nuclear journals publishing works in the different areas of knowledge, that are determined according to the number of citations received, which is why its use, apart from a bibliographic source, as a an instrument for appraising scientific agents and source journals publishing the works has extended. These databases compile the works published in 5900 journals in 150 science disciplines and 1725 journals in over 50 disciplines in the field of social sciences, respectively.

For retrieving documents, a search was composed with the generic descriptors *steroid*, *anabolic* and *androgenic* enriched with terms specific to these substances and combined into a set of descriptors referring to substance consumption either in sport or as drugs of abuse (Table 1). The search was limited to the time period 1996-2005 and to the document type 'original articles'.

Table 1. Listing of the terms used to build the search profile (the search was carried out in June. 2006).

*: Truncated to retrieve derived forms.

Generic chemical terms and steroid or anabolic substances			
anaboli*	danazol	gestrinon*	*oxabolon**
androgen*	dehydrochloromethyltestosteron*	mestanolon*	*oxandrolon**
androstendediol	dehydroepiandrosterone	mesterolon*	*oxymesteron**
androstendiol*	dihydrotestosteron*	methandienon*	*oxymetholon**
androstendion*	drostanolon*	methandriol*	*prasteron**
androstenedione	epitestosterone	metenolon*	*quinbolon**
bolasteron*	estanozolol	methyltestosteron*	*stanozolol*
boldenon*	flormebolon*	miboleron*	*steroid**
calusteron*	fluoxymesteron*	nandrolon*	*trenbolon**
clostebol*	furazabol*	noretandrolon*	*19-norandrostend**
Terms referring to the use and consumption of substances or to addictions			
abuse	codependen*	drug misuse	*substance abuse*

addiction	doping	drug prevention	*substance dependence*
black market	dependenc*	illicit drug use	*substance misuse*
body dysmorphic disorder	drug detection	psychotropic substance use	*substance-related disorders*
withdrawal			
Generic and other terms connected with sport			
body image	mass media	reverse anorexia	*sport**
elite athlete*	performance	role model	*strength training*
suspension			

b) Building a database of the bibliographic data retrieved and having a panel of experts assess the records

The database was structured as an ad hoc application of Microsoft Access. The records specified the database from which the data was drawn and the bibliographic information that appeared in the records retrieved. The records were evaluated by an independent panel of three subject experts from sport medicine and substance abuse with the aim of selecting only those that were relevant to the use and consumption of AS in sports or as drugs of abuse. Conversely they rejected records that had to do with the use of these drugs as pharmaceuticals or for other medical and therapeutic purposes, and likewise basic research on them in animals (in the case of databases where it had been impossible exclude this aspect from the raw search). Records were accepted as relevant when the three evaluators were in agreement about them. When there was no consensus about the records, the full texts of the documents were examined. In addition, documents classified in the 'Level' field of SportDiscus as 'Beginning' were eliminated because they were usually popular science publications or practical advice not intended for specialists and were not structured like scientific publications.

c) Bibliometric analysis

The following measures and indicators were computed: absolute contribution index, specific contribution index and index of overlap between databases; core journals in which the documents appeared; scientific productivity ranking and patterns of author collaboration (number of documents, number of authors, collaboration index or average of authors per document, number of collaborators); ranking of institutional affiliations of the most productive authors. It should be stressed that the analysis of the institutions is based on identifying the institutional affiliation of the most productive authors, as all the institutional affiliations of the authors of the documents are not given in one of the main databases used (MEDLINE).

The Absolute Contribution Index is the percentage of bibliographic references provided by a given bibliographic source compared with the total of references obtained from all sources (ignoring repetitions). The Specific Contribution Index is the percentage of references retrieved uniquely from one source (i.e., excluding overlaps) compared with the total of references from all the sources (ignoring repetitions). The Overlap Index is the percentage of references that are common to two or more sources compared with the total of all references from all sources (ignoring repetitions).[13, 14]

d) Building social networks of authors and performing a subject analysis of terms

A structural analysis was carried out in the form of networks. All co-authorships (combinations of pairs of authors) were identified for each document, the number of such relationships being in proportion to the number of authors. Thus, in a publication with a single author there was no co-authorship; with two authors there was a single co-author relationship; with three authors, three relationships (A with B, A with C, B with C), with four authors, six relationships (A with B, A with C, A with D, B with C, B with D and C with D) and so on. Next the number of co-authorships had to be recalculated in order to arrive at the *collaboration intensity*, because many of them are repeated when a document collection is large. This information was fed into an algorithm for identifying clusters of authors or research teams. A cluster was considered to exist when at least two authors were identified who were linked to one another by a number of co-authorships equal to or greater than a number decided on a priori; the algorithm was iterated for a range of >=2 to >=6 co-authorships. These thresholds were applied to learn how the degree of collaboration evolved and with a view to concentrating the analysis on the most intense relations, thus enabling an appropriate visualisation and representation of the network.

