Anthropometry and Scan: A Computational Exploration on Measuring and Imaging

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Abstract. New developments in the field of technology have led to the use of scanners in order to obtain anthropometric measurements. As a matter of fact, anthropometry finds its roots in the seventeenth century, currently its usage has been strengthened by the employment of scanners. 3D whole-body scanners allow to collect reliable data and to visualise the exact human body shape. Thus, this paper aims at exploring the combination of these topics, anthropometry and scan, through an innovative tool, the scientometrics analysis. This technique provides a clear overview of the existing literature in the field investigated. In our study we examined 1'652 papers from the Web of Science Core Collection database. Network analyses have shown an interesting scenario, emphasising the research evolution over time. Specifically, endocrinology and metabolism emerged as the most active publication domains. Accordingly, the two most high-impact journals and the most cited paper regard nutrition issues and metabolic risk factors respectively. However, the predominance of the USA for number of publications has not been confirmed by the institution's analysis, which has shown the University of Copenhagen as the most influential one. On the other hand, Yumei Zhang currently appears as the main authority in the field and Leslie G. Farkas as the most influential author over the entire time span analysed. The relevant implications of the findings are discussed in terms of future research lines.

Keywords: Anthropometry · Scan · 3D scan · Anthropometric measurements · Scientometrics analysis · Network analysis

1 Introduction

Nowadays human body shape has increasingly become useful to assess in several research fields. Digital anthropometry exploits mathematical analyses to investigate and define the shape of the body. These evaluations are performed using optic measuring methods with 3D imaging modalities. These techniques ensure that reliable data are

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obtained, and that these can be used in studies aim at improving human quality of life. Body parts and proportions have been of great interest, especially for aesthetic and figurative purposes, however from the 17th century the study of body shapes shifted to the scientific and medical field. By definition, anthropometry is considered a branch of morphometry and is the study of size and form of the body and its variations [1]. Traditional anthropometry aims at providing information about linear measurements and ratios, these consist of lengths, widths and depths whereas geometric (modern) anthropometry gives geometric information of the structure and it is a coordinates-based method [1, 2]. In particular the use of anthropometry in medicine has been applied in the context of nutritional status, within this field different anthropometric variables are used to assess morphological status and body composition [3]: height, weight, Body Mass Index (BMI), Waist to Height Ratio (WHtR), waist, hip, mid-upper arm and mid-arm muscle circumference, Waist-Hip Ratio (WHR), Sagittal Abdominal Diameter (SAD) and skinfold measurements are the most common variables applied for the study of clinical nutrition. Recent proceeding in the field of anthropometry has yielded to remarkable change due to the introduction of new tools for the study of the body, such as 3D whole body scanners, that are now powerful competitors of simple anthropometric tools/measurements and calipers [1, 4]. These 3D scanners use infrared light to create high-quality images of the body with non-invasive optical method. So far, 3D scanner has been applied in different context, initially in the clothing industry, then in psychology (e.g. body image) and medicine (e.g. anthropometry and musculoskeletal condition) [5]. For instance, different study used 3D scanner to provide 3D avatars in combination with virtual reality (VR) to study body image distortion in patients with anorexia nervosa [6, 7]. In the medical field, 3D scanners can be used to study obesity, risk factors associated with metabolic syndrome and body composition [8, 9]. Moreover, recent development in radiology allowed the study of internal structures by means of imaging techniques such as Computed Tomography (CT), Dual-energy X-ray Absorptiometry (DXA) and Magnetic Resonance (MR) [1, 10]. 3D scanner images can be used in combination with these data. For instance, 3D scan can be used in combination with DXA and traditional measurements to cluster participants by age, height, weight, BMI, percentage of fat mass, free fat mass, lean mass and bone mass [11].

According to Heymsfield and colleagues [4] whole body scanner can be used to extract anthropometric measures (e.g. height, hip, waist) and body shapes and to predict body composition, health risk and DXA, CT and MR images; additionally, digital anthropometry is considered a faster, cheaper and safer technique compared to classic imaging methods and can provide additional variables useful for the study of body parts and shapes [4, 5].

