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The bioelectrical impedance analysis (BIA) international database: aims, scope, and call for data

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(Article begins on next page)

1 **The Bioelectrical Impedance Analysis (BIA) International Database: Aims, Scope,**  
2 **and Call for data**

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140 **Abstract**

141 **Background:** Bioelectrical impedance analysis (BIA) is a technique widely used for  
142 estimating body composition and health-related parameters. The technology is relatively  
143 simple, quick, and non-invasive, and is currently used globally in diverse settings,  
144 including private clinicians' offices, sports and health clubs, and hospitals, and across a  
145 spectrum of age, body weight, and disease states. BIA parameters can be used to estimate  
146 body composition (fat, fat-free mass, total-body water and its compartments). Moreover,  
147 raw measurements including resistance, reactance, phase angle, and impedance vector  
148 length can also be used to track health-related markers, including hydration and  
149 malnutrition, and disease-prognostic, athletic and general health status. Body composition  
150 shows profound variability in association with age, sex, race and ethnicity, geographic  
151 ancestry, lifestyle, and health status. To advance understanding of this variability, we  
152 propose to develop a large and diverse multi-country dataset of BIA raw measures and  
153 derived body components. The aim of this paper is to describe the 'BIA International  
154 Database' project and encourage researchers to join the consortium.

155 **Methods:** The Exercise and Health Laboratory of the Faculty of Human Kinetics,  
156 University of Lisbon has agreed to host the database using an online portal. At present,  
157 the database contains 277,922 measures from individuals ranging from 11 months to 102  
158 years, along with additional data on these participants.

159 **Conclusion:** The BIA International Database represents a key resource for research on  
160 body composition.

161 **Keywords:** Reactance, Phase angle, Vector length, Body composition, Nutrition,  
162 Obesity, Consortium

163 **Background**

164 The use of bioelectrical impedance analysis (BIA) to investigate human body  
165 composition began in the 1960s, when Thomasett showed that total body water (TBW)  
166 could be estimated from whole-body impedance <sup>1</sup>. Subsequent development of this  
167 approach has substantially extended its capacity to provide information about tissue  
168 composition and function <sup>2-5</sup>. The feasibility, portability, and safety of BIA makes it  
169 relatively unique among body composition methods <sup>6</sup>. The technology is relatively  
170 simple, quick, and non-invasive, and is currently used globally in diverse settings,  
171 including private clinicians' offices, sports and health clubs, and hospitals, and across a  
172 spectrum of age, body weight, and disease states. In turn, this has resulted in an  
173 exponential increase in the availability of BIA data. As yet, however, the potential of this  
174 high data volume has not been comprehensively exploited to improve our understanding  
175 of human body composition variability, in relation to sex, age, health status, lifestyle and  
176 population.

177 Several different approaches can be used to extract information on body composition  
178 from BIA. In the single frequency approach (SF-BIA), through the application of a 50  
179 kHz alternating current, BIA provides measures of impedance ( $Z$ , ohm) by conductive  
180 tissues such as blood, muscle/organs and cerebrospinal fluid.  $Z$  comprises a purely  
181 resistive component (resistance,  $R$ , ohm) that is related to water and electrolytes in fluids  
182 and tissues, and a capacitive component (reactance,  $X_c$ , ohm) responsible for the delay  
183 of the current entering cells, associated with cell membrane integrity and cell interfaces  
184 <sup>7,8</sup>. While single-frequency 50 kHz BIA machines are popular, tetra polar multi-frequency  
185 BIA (MF-BIA) or bioelectrical impedance spectroscopy (BIS) instruments also provide  
186 frequency-specific readings at 50 kHz.

187 One approach to estimating body composition from raw BIA data is to predict TBW or  
188 fat-free mass (FFM) from the impedance index, calculated as the square of height ( $HT$ ,  
189 cm) over impedance ( $HT^2/Z$ ). Based on research studies, numerous such equations have  
190 been published for healthy populations and with diseases <sup>1, 9-33</sup>. This approach can be  
191 extended to the main compartments of TBW, extracellular water (ECW) and intracellular  
192 water (ICW), by exploiting the fact that whether the current passes only through ECW,  
193 or through both ECW and ICW, depends on its frequency <sup>34,35</sup>. At the cellular level, BIA-  
194 derived body cell mass <sup>18,36,37</sup>, and at the tissue level, skeletal muscle (SM) mass, can be