These analyses, applied to the study of coauthorship and collaborative relationships between institutions for scientific publications, allow the existing relations between the social agents responsible for the publications to be identified and represented graphically, setting out the number of members in the network, the intensity of the relationship existing between them (represented by different thickness lines) and who the most relevant members are with respect to a wide range of measures or indicators.

Finally, a subject field analysis was performed by building a network of concept relationships. This involved identifying and quantifying the terms included in the title field of the bibliographic records. Non-content (closed class) words were eliminated; plurals and other variants were lemmatised so that word forms expressing a same concept or one very close to it semantically could be normalised.

The Pajek network analysis program was used for constructing the author networks and the concept map.[15]

RESULTS

The search retrieved 6,998 documents from the MEDLINE database, 1,238 from SportDiscus and 5,541 from SCI-Expanded and SSCI. The manual revision of the records led to 6,162 MEDLINE (88.05%), 790 SportDiscus (63.81%) and 5,145 SCI-Expanded and SSCI citations (92.85%) being eliminated.

Consequently, the analysis was performed on 1,325 different documents (Table 2). MEDLINE was the database with the highest indices, in terms of absolute contribution (63%), specific contribution (44%) and overlap (19%). The absolute contribution indices of SportDiscus and MEDLINE were similar (34% and 30% respectively); the SportDiscus specific contribution index was appreciably higher than that of SCI/SSCI, while the overlap index of the latter two was

higher than that of SportDiscus. Fig. 1 shows how the absolute contribution index evolved over time.

Table 2. Contribution Indices of the databases analysed

Indices	MEDLINE		SportDiscus		SCI/SSCI		All DBs	
	Papers	%	Papers	%	Papers	%	Papers	%
Absolute Contribution	836	63.09%	448	33.81%	396	29.89%	1325	100%
Specific Contribution	583	44%	281	21.21%	170	12.83%	1034	78.04%
Overlap	253	19.09%	167	12.6%	226	17.06%	646	48.75%

As for the journals in which the publications appeared (Table 3), *International Journal of Sports Medicine* came first in the productivity ranking (45 articles), followed by *Medicine and Science in Sports and Exercise* (39), *British Journal of Sports Medicine* (28), *Clinical Journal of Sport Medicine* (26), *Sports Medicine* (22), *European Journal of Applied Physiology* (17) and *Clinical Chemistry* (16). Another 10 journals scored more than nine articles, and 30 journals published between six and nine articles. The remainder of the articles were scattered over another 542 journals that published five or less.

Table 3. Source journals for the articles

Journal Title	Papers
International Journal of Sports Medicine	45
Medicine and Science in Sports and Exercise	39
British Journal of Sports Medicine	28
Clinical Journal of Sport Medicine	26
Sports Medicine	22
European Journal of Applied Physiology	17
Clinical Chemistry	16
Journal of Sports Sciences	13
Journal of Strength and Conditioning Research	12
Journal of Analytical Toxicology	11
Journal of Chromatography B	11
Journal of Clinical Endocrinology and Metabolism	11
Journal of Sports Medicine and Physical Fitness	11
Science & Sports	11
Forensic Science Internacional	10
International Journal of Sport Nutrition and Exercise Metabolism	10
Medicina Dello Sport	10
9 journals with 9 publications	81
1 journal with 8 publications	8
8 journals with 7 publications	56
12 journals with 6 publications	72
13 journals with 5 publications	65
16 journals with 4 publications	64
35 journals with 3 publications	105
93 journals with 2 publications	186
385 journals with 1 publication	385
TOTAL	**1.325**

The whole corpus of 1,325 articles was produced by 3,131 different researchers, responsible collectively for 4,398 authorships, which gives an Author / Article Index of 3.32. Table 4 is a listing of the most productive authors (>=10 publications), the patterns of collaboration in their articles and their institutional affiliations.