Fields of applications and methods used in the context of 3D scanners are multiple and in order to clarify past and current literature and future directions. The present scientometrics analysis has the objective to summarize and outline an overview of this technology in the field of anthropometry. This analysis is a computational bibliometric exploration that allows to visualize the existing literature within the scientific domain selected and to identify trends and patterns within the field. Citespace is a freely available computer program written in Java useful in this purpose, it takes bibliographic information, especially from the Web of Science and generates interactive visualizations of nodes and links (i.e. networks).

2 Methods

2.1 Selection Criteria and Data Collection

The input data, for the analysis, were collected from Web of science Core Collection scientific database. The topics selected to carry out the computer-based research were "anthropometr*" and "scan*". The search regarded papers published over the period from 1970 to 2018. Web of Science Core Collection is composed of: Citation Indexes, Science Citation Index Expanded (SCI-EXPANDED) – 1970-present, Social Sciences Citation Index (SSCI) – 1970-present, Arts & Humanities Citation Index (A&HCI) – 1975-present, Conference Proceedings Citation Index- Science (CPCI-S) – 1990-present, Conference Proceedings Citation Index- Social Science & Humanities (CPCI-SSH) – 1990-present, Book Citation Index– Science (BKCI-S) – 2009-present, Book Citation Index– Social Sciences & Humanities (BKCI-SSH) – 2009-present, Emerging Sources Citation Index (ESCI) – 2015-present, Chemical Indexes, Current Chemical Reactions (CCR-EXPANDED) – 2009-present (Includes Institut National de la Propriete Industrielle structure data back to 1840), Index Chemicus (IC) – 2009- present, the last two citation indexes were excluded from the articles sampling. The final input dataset was composed of 1'652 records, the bibliographic records contained various fields, such as author, title, abstract, keywords and all the references (needed for the citation analysis). The research tool to visualize the networks was Cite space v.5.3. R7 SE (32 bit) [12] under Java Runtime v.8 update 91 (build 1.8.0_91-b15). Some figures were done with Microsoft Excel and MapChart (https://mapchart.net).

3 Results

The literature collected includes 1'652 articles, according to the document types analysis of WoS, specifically, 84.56% are articles, 15.17% proceeding papers, 1.63% reviews, 1.27% book chapters, 0.72% meeting abstracts, 0.18% letters and 0.06 of both data paper and editorial material. Figure 1 provides preliminary information about the beginning of scientific research in this area. From the 90's the anthropometric research has been enriched by the use of the scan. In fact, more than 100 articles have been published in the last years, with a peak in 2017.

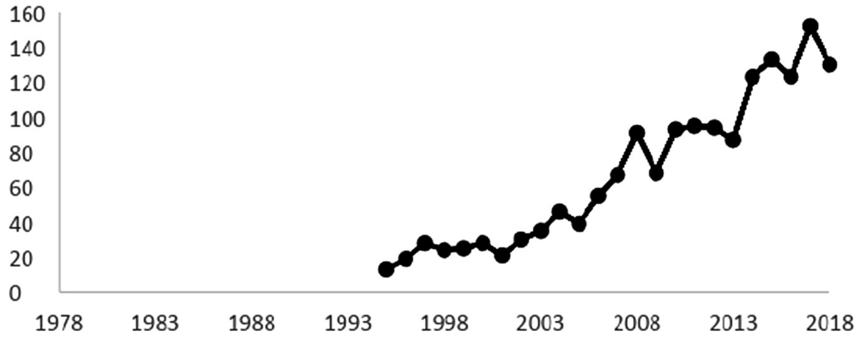


Fig. 1. Number of publications per year.

3.1 Categories

According to WoS categories analysis, the most ranked field of publications concerning anthropometry and scan is endocrinology and metabolism with a total record of 224 papers, following surgery with a total of 161 records, nutrition dietetics and sport science with at least more than 100 records.