195 accurately predicted in healthy populations, as compared to magnetic resonance imaging  
196 or computerized tomography<sup>38</sup>. These components have a recognized implication in  
197 health and performance, specifically intracellular water<sup>39-41</sup>, but also in disease  
198 susceptibility due to increased levels of fatness and loss of SM<sup>42-45</sup>. The latter is also a  
199 key characteristic of sarcopenia, a SM disease rooted in adverse muscle changes that  
200 accrue across a lifetime<sup>46</sup>. Indeed, for sarcopenia diagnosis, BIA has been recognized as  
201 a useful tool to estimate SM quantity (mass) and quality (amount of strength and/or power  
202 per unit of SM mass)<sup>46</sup>.

203 A second approach focuses on direct measures provided by BIA that have been widely  
204 used to explore malnutrition, growth and development, athletic performance, sexual  
205 dimorphism, pregnancy, and ageing in several populations<sup>47-55</sup>. Indeed, the raw BIA  
206 parameter phase angle (PhA), representing the arc tangent of  $X_c/R$ , is a compound  
207 indicator of the distribution between intra and extracellular fluids and of body cell mass  
208<sup>8, 53</sup>. There has been growing interest in the use of such raw BIA parameters as proxy  
209 markers of health, physical fitness and function, and disease status, avoiding the need for  
210 prediction equations<sup>56-64</sup>. However, the practical application of PhA measurements to  
211 define nutrition status still requires normative values. To date, reference data for PhA are  
212 available for healthy American<sup>65, 66</sup>, German<sup>67</sup> and Swiss<sup>68</sup> adult populations, as well as  
213 athletes<sup>69</sup> and UK children<sup>70</sup>, but given the large inter individual variability associated  
214 with factors such as age, sex and ethnicity, consensus on the normal range is still lacking  
215 and more comprehensive standards are required.

216 An interesting extension of the insights from research on PhA is represented by  
217 bioelectrical impedance vector analysis (BIVA)<sup>71</sup>, which in turn has been developed in  
218 different ways. BIVA<sup>71, 72</sup> analyzes  $R$  and  $X_c$ , and the derived variables PhA and vector  
219 length (i.e.,  $Z$ ), without relying on assumptions of a fixed FFM hydration, or on constant  
220 body geometry and resistivity values. Particularly, PhA describes the direction of the  
221 vector on the  $R$ - $X_c$  graph and represents the distance from the vector to the  $X$  axis. Classic  
222 BIVA adjusts raw BIA parameters for HT, whereas specific BIVA standardizes on the  
223 basis of estimated body volume, derived from data on both HT and cross-sectional area.  
224 This means that specific (sp) BIVA parameters ( $R_{sp}$ ,  $X_{csp}$ ,  $Z_{sp}$ ) are influenced by the  
225 properties of the tissues rather than body size and shape. BIVA allows a better  
226 understanding of body composition variability than does PhA alone independent of vector  
227 length, or  $R$  independent of  $X_c$ . In classic BIVA, variation in vector length indicates

228 different hydration conditions for a given PhA <sup>71</sup>, whereas in specific BIVA it indicates  
229 different levels of FM% <sup>72-74</sup>. Hence, both classic and specific BIVA can be used  
230 simultaneously <sup>75</sup>. Population-specific reference values for classic and specific BIVA are  
231 available for U.S. children, adolescents, and adults, Italian children and adolescents,  
232 Italian-Spain young adults and elderly Italians <sup>72-74, 76-79</sup>, but factors such as race and  
233 ethnicity, geographic ancestry, lifestyle, socio-economic status have not yet been  
234 considered in depth.

235 Body composition shows profound variability in association with age, sex, race and  
236 ethnicity, geographic ancestry, lifestyle and health status. In turn, this incorporates  
237 variability both in bio-conducting tissues, and also in total and regional body composition  
238 <sup>52, 80-82</sup>. To date, due in part to the difficulty of applying most methods at scale, we lack a  
239 large representative body composition database that incorporates variability in age, sex,  
240 race and ethnicity, geographic ancestry, lifestyle, environment, socio economic factors  
241 and athletic status.