Table 4. Most productive authors (>=10 papers), with institutional affiliations and collaboration patterns

Author	Papers	Signatures	Collaboration index (average signatures/paper)	Collaborators*	Institutional Affiliation
Kraemer WJ	20	163	8.15	65	Ball State University (USA)
Kintz P	19	55	2.89	11	Institut de Médecine Légale de Strasbourg, Université Louis-Pasteur (France)
Pope HG	18	79	4.39	41	Harvard University (USA)
Kuipers H	14	57	4.07	16	Maastricht University (Netherlands)
Segura J	14	59	4.21	23	Institut Municipal d´Investigació Mèdica, Universitat Pompeu Fabra (Spain)
Hakkinen K	13	124	9.54	50	University of Jyväskylä (Finland)
Catlin DH	12	55	4.58	23	University of California (USA)
Cirimele V	12	46	3.83	9	Institut de Médecine Légale de Strasbourg-Université Louis-Pasteur (France)
Hartgens F	12	52	4.33	15	Maastricht University (Netherlands)
Volek JS	12	124	10.33	55	Ball State University (USA)
Yesalis CE	12	33	2.75	10	Pennsylvania State University (USA)
Ludes B	11	43	3.91	9	Institut de Médecine Légale de Strasbourg, Université Louis-Pasteur (France)
Schanzer W	11	36	3.27	15	Institute of Biochemistry, German Sport University Cologne (Germany)
Bahrke MS	10	30	3	9	Pennsylvania State University (USA)
Davies B	10	43	4.3	12	University of Strathclyde (UK)
Grace FM	10	43	4.3	12	University of Glamorgan (UK)
Kindermann W	10	33	3.3	11	Institute of Sports and Preventive Medicine, University of Saarland (Germany)
Urhausen A	10	31	3.1	10	Institute of Sports and Preventive Medicine, University of Saarland (Germany)

* Total No. of authors collaborating (an indicator that shows the size of an author's collaborator team).

Using a threshold of three or more publications written in collaboration, 52 author clusters and research groups were identified, made up of 192 authors and with the largest team having 18 members. Figs. 2 to 4 represent the main groups (>= 4 members) graphically, and Table 5 shows the values obtained by applying different thresholds and intensities of collaboration.

Table 5. Values resulting from the identification of clusters or groups of authors when applying different collaboration thresholds

Threshold (co-authored publications)	Different co-authorships	Clusters	Authors in the clusters	Authors in the largest cluster	Average authors/cluster
>=6	23	11	28	5	2.54
>=5	50	18	54	9	3
>=4	116	32	102	14	3.19
>=3	279	52	192	18	3.69
>=2	755	110	459	32	4.17

Turning now to the institutional affiliations of the most productive authors in the research groups identified (Table 6), Ball State University occupies first place with 12 members. Next in line come six institutions with six members each: École Nationale Vétérinaire de Nantes (French Ministry of Agriculture), Institut Municipal d´Investigació Mèdica (Pompeu Fabra University, Barcelona), Institute of Biochemistry (German Sport University, Cologne), Iowa State University, Maastricht University and the University of Iowa. Another four institutions have five members, and finally there are seven institutions with four researchers each.

Table 6. Principal institutions of affiliation of the authors in the clusters.

Institution	Authors	Most productive authors (>9 papers)
Ball State University (USA)	12	2
Ecole Nationale Vétérinaire de Nantes, Ministry of Agriculture (France)	6	0
Institut Municipal d´Investigació Mèdica-Universitat Pompeu Fabra (Spain)	6	1
Institute of Biochemistry, German Sport University Cologne (Germany)	6	1
Iowa State University (USA)	6	0
Maastricht University (Netherlands)	6	2
University of Iowa (USA)	6	0
Harvard University (USA)	5	1
State University of New York (USA)	5	0
University of Gothenburg (Sweden)	5	0
University of Heidelberg (Germany)	5	0
Arizona State University (USA)	4	0
Centro de Investigacion y Medicina del Deporte de Navarra, Government of Navarre (Spain)	4	0
Drew University of Medicine and Science (USA)	4	0
Institut de Médecine Légale de Strasbourg, Université Louis-Pasteur (France)	4	3
Institute of Doping Analysis and Sports Biochemistry of Kreischa (Germany)	4	0
University Institute of Motor Sciences (Italy)	4	0
University of Glamorgan (UK)	4	1

Fig. 5 consists of the map of concept relationships graphed from the co-occurrence frequencies of the terms appearing in the document titles. Two noticeable elements are the terms for populations and for consumption contexts (*youth*, *adolescent*, *athlete*, *sport*, *exercise*, etc.) Another group of terms refers to substances (*testosterone*, *epitestosterone*, *nandrolone*) and the means for *detecting* them (connected with *gas chromatography*, *urine* analysis and *hair* analysis). Finally, there is another set of terms relating steroids with patterns of consumption (for example *use*, *abuse*, *dependency*, nutritional *supplements*), *behavior* and *effects*.