On the other hand, categories based on research areas carried out with Citespace shows engineering as the most influent field, which constitutes the 16.74% of the total literature regarding the selected topics. Figure 2 illustrates the top ranked categories by citations count.

While, Fig. 3 represents the categories network assuming a threshold ≥ 10 citations per each category. Network analysis was conducted to calculate and to represent the centrality [13, 14].

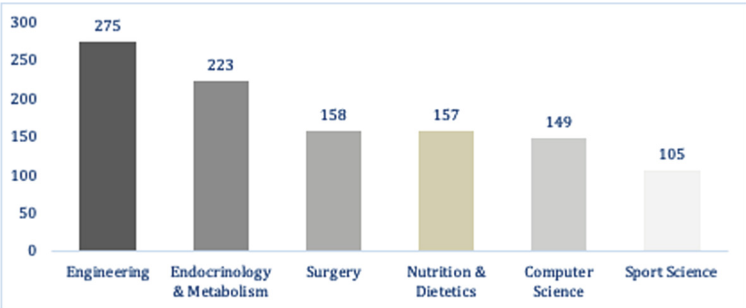


Fig. 2. Top ranked categories according to citations count.

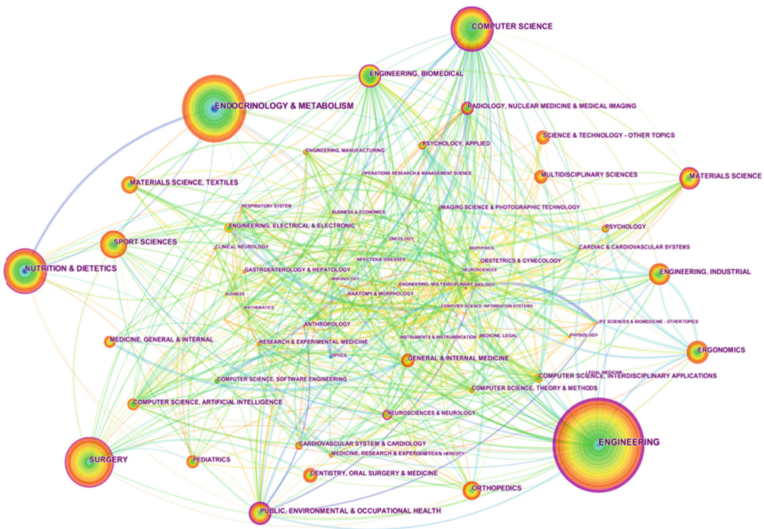


Fig. 3. Categories network. The dimensions of the nodes represent centrality, the dimensions of the characters represent the rank of the category.

3.2 Countries

Figure 4 displays the top ranked countries according to WoS records count. Table 1 shows the situation of the most influential countries in terms of publications calculated by citation count. Figure 5 illustrates a network of countries based on cited reference count and assuming a threshold of at least 35 citations for country. While, Table 2 provides indications about citation burst of each country. Bursts indicate the period in which a country has been most active in terms of scientific production. Bursts analysis represent a detection of a burst event, which can last for multiple years as well as a single year. A burst provides, for example, evidence that a particular publication is associated with a surge of citations. The burst detection is based on Kleinberg's algorithm [15].