242 Developing such a database for BIA would allow a range of potential applications.  
243 Among these we highlight:

- 244 • Developing a comprehensive integrated model of healthy body composition by  
245 pooling BIA data across multiple populations.
- 246 • Relating BIA data to other phenotype data on health, lifestyle and disease state.
- 247 • The capacity for BIA data to guide clinical management across a wide range of  
248 disease states.
- 249 • The capacity for BIA data to help assess the efficacy of large public health  
250 interventions.
- 251 • The capacity for BIA data to be routinely collected by individuals in the home,  
252 gyms and health clubs, in order to help them maintain healthy weight and body  
253 composition.
- 254 • To contribute to academic training and teaching by enabling the use of a large and  
255 unique dataset adequately managed.

256 Beyond the direct implications for health, increasing the capacity to measure body  
257 composition at scale may have substantial economic benefits, through increasing the  
258 success of lifestyle interventions, optimising drug dose calculations, and improving the  
259 efficiency of healthcare.

260 The aim of this project is therefore to build a large and diverse dataset of BIA raw  
261 measures and derived body components by pooling data from multiple countries. These  
262 data can be shared for research investigations to enable a better understanding about body  
263 composition variability in association with age, sex, race and ethnicity, geographic  
264 ancestry, lifestyle and health status and to develop robust normative values. Here, we  
265 describe this ongoing ‘BIA International Database’ project and encourage researchers,  
266 especially those from low- and middle-income countries, to contribute data.

267

#### 268 **Call for data**

269 The BIA International Database had its genesis in 2017 at a Summer School training  
270 workshop in Sardinia, Italy (<https://sssnsa.wordpress.com/>), when the idea and benefits  
271 of compiling all published BIA measurements on humans was proposed. Alone, each  
272 individual dataset is unable to tackle relevant questions in sports, nutritional, and medical  
273 sciences, whereas combining information across studies offers many new opportunities.

274 The application of BIA to humans vastly increased since 2000<sup>83</sup>, with 19713 publications  
275 between 1960 and 2021 based on a search in the ISI Web of Science core collection using  
276 the search string ((Bioelectrical impedance analysis) OR BIA OR bioimpedance), as  
277 illustrated in **Figure 1**.

278 **\*\*INSERT FIGURE 1\*\***

279 This large-scale application of BIA demonstrates the data that is potentially available for  
280 pooled analysis. We therefore invite contributions from researchers worldwide. The  
281 Faculty of Human Kinetics of University of Lisbon agreed to host the database, and a  
282 total of 276,410 measurements (1 record = 1 measurement on 1 person) have been initially  
283 uploaded to the website. The URL of the website is  
284 <https://labes.fmh.ulisboa.pt/projetos/a-decorrer/item/101-bia-international-database> .

285

## 286 **Overall Approach and Procedures**

287 This is an ongoing project, soliciting collaboration among researchers for sharing BIA  
288 datasets with particular emphasis on low-income countries to complement the extensive  
289 data from high-income countries already received and published in the literature. All  
290 participants included in the final dataset have provided their consent to participate in the  
291 study conducted by each contributor, following the approval granted by the institution's  
292 ethics committee.

293 We will address the following steps:

294 **Step 1: Building a large database** of BIA raw and derived parameters, with the  
295 following characteristics:

296 1. **Minimal BIA and associated data:** age, sex, anthropometry (body mass and  
297 height), R, Xc, Z, and PhA, population, year of data collection, device  
298 characteristic (SF-BIA, MF-BIA / BIS), and health status.

299 2. **Additional data:** segmental raw BIA measures (R, Xc, PhA, Z), for specific  
300 BIVA, arm, waist and calf circumferences, race and ethnicity (White, Black,  
301 Hispanic, Asian, Other), and geographic ancestry (Africa, America, Central South  
302 Asia, East Asia, Europe, Middle East, Oceania).

303 3. **Desirable additional data:** to explore links between BIA raw parameters and  
304 other outcomes: other body composition data (e.g., dual-energy X-ray  
305 absorptiometry- DXA total and regional estimates), physiological/metabolic data  
306 (e.g., glucose, lipid, and protein metabolism, hormones), and physical function  
307 (e.g., strength and physical performance), athletic status, education, socio-  
308 economic and lifestyle characteristics (e.g., physical activity, diet). Specific  
309 guidelines for preparing the database for providing these additional variables will  
310 be detailed on the website [https://labes.fmh.ulisboa.pt/projetos/a-  
311 decorrer/item/101-bia-international-database](https://labes.fmh.ulisboa.pt/projetos/a-decorrer/item/101-bia-international-database) .