DISCUSSION

In any field of research, there are principal agents, social actors, who can be considered 'leading edge' because of their high productivity and their intense collaboration with their peers.[16] They include the individuals, teams and institutions that are engaged in or responsible for research on AS, and the method applied here has made it possible to identify them. In addition, we have mapped the main research topics and their relationship with the consumption of these substances in sport and as drugs of abuse.[17]

The present study nevertheless has the following limitations: a) only three databases were used; b) it is possible that the search profile was not comprehensive enough to retrieve all the publications related to the field; c) we did not analyse other types of document than articles, such as monographs and theses. We would point out, however, that a) the databases were the most representative on account of their wide coverage (MEDLINE), their specialisation on sports (SportDiscus), or because they were compiled from source journals with the greatest international impact and diffusion (SCI-Expanded, SSCI);[18, 19] b) using a research profile achieved greater accuracy of retrieval than would have been possible without one; c) the document type chosen is the one that best mirrors the current state of research.

The study makes it clear that the databases we used complement one another as sources for the subject area concerned, since 78.04% of the publications were cited in only one of them. However, it also stands out that it is a relatively general database like MEDLINE which is the main source of information. The comparative chronological graph of contribution indices (Fig. 1) reveals a sharp rise in the number of publications in MEDLINE and a stable contribution from SCI-Expanded / SSCI, while SportDiscus is the most irregular. This last is marked by a sharp drop in contribution in recent years (2003-2005) due to an indexing backlog; thus there were 50,000 records for 2003, but only 25,000 for 2004 and 13,000 for 2005. The large number of documents eliminated after retrieval from the MEDLINE and SCI-Expanded / SSCI data can be explained by the more general and multidisciplinary character of those databases, which leads to a high proportion of noise.

As regards the source journals of the publications, it is noteworthy that the sports medicine journals head the productivity ranking; indeed the five highest-ranking journals belong to that area, as well as numerous other less productive

journals. The top-ranking positions are occupied by chemistry, physiology, endocrinology and substance abuse journals.

As regards the groups, only a small number of these are formed by a large number of authors with stable cooperation relationships. Most of the groups have a national distribution, with some international contact. In this respect one essential aspect is the encouragement for creating interdisciplinary groups and transnational research [20]. As for the institutions to which the authors are affiliated, there is a prevalence of the ones connected with methods for detecting substances or anti-doping control. Other centres work in physiological studies, the effects of consumption, use of as outside the sports field and the evidence of psychological dependence on these. The United States, along with certain European Union countries, prominently France, Germany, UK, the Netherlands and Spain, lead the way in research in this area, and one can stress the absence of countries from other geographical spheres, such as Asia, Oceania or Latin America.

In conclusion, the concept map enables one to draw some interesting inferences concerning consumer groups and contexts, because it highlights the fact that besides the research focused on sport and elite athletes, there is a set of terms connecting AS with other consumer populations and contexts, for example *bodybuilding*. There are indeed numerous studies that have drawn attention to the completely uncontrolled use of AS in places like gymnasiums, physical culture clubs, health centres and university physical education departments;[6] likewise among professionals in the armed forces and members of public and private security corps.[21] Also in the map, one can hardly fail to notice the terms referring to pre-adult populations, for instance *adolescent* and *student*. In this connection, an American study revealed as long ago as 1990 that the most serious drug problem in many USA schools was not banned substances like cannabis or cocaine but AS.[22] More recent studies in the United States and Australia indicate that 5-10% of secondary and postsecondary students in those countries take AS to improve their physical appearance.[9, 23, 24]

Apart from the aspects mentioned which have been identified, there should be deeper research into the relationship of as with polyconsumption. Hence, different studies reveal a correlation between the adolescent population's use of anabolic steroids and their consumption of other drugs, such as cocaine, crack or cannabis, and with risk conducts such as binge-drinking, unprotected sexual relations, failure to use the safety belt and carrying weapons [25]. It will also be necessary to carry out epidemiological studies on the consumption of as as a drug of abuse among the population in general and particularly on the physical and psychic effects produced by the abusive consumption of as in particular in younger people and with special stress on dysmorphic body disorders such as adonis complex. It would finally be desirable to go further into research on the validity and reliability of the methods of detecting anabolic substances and the analysis of emerging substances, considering all sports alike.