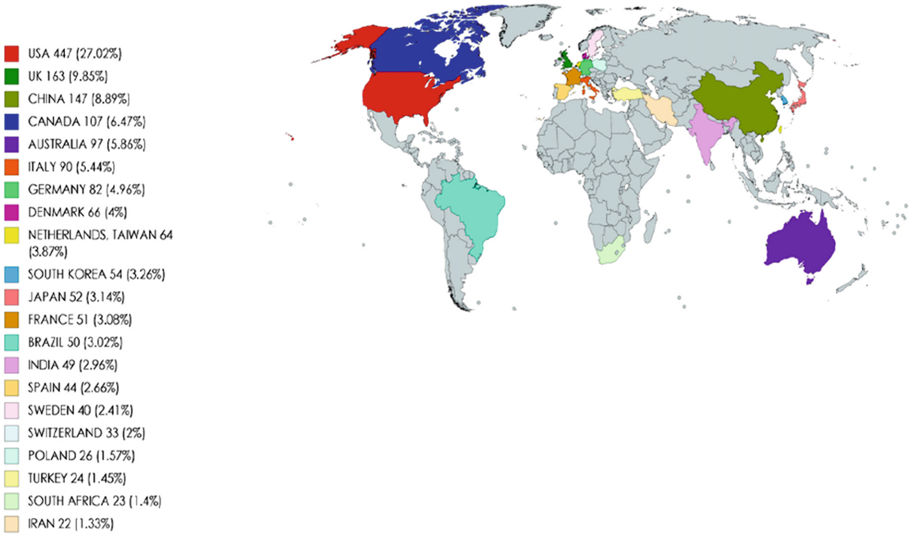


Fig. 4. Countries producing the highest number of publications

Table 1. Citations for countries.

Citations count	Country
423	USA
154	UK
146	CHINA
101	CANADA
94	AUSTRALIA
84	ITALY
80	GERMANY
60	TAIWAN
57	NETHERLANDS
55	DENMARK

Table 2. Top 10 countries with the strongest citation bursts.

Countries	Year	Strength	Begin	End	1990 - 2018
USA	1990	7.2673	**1991**	1998	
AUSTRALIA	1990	4.635	**1997**	2001	
SWEDEN	1990	4.9666	**1999**	2001	
JAPAN	1990	6.7446	**2000**	2011	
FINLAND	1990	5.1957	**2001**	2003	
CANADA	1990	3.7555	**2005**	2007	
TAIWAN	1990	4.333	**2010**	2011	
IRAN	1990	3.9249	**2013**	2018	
PORTUGAL	1990	4.0719	**2014**	2018	
BRAZIL	1990	4.486	**2015**	2018	

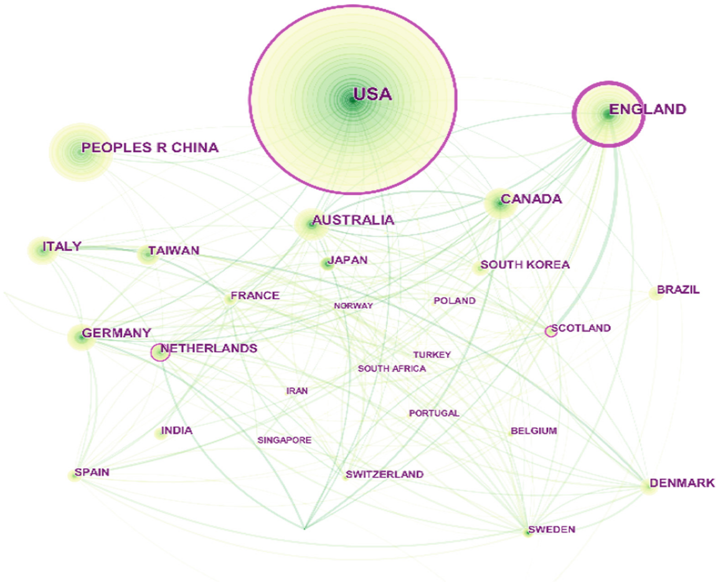


Fig. 5. Network of countries. The dimensions of the nodes represent centrality, the dimensions of the characters represent the rank of the country.

What emerges from countries analysis is that USA is the most authoritative country both in terms of scientific production and citation frequency. The network represented by Fig. 5 emphasizes the central position of USA. It displays a higher degree of connections with other countries and it's represented by the biggest node in the network.

Another interesting observation is that Brazil and Portugal got interested and to published in this field in the last four years, Brazil has produced over 50 publications in this period indeed.