312 All data are de-identified, being either the data of partners or collaborators of the  
313 consortium, or open-access public use files from international databases (e.g., NHANES).

314 In order to integrate disparate and heterogeneous data, we will compare and harmonise  
315 different acquisition technologies and operation procedures of BIA, including the  
316 calibration and standardization of methods (data quality assessment) while also taking  
317 into consideration the position in which the exam was performed (i.e., standing, sitting,  
318 and lying). The end result of this step will comprise information on representative groups  
319 of children, adults, and elderly people; it will be a large and homogeneous database of  
320 BIA raw and derived parameters, demographics, anthropometrics, and when available,  
321 metabolic variables, education, lifestyle, and socio-economic information, performance-  
322 related information, and data on other body components such as those derived from DXA.

### 323 **Step 2. Data Management**

324 The data will be deposited at the research database at Lisbon. The site is interactive and  
325 contains the number and type of measurements made in any target country.

326 Regarding data security, all included datasets will be part of projects approved by the  
327 respective ethics committee of each research group. After confirmation of inclusion by  
328 the management group, each individual in each database will be given a new code (related  
329 to the current project) to further guarantee confidentiality and privacy. Hence, the  
330 received databases have already codified data without any personal identifier, making the  
331 data untraceable to the corresponding individual, and complying with the General Data  
332 Protection Regulation (GDPR) key requirements. Furthermore, all received data will be  
333 converted into password protected files and stored at FMH server, with access limited to  
334 the chairman of the management group, Analiza M Silva, or designated members.

335 Access to the whole or part of the database will be supervised, as authors aiming to use  
336 the database must first obtain the approval by the management group, providing their  
337 intended analysis (i.e., scope and aim of the analysis, the intended variables and sample  
338 characteristics, as well a list of authors and a brief chronogram) and assuring that rules of  
339 privacy and data protection will be complied with. After following these steps, and if  
340 accepted by the management group, a separate password-protected file will be generated  
341 including the selected columns of interest. A detailed record will be created to monitor  
342 this data-sharing process.

### 343 **Step 3. Data Analysis**

344 A short description of the types of data already available in the database is displayed in  
345 **Figure 2**, including the geographical distribution of where the data was collected, the sex  
346 and age distribution of the sample.

347 **\*\*INSERT FIGURE 2\*\***

348 An overall description of the types of data available in the database can be also found on  
349 the website under the “data overview tab”. A more comprehensive understanding of the  
350 database contents can be obtained by downloading the excel file example including  
351 details on the variables included in the main database.

352 So far, the database includes 277,922 measurements of children and adult male  
353 (n=59,450) and female measurements (n=218,472) aged between 11 months up to 102  
354 years, mainly healthy. As an indication of the size of the database and the variability in  
355 the data it contains, **Figure 3** illustrates data from healthy individuals, stratified by sex  
356 and age (<18 and ≥18 years) for the relationship between impedance index (cm<sup>2</sup>/kHz) and  
357 FFM (assessed by DXA).

358 **\*\*INSERT FIGURE 3\*\***

359 The plots illustrated in Figure 3 show the strong association between impedance index  
360 and FFM assessed by DXA in both sexes and age categories, particularly in children,  
361 underscoring the relevance of the impedance index as an indicator of volume, though a  
362 large inter individual variability is observed in males and females among age categories.

#### 363 **Step 4. Data access**

364 If the contributors wish to perform an analysis in the database several steps are required.  
365 Briefly, contributors should: i) Examine the list of planned analyses; ii) check out sample  
366 data set to determine if there are sufficient data; iii) download and fill out a template form  
367 with a succinct summary, including the variables from the dataset that will be required;  
368 iv) agree up front to the publication policy and approve the manuscript within 21 days.  
369 The management group will discuss the idea and will provide feedback within 4 weeks  
370 along with a form to be signed and returned. If the analysis is not performed within 18  
371 months of approval the application will be removed from the planned analyses.

#### 372 **Step 5. Publication policy**

373 The new knowledge provided by the BIA International database will be disseminated  
374 through scientific publications as a key performance indicator for academic partners,  
375 remaining a priority for the project, subject to intellectual property restrictions and the  
376 publication management model.

