Worldwide inequality in access to full text scientific articles: the example of ophthalmology

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Background: The problem of access to medical information, particularly in low-income countries, has been under discussion for many years. Although a number of developments have occurred in the last decade (e.g. the open access movement and the website Sci-Hub), everyone agrees that these difficulties still persist very widely, mainly due to the fact that paywalls still limit access to approximately 75% of scholarly documents. In this study, we compare the accessibility of recent full text articles in the field of ophthalmology in 27 established institutions located worldwide. **Methods:** Two-hundred references from articles were retrieved using the PubMed database. Each article was individually checked for Open Access (OA). Full texts of non-OA (i.e. "paywalled articles") were examined to determine whether they were available using institutional and Hinari access in each institution studied, using "alternative ways" (i.e. PubMed Central, ResearchGate, Google Scholar, and Online Reprint Request), and using the website Sci-Hub. **Results:** The number of full texts of "paywalled articles" available using institutional and Hinari access showed strong heterogeneity, scattered between 0% full texts to 94.8% (mean= 46.8%; SD=31.5; median=51.3%). We found that complementary use of "alternative ways" and Sci-Hub leads to 95.5% of full text "paywalled articles", and also divides by 14 the average extra costs needed to obtain all full texts on publishers' websites using pay-per-view. **Conclusions:** The scant number of available full text "paywalled articles" in most institutions studied encourages researchers in the field of ophthalmology to use Sci-Hub to search for scientific information. The scientific community and decision-makers must unite and strengthen their efforts to find solutions to improve access to scientific literature worldwide and avoid an implosion of the scientific publishing model. This study is not an endorsement for using Sci-Hub. The authors, their institutions, and publishers accept no responsibility on behalf of readers.

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65

Abstract

66

67 **Background:** The problem of access to medical information, particularly in low-income

68 countries, has been under discussion for many years. Although a number of developments have

69 occurred in the last decade (e.g. the open access movement and the website Sci-Hub), everyone

70 agrees that these difficulties still persist very widely, mainly due to the fact that paywalls still

71 limit access to approximately 75% of scholarly documents. In this study, we compare the

72 accessibility of recent full text articles in the field of ophthalmology in 27 established institutions

73 located worldwide. **Methods:** Two-hundred references from articles were retrieved using the

74 PubMed database. Each article was individually checked for Open Access (OA). Full texts of

75 non-OA (i.e. "paywalled articles") were examined to determine whether they were available

76 using institutional and Hinari access in each institution studied, using "alternative ways" (i.e.

77 PubMed Central, ResearchGate, Google Scholar, and Online Reprint Request), and using the

78 website Sci-Hub. **Results:** The number of full texts of "paywalled articles" available using

79 institutional and Hinari access showed strong heterogeneity, scattered between 0% full texts to

80 94.8% (mean= 46.8%; SD=31.5; median=51.3%). We found that complementary use of

81 "alternative ways" and Sci-Hub leads to 95.5% of full text "paywalled articles", and also divides

82 by 14 the average extra costs needed to obtain all full texts on publishers' websites using pay-

83 per-view. **Conclusions:** The scant number of available full text "paywalled articles" in most

84 institutions studied encourages researchers in the field of ophthalmology to use Sci-Hub to

85 search for scientific information. The scientific community and decision-makers must unite and

86 strengthen their efforts to find solutions to improve access to scientific literature worldwide and

87 avoid an implosion of the scientific publishing model.

88 This study is not an endorsement for using Sci-Hub. The authors, their institutions, and

89 publishers accept no responsibility on behalf of readers.

Introduction

90

91 High-quality information is essential for effective health systems as well as scientific progress

92 and development (UNESCO, 1997; Koehlmoos & Smith, 2011). Access to information in order

93 to facilitate adequate health care is also considered to be a human right (Goehl, 2007; "Universal

94   Declaration of Human Rights," 2015). On the contrary, the lack of access to knowledge is the

95   main limitation to human development (The Lancet, 2011) and the principal barrier to

96   knowledge-based health care in developing countries (Godlee et al., 2005).

97   Research studies are based on bibliographic research work to achieve "the state of the art". This

98   stage not only makes it possible to carry out research studies based on existing and well

99   established scientific foundations, but also prevents carrying out studies already conducted by

100 other researchers in the world. Thus, access to scientific articles for researchers around the world

101 is crucial for assessing high-quality research. In the current revenue-models of scientific journals,

102 access to scientific papers is often restricted by paywalls. This implies that full text articles are

103 only available upon subscription or pay-per-view on publisher websites. One is forced to note

104 that paywalls still limit access to approximately 75% of scholarly documents in all disciplines

105 (Bosman & Kramer, 2018; Piwowar et al., 2018), including biology and medicine (Boudry &

106 Durand-Barthez, 2017; Bosman & Kramer, 2018). Moreover, "paywalled articles" are known to

107 disadvantage the lowest-income countries in terms of access to articles (Aronson, 2004;

108 Himmelstein et al., 2018).

109 Several initiatives have been implemented worldwide to facilitate access to scientific literature.

110 For researchers in developing countries, a specific program called Hinari (Health InterNetwork

111 Access to Research Initiative) was launched in 2002 for medicine. Hinari was developed by the

112 World Health Organization (http://www.who.int/hinari/en/) and is now part of one of the five

113 Research4Life programs created to reduce the knowledge gap in developing countries. It

114 provides free or very low-cost online access to resources in the biomedical literature for not-for-

115 profit institutions in developing countries, based on socio-economic factors ("WHO | Hinari

116 Access to Research for Health programme"). In 2011, in response to a lack of access to scientific

117 articles in Kazakhstan (Bohannon, 2016), Alexandra Elbakyan launched website Sci-Hub,

118 allowing direct downloading of articles, bypassing publisher paywalls. A recent study showed

119 that Sci-Hub contains 85.1% of all articles published in subscription-based journals

120 (Himmelstein et al., 2018), and is extensively used worldwide in low-, middle- but also in high-

121 income countries to circumvent paywalls (Bohannon, 2016). Such means of obtaining full text

122 articles raises many legal (Kemsley; Greco, 2017) and ethical questions (Bendezú-Quispe et al.,

123 2016; Saleem, Hasaali & Ul Haq, 2017; Hoy, 2017).