3.3 Journals

Influential journals in the specific fields of anthropometry and scan are listed in Table 3, specifically, Fig. 6 represents the journals' co-citation analysis and the top five are represented by the biggest nodes on the right-hand side of the network. Co-citation is defined as the frequency with which two documents are cited together by other documents. In this case, if two journals are cited together by at least another journal, the two journals are defined as co-cited. If at least one other document cites two documents in common these documents are said to be co-cited. The more co-citations two documents receive, the higher their co-citation strength, and the more likely they are semantically related.

Table 3. Citations count and impact factors of journals.

Citation counts	Journals	Impact factor
445	The American journal of CLINICAL NUTRITION	6.549
358	International journal of OBESITY	5.151
330	Journal of Clinical Endocrinology & Metabolism	5.789
317	The Lancet	53.252
272	The NEW ENGLAND JOURNAL of MEDICINE	79.258
210	Diabetes Care	13.397
201	The Journal of the American Medical Association	47.661
187	Diabetes	7.273
187	British Medical Journal BJM	23.295
181	American Journal of Epidemiology	4.322

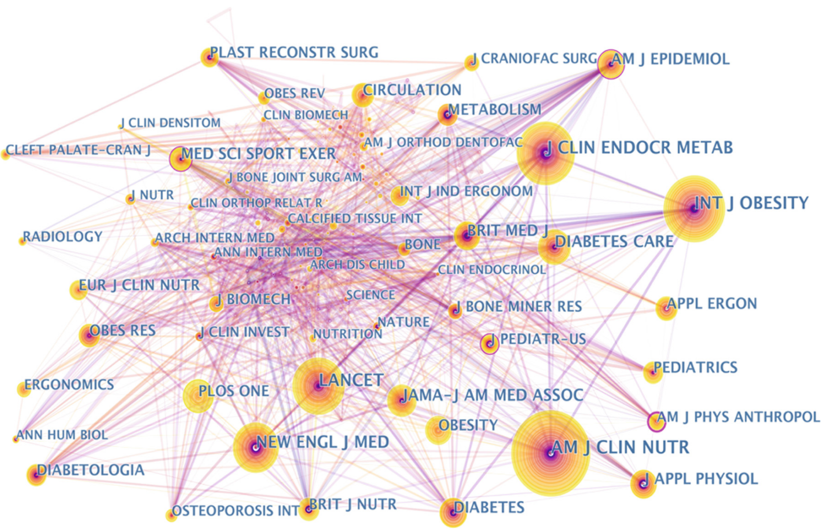


Fig. 6. Co-citation network of journals. The dimensions of the nodes represent centrality. The dimensions of the nodes represent centrality, the dimensions of the characters represent the rank of the journal.

3.4 References

The co-citation analysis allows to individualize the most cited references in the field investigated. We focused on the highly-cited documents in this area that are most influential papers in the area of anthropometry and scan domain [16–18]. We set a threshold of at least 7 citations per publication in the graphic representation in Fig. 7. While Table 4 reports the most influential publications in the domain from 1990 to 2018.

Table 4. Top ranked articles by citations count.

Citations count	Papers
20	Fox CS, 2007, CIRCULATION, 116, 39
16	Ball R, 2010, APPL ERGON, 41, 832
14	Daanen HAM, 2013, DISPLAYS, 34, 270
13	Wong JY, 2008, CLEFT PALATE-CRAN J, 45, 232
13	Han H, 2010, INT J IND ERGONOM, 40, 530
13	Robinette KM, 2006, APPL ERGON, 37, 259
13	Kouchi M, 2011, APPL ERGON, 42, 518
13	Witana CP, 2006, INT J IND ERGONOM, 36, 789
12	Lu JM, 2008, EXPERT SYST APPL, 35, 407
12	Aldridge K, 2005, AM J MED GENET A, 138A, 247