377 Individuals submitting data will be acknowledged as authors on publications from the  
378 database that use the data they contributed, allowing up to 2 authors per contributed  
379 dataset. Manuscripts using the database must adhere to a number of rules that have been  
380 agreed upon by the management group, including that draft manuscripts must be  
381 approved by the management group, though the authors still maintain the authority and  
382 ownership of their own dataset, allowing them to use their dataset for other purposes. This  
383 may generate a large author list but follows the common practice in many multi-  
384 laboratory collaborations.

385

## 386 **Discussion**

387 This paper describes the BIA International Database goals, scope, and issues a “call for  
388 data”. Through pooling BIA raw and derived population-based data from several  
389 countries, our consortium will be able to break new ground exploring human body  
390 composition variability and its potential associations with environment, lifestyle, socio-  
391 economic factors, disease-related malnutrition, and sports-related outcomes, while also  
392 providing normative values for diagnostic purposes.

393 We anticipate the impact of this project in several different contexts. First, we expect to  
394 improve understanding of the factors that drive the individual variability evident in figure  
395 3 plots. Evidence has been accumulating underlining the influence of the life cycle, sexual  
396 dimorphism, race and ethnicity, geographic ancestry, athletic and disease status <sup>47, 48, 50,</sup>  
397 <sup>51, 55, 59, 60, 84, 85</sup> on variability in raw BIA variables among populations. A comprehensive  
398 appreciation of these factors is required for a better understanding of the wide variability  
399 in body composition, with emphasis on regional and total fatness and SM.

400 Second, by providing a target to achieve a “healthier” body composition, this project will  
401 contribute to the design of appropriate lifestyle interventions, enabling personalised  
402 exercise or dietary interventions and improving optimal clinical decision making. For

403 instance, by proposing robust normative values for BIA-derived SM, cancer treatment  
404 doses can be optimized and the benefits of chemotherapy maximized, as SM loss is  
405 associated with an increased toxicity of chemotherapy and thus poorer prognosis <sup>86</sup>. Drug  
406 clearance rates depend on body composition and, consequently, we expect that normative  
407 values for BIA-derived body components may advance therapeutic options.  
408 Individualized prevention of non-communicable diseases and risk factors may also  
409 benefit from personalized data at the population level.

410 Third, this project will contribute to stimulating research, technology development and  
411 innovation. The large database will contribute to strengthening of scientific knowledge  
412 and to the academic training of young researchers. This new knowledge will benefit the  
413 research community by providing a simple and practical way of using quality data.  
414 Additionally, the BIA International Database findings will contribute to developing  
415 potential technological outputs, with benefits for a wide range of stakeholders, including  
416 fitness and sports fields, the healthcare system and the general public that can benefit  
417 from potential applications of the findings into technological products and services.

418 Finally, we expect environmental and social impacts from this project. The social value  
419 of the BIA international outputs is potentially substantial. The project will include and  
420 analyse data from both high- and low-income populations, helping understand the social  
421 determinants of body composition variability <sup>87</sup>. We look forward in particular to  
422 receiving data from vulnerable populations in countries with weaker health systems and  
423 those facing existing humanitarian crises, in order to identify new opportunities whereby  
424 body composition assessment can aid in describing and combating the emerging double  
425 burden of malnutrition at the individual level <sup>88</sup>. More generally, the project provides a  
426 new basis for personalized medicine, addressing age, race and ethnicity, geographic  
427 ancestry, disease-related malnutrition, environment, and socio-economic factors. This is  
428 challenging across worldwide populations that are facing an obesity epidemic, related  
429 non-communicable diseases and demographic changes due to e.g., ageing and migration.  
430 This contributes to healthier communities, enables informed disease prevention,  
431 ultimately reducing healthcare costs that represents an increased proportion of overall  
432 state spending. Nevertheless, we anticipate some limitations in the process of building the  
433 dataset, as it is likely that the repository will lack representation from ethnic minorities  
434 given the principles for indigenous data sovereignty and governance ([15](https://www.gida-</a></p></div><div data-bbox=)



435 global.org/history-of-indigenous-data-sovereignty), as there are population groups for  
436 whom the sharing of biometric data with overseas entities is difficult.