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What is already known on this topic?

Some works have stressed the interest of bibliometric studies applied to Sports Sciences, analysing some journals in the area. Recently there has been great interest for the Analysis of Social Networks for identifying social structures and characterising cooperation between scientific agents as well as conceptual maps enabling learning the spheres of research tackled in different disciplines or areas of knowledge.

What this study adds?

This study sets out to assess the state of scientific research in the area. There is an identification of the nuclear journals published, the contribution of the main databases, the authors and research groups. A conceptual map has been constructed identifying the main subjects dealt with and any gaps in the research work done.

Fig. 1. Chronological evolution of the Absolute Contribution Index of the databases.

Fig. 2. Author clusters (>6 members) when applying a collaboration threshold of three or more publications co-authored.

Fig. 3. Author clusters (5-6 members) when applying a collaboration threshold of three or more publications co-authored.

Fig. 4. Author clusters (4 members) when applying a collaboration threshold of three or more publications co-authored.

Fig. 5. Concept network from applying a co-occurrence threshold of 10 or more papers.

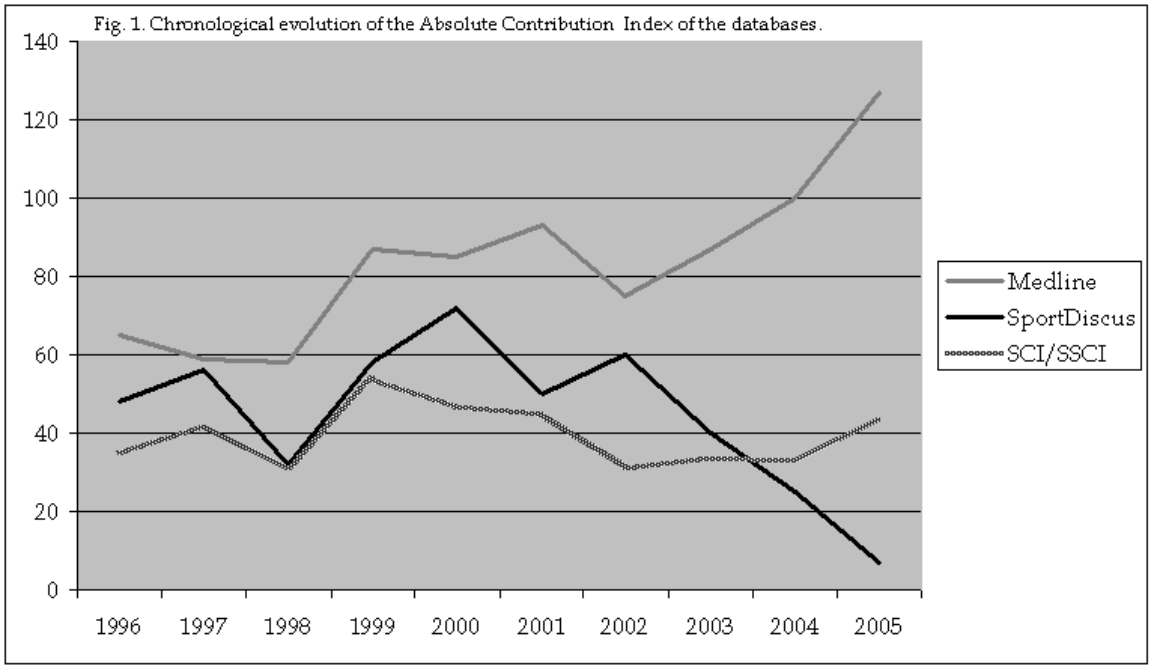

Fig. 2. Author clusters (>6 members) when applying a collaboration threshold of three or more publications co-authored.