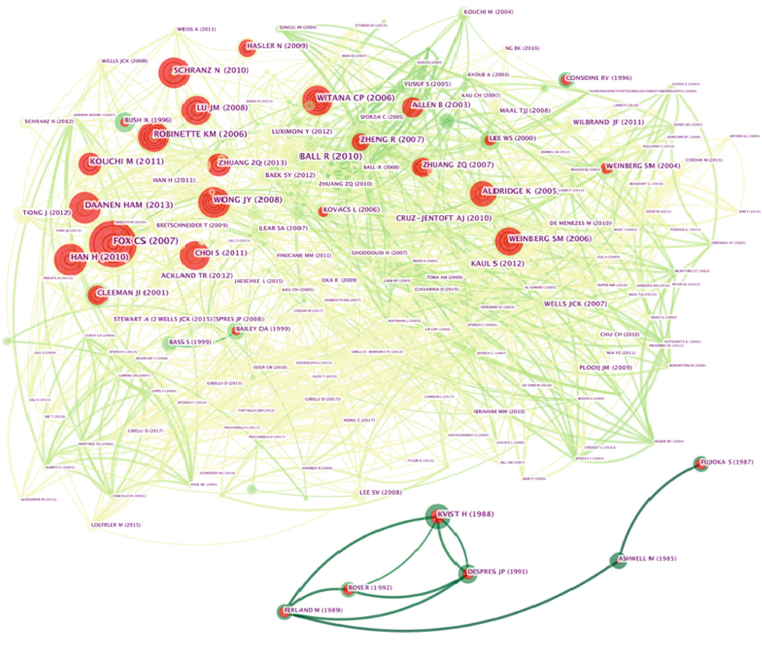


Fig. 7. Network of document co-citations. The dimensions of the nodes represent centrality, the dimensions of the characters represent the rank of the article rank.

3.5 Authors

In regards to the most active researchers in the topic of scan and anthropometry, clearly there are few authors that distinguish from others. ZHANG Y. with 9 citations, SFORZA C. with 7 citations, ZHANG X. with 7 citations and LI ZZ. with 6 citations. Figure 8 shows all authors in this field. While authors co-citation analysis (Fig. 9) highlights the authors in term of their impact on the literature over the entire time span of the field indeed [16, 19, 20].

The purpose of this analysis is to focus on the relations within the society of authors who contribute to this topic research. As for journals co-cited analysis in this case provides information about how two authors are semantically related in terms of topics addressed since they are mentioned together.

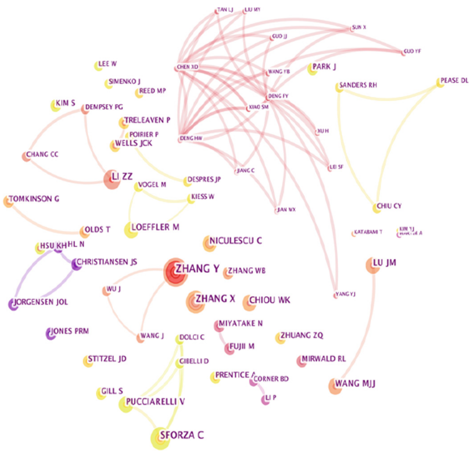


Fig. 8. Authors network. The dimensions of the nodes represent centrality index, and the dimensions of the characters represent the author's rank.

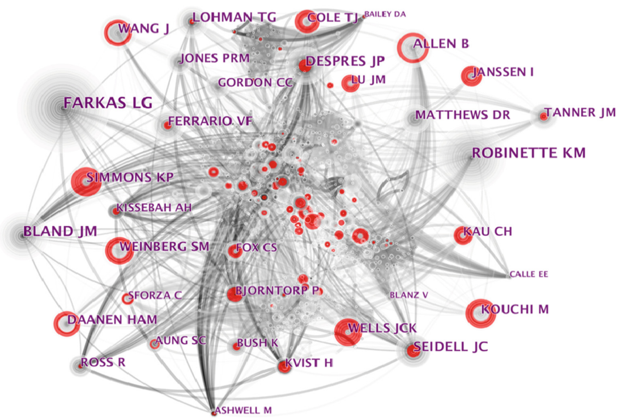
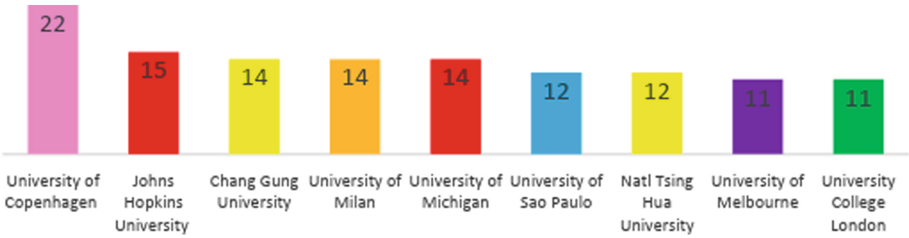