437

#### 438 **Conclusion**

439 The goals, scope and procedures of the ‘BIA International Database’ project are described  
440 and we issue a “call for data”. The consortium aims to pool raw and derived population-  
441 based BIA data from multiple countries to enable analyses that capture the heterogeneity  
442 of the global population. We expect this project to provide a comprehensive integrated  
443 model of healthy body composition, clarify its wide variability, and contribute to  
444 developing and improving diagnostic tools.

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874

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878

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882

883 **Statement of Ethics**

884 The authors have no ethical conflicts to disclose for this review because there were no  
885 humans or animals involved directly.

886

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893

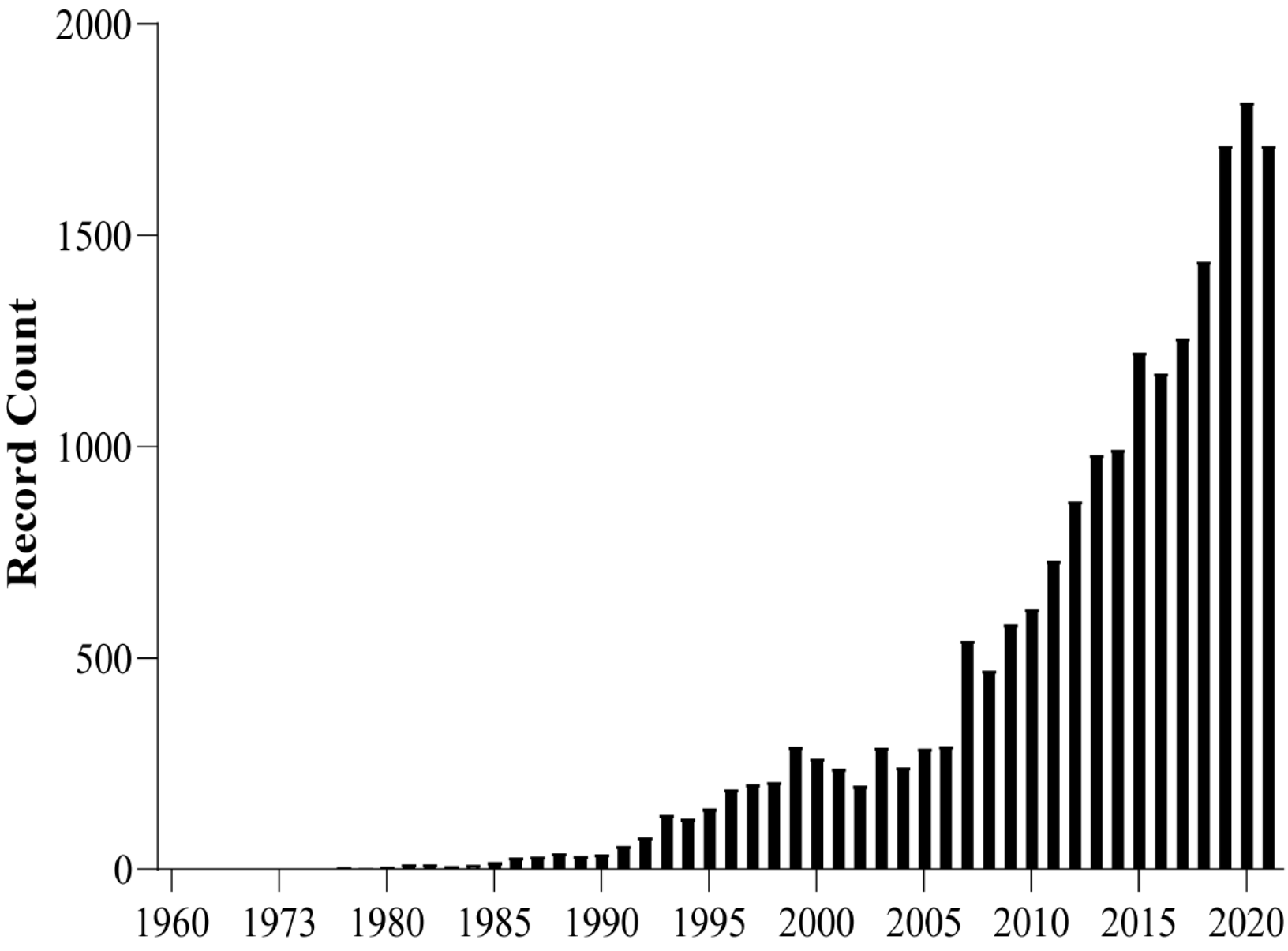
894 **Figure Legends**

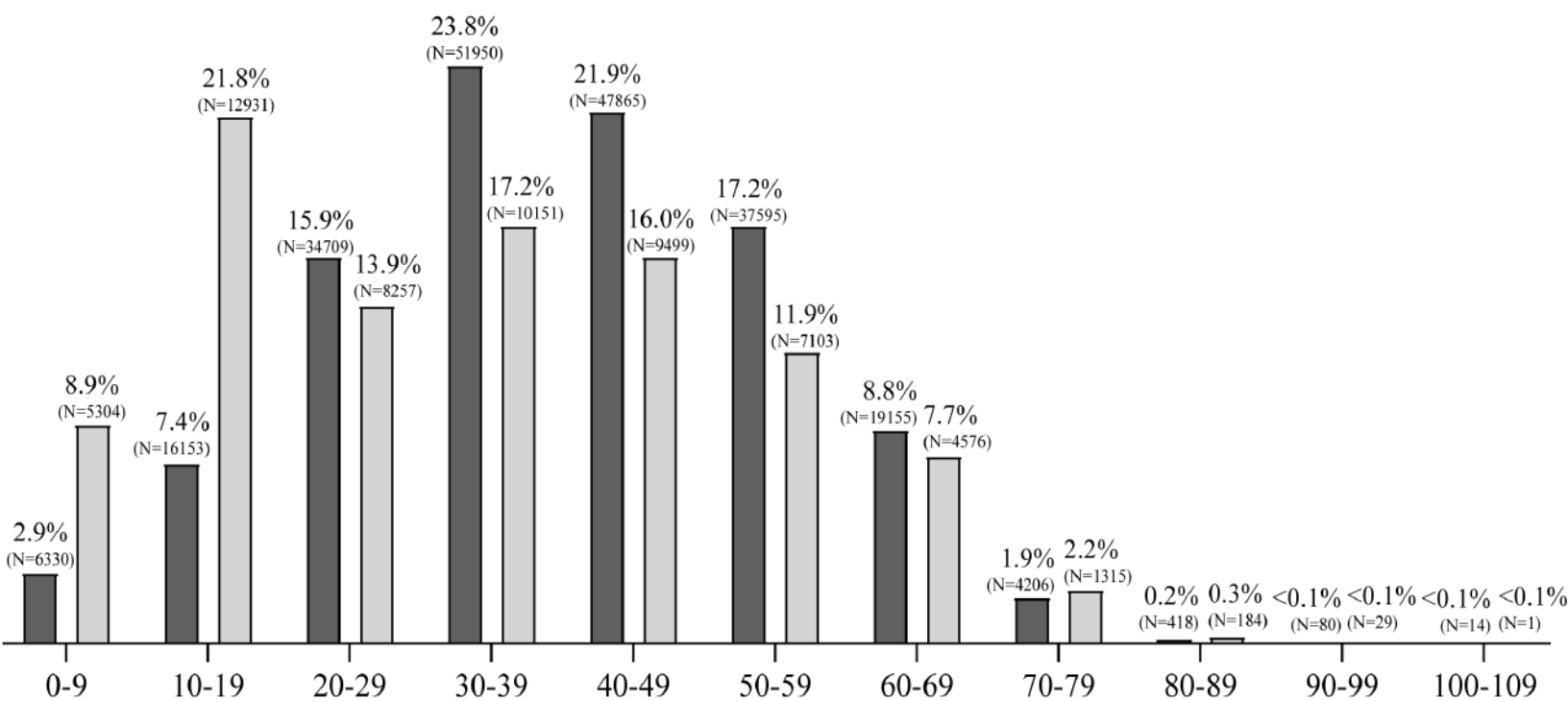
895 **Figure 1.** ISI-indexed publications using bioelectrical impedance analysis.

896 **Figure 2.** Data collected by sex regarding age (A) and region (B).

897 **Figure 3.** Graphical representation of the relationship between impedance index  
898 ( $\text{cm}^2/\text{kHz}$ ) and FFM (assessed by DXA), stratified by age and sex, in (A) female children  
899 and adolescents (<18 years, N=2190), (B) male children and adolescents (<18 years,  
900 N=3574), (C) female adults ( $\geq 18$  years, N=4741), and (D) male adults ( $\geq 18$  years,  
901 N=5205).





**A****B**