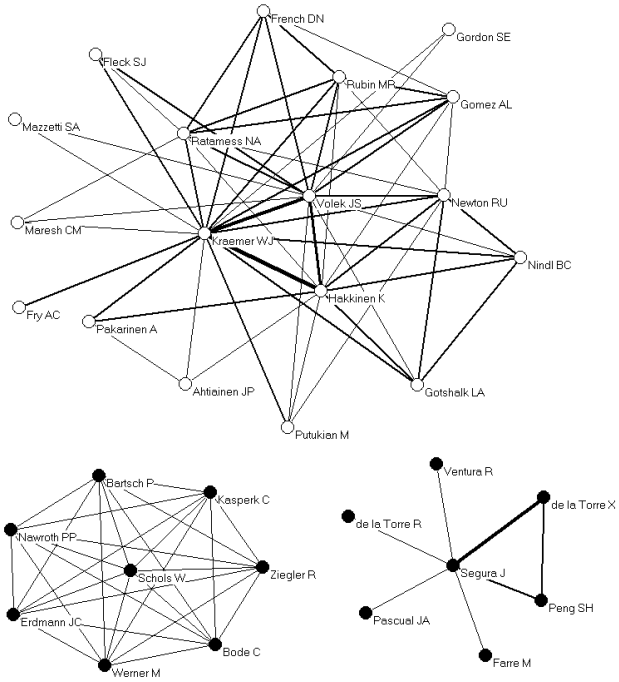

Fig. 3. Author clusters (5-6 members) when applying a collaboration threshold of three or more publications co-authored.

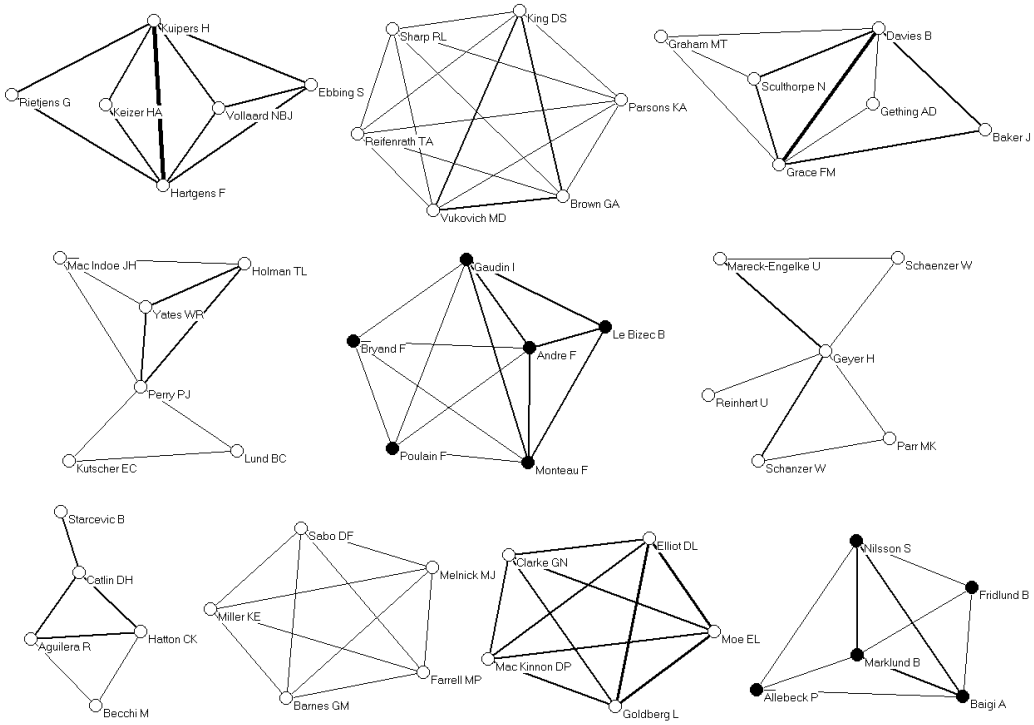

Fig. 4. Author clusters (4 members) when applying a collaboration threshold of three or more publications co-authored.

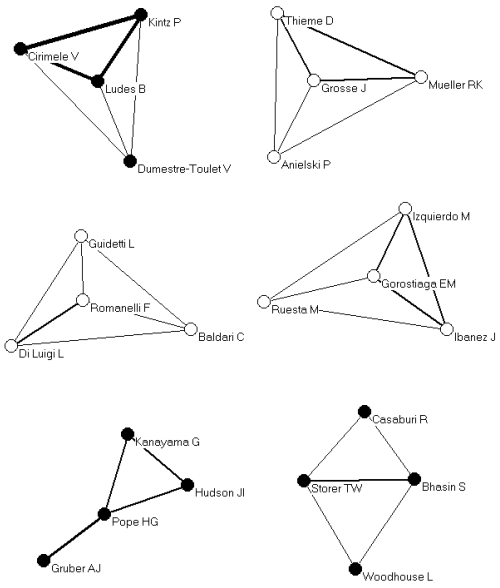

Fig. 5. Concept network from applying a co-occurrence threshold of 10 or more papers.