Fig. 9. Authors co-citation network. The dimensions of the nodes represent centrality index, and the dimensions of the characters represent the author's rank.

3.6 Institutions

In the same view as the countries analysis, according to Table 5 United States shows a clear predominance regarding the most influential universities in terms of citation count although University of Copenhagen holds the record for number of citations as it's graphically reported in Fig. 10.

Table 5. Citation counts for institution. The colors used in the histogram recall those used for nations in Fig. 2.



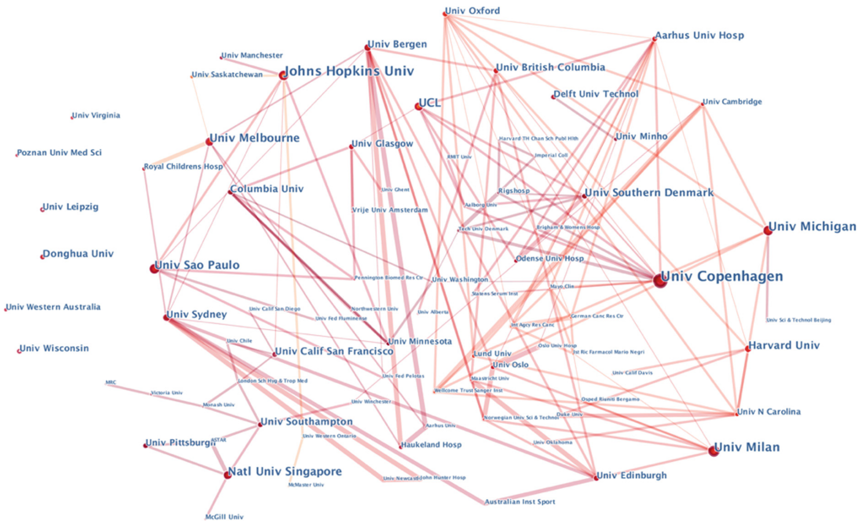


Fig. 10. Network of institutions. The dimensions of the nodes represent centrality index, and the dimensions of the characters represent the institution's rank.

4 Discussion

The study aims to analyse all the existing literature and citations about two topics, anthropometry and scan, that have been investigated together as a single field. The objective of this scientometrics analysis is to report all the information related to the current and future trends in this area.

Results highlight how the field of study investigated has expanded and evolved. Anthropometry research has developed since the 17th century [1, 21]; while, its association with scanner dates back to the nineties as displayed from the publication's years report. From nineties to nowadays, although the birth of anthropometry is much more dated, the use of the scans has allowed to obtain geometric measurements of the body, and in more recent times the use of 3D scanners has led to the achievement of three-dimensional body visualizations. Regarding the engineering field, continuous developments reflect the latest technological advances. Engineering represents the most cited area followed by subareas of medical and computer science. In fact, both new technological tools and clinical measurements are necessary to expand this research in both applicability and usability. While, among all the possible fields of application stands out medicine more than psychology and the clothing industry, meaning that the usefulness of these technologies has been widely exploited.

Specifically, endocrinology and metabolism constitute the most active publication domain, in regards to this field the use of the scanner mostly aims at investigating body composition. Body composition assessments are carried out in order to monitor the nutritional status in pathologies such as obesity and anorexia, planning therapeutic interventions and to facilitate new practical tools [22]. The most common anthropometric measurements such as height, weight, skinfold thickness, trunk and limb sizes are obtained through the scan employment. All of them are collected and used to create sets of reliable data useful in both prognostic and progression diseases' phases. BMI is the most used index in the domains of obesity and eating disorders [23]. However, other anthropometric measurements, obtained using the scan, have been demonstrated to be more predictive of several diseases. For instance, waist-to-hip ratio shows a graded and highly significant association with myocardial infarction risk [24], the ratio of supine sagittal abdominal diameter to mid-thigh girth ("abdominal diameter index"; AD) and the waist-to-thigh ratio of girths (WTR) are predictive of ischemic heart disease risk [25]. Therefore, from these findings endocrinology and metabolism represent the most active category in terms of publications. Accordingly, the American Journal of Clinical nutrition together with the International Journal of Obesity and the Journal of Clinical Endocrinology & Metabolism are placed on the 1_{st}, 2_{nd}, 3_{rd} positions respectively in the ranking of the most cited journals regarding this topic. These journals deal with arguments such as metabolic risk factors individualization, 3D whole-body scan applications and ergonomics fields.

Looking at the countries' investigation, USA currently holds the record for both citations and scientific production. In fact, this country owns two of the best scanners on the market. The first 3dMD body system is used in healthcare, mainly in digital dentistry, oral, maxillofacial and reconstructive plastic surgery; in research, for instance, in anthropology, biometrics, computer vision, ergonomic, product engineering, psychology, as well as others. The second is Canfiled Vectra XT, this scanner is mainly used in plastic surgery to help assess the risks and simulate the outcomes of plastic surgery interventions; it is able to capture in three dimensions the face, breast and the body images in ultra-high resolution within 3.5 ms capture time [26–28].

The bursts analysis has shown USA predominance in the literature panorama up to 2000, while, in more recent years other non-European and European countries catch the scene. While, considering the network institution, although USA is the most influential country in terms of citations and articles, so far, the University of Copenhagen is the most cited institution worldwide. This institution implies technologies such as DEXA scan in order to assess body composition [29, 30]. With respect to citations count, Yumei Zhang is the main authority within the field, affiliated to department of Nutrition of the School of Public Health of Beijing (China), his research predominantly focuses on nutritional problems and associated risk factors for metabolic and cardiovascular diseases among the Chinese population [31, 32]. On the other hand, the number two on this rank is an Italian researcher, Chiarella Sforza, affiliated to the Department of Biomedical Health Sciences, her studies are mainly related to human anatomy evaluation, such as three-dimensional analysis of human facial morphology [33, 34]. Authors with higher numbers of citations tend to be the scholars who drive the fundamental research in the field. While, from the authors co-cited network, which highlights authors in term of their impact on the literature over the entire time span considered and provides insights on most cited authors.

Farkas emerges as the most relevant one, he is considered the pioneer of craniofacial anthropometry. His lifelong devotion to research represents a major contribution to our understanding of the craniofacial complex. This author has collected more than 100 citations from other active authors in the field of scanner applications to anthropometry measures indeed.

The second most cited is Robinette, a researcher who focused on anthropometric differences comparing faces' morphology and analysing age-related changes [35–37]. Both authors have drawn the principles of anthropometric measurements, thus, their works are considered milestones in this area.

Turning to the citations' network the most cited papers investigate body composition, in order to define metabolism risk factors [38]; head shape anthropometric analysis through 3D scanner [39] and 3D whole body scanner usability and applicability [40, 41].

Therefore, it is reasonable to suppose that human body shape analysis deriving from 3D sensors has a real possibility to improve public health in a society where obesity and related metabolic and cardiovascular risks are pandemic.

Overall, the use of scanners for anthropometric analysis, specifically 3D whole body scanner, leads to quickly obtain body-shape reliable information providing high quality images with non-invasive optical methods. Since clinical applications and technologies developments are constantly evolving, many aspects should be further investigated within the area of research. In regards to all keys factors analysed, this paper provides information about the current state of art in this field, additionally, it may elucidate on perspectives and challenges expected in the future.

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