124   Data on the availability of scientific literature are often obtained from single-nation studies

125   (Nisonger, 2011; Malapela & de Jager, 2017), and to the best of our knowledge, worldwide

126   comparisons have not been carried out. Consequently, it is still not well known how paywalls

127   may affect researchers worldwide. The primary objective of this study was to evaluate the

128   accessibility of recent full text articles in the field of ophthalmology in established institutions

129   distributed worldwide using "institutional and Hinari access", then "alternative ways" (PubMed

130   Central, ResearchGate, Google Scholar and Online Reprint Request), and finally Sci-Hub. The

131   secondary objective was to calculate extra costs institutions or researchers must bear to recover

132   all full texts, buying them on publishers' websites.

Materials & Methods

134   The search for articles to be included in this study was carried out on March 29th, 2018 using the

135   PubMed database (http://www.ncbi.nlm.nih.gov/pubmed), developed by the National Center for

136   Biotechnology Information (NCBI) at the National Library of Medicine (NLM). The search

137   strategy was: eye diseases [MH] AND 2017:2018 [DP] AND english [LA] AND Journal Article

138   [PT] where MH stands for "Medical Subject Headings," DP "Date of Publication," and PT

139   "Publication Type". "Journal Article" includes the following publication types: journal articles,

140   introductory journal articles, and reviews as previously described in the field of ophthalmology

141   (Boudry et al., 2016). Data were downloaded from PubMed in Comma-Separate values (CSV)

142   and were imported to Microsoft Excel 2013 (Microsoft, Redmond, USA) for data processing.

143   This publication search resulted in a total of 11,103 articles recently published in the field of

144   ophthalmology from which two hundred (Tenopir et al., 2010) were randomly selected.

145   Confidence intervals were calculated taking into consideration the sample size studied (200),

146   with a margin of error of 5%.

Access to full text articles

148   Each of these two hundred articles was individually checked for Open Access (OA) on the

149   publisher's websites on April 3rd and 4th, 2018. Articles were labelled as "publisher OA" if the

150   full text was accessible freely on the publisher's website without requiring subscription. Articles

151   were labelled as "paywalled" if the full text was only available with a subscription.

152   The recruitment of the participants in the different institutions included in this study was done by

153   searching recent articles (published in 2017 or 2018) in the field of ophthalmology. The

154   researchers were contacted by email using corresponding authors' email addresses, or by

155   contacting researchers already known by CB and FM directly. Only researchers working in

156   capital cities or belonging to the most populated cities in their countries were chosen. Emails

157   were sent to correspondents/colleagues to ask them to participate in this study, with the goal of

158   reaching at least 25 countries located worldwide and spread over all continents.

159   Countries of researchers who agreed to collaborate were classified by continents according to the

160   United Nations classification ("United Nations Statistics Division- Standard Country and Area

161   Codes Classifications (M49)") and classified by income level according to the World Bank

162   classification ("Data | The World Bank"). Each participant had to search for "paywalled articles"

163   in order to recover their full texts, using their institutional access and Hinari resources if

164   available in their institutions, following a normalized protocol *(see Supplemental Information 1*

165   *and Supplemental Information 2)*. The Hinari offer is available to two groups of countries: group

166   A (free access for 69 countries) and group B (1500 US dollars per calendar year for 50 countries)

167   ("WHO | Hinari Access to Research for Health programme").

168   Additionally, individual searches for all full text "paywalled articles" were done using

169   "alternative ways" for evaluating the ability to find full texts of unavailable "paywalled articles"

170   through institutional and Hinari access. These searches were done using the Digital Objects

171   Identifiers (DOI) or titles of each article in the following order:

172   - Via PubMed Central open repository (https://www.ncbi.nlm.nih.gov/pmc/), the main free full-

173   text open archive of biomedical and life sciences journal literature. Full text articles on PubMed

174   Central are legally deposited either by publishers or by authors themselves;

175   - Via the academic social network ResearchGate (http://www.researchgate.net/). Full text articles

176   on ResearchGate (RG) are deposited by authors, sometimes without respecting publishing

177   agreements and copyright laws (Jamali, 2017);

178   - Via Google Scholar (https://scholar.google.com/), looking at the first ten results listed

179   (Nicholas et al., 2017). Full texts retrieved via Google Scholar are those found by the search

180 engine on websites throughout the internet, without any guarantee of legality regarding copyright

181 laws;

182 - Via online reprint request (ORR). ORR use the corresponding author email to obtain non-open-

183 access literature using reprints furnished by publishers to the corresponding author after

184 publication of an article. ORR is thus fully legal.

185 Full texts retrieved via PubMed Central, RG, Google Scholar or ORR were labelled as

186 "alternative ways".

187 - Via the Sci-Hub website. This means of obtaining full text is illegal in many countries in the

188 world as full texts on Sci-Hub are pirated from legal websites such as libraries, without regard to

189 copyright laws.

190 As the accessibility of full text "paywalled articles" using Sci-hub was independent of the

191 geographical location where the search was done, searches for full text "paywalled articles"

192 using Sci-hub were performed from France, from a non-university Internet access. No university

193 or institution of the authors of this study was therefore involved in downloading articles via Sci-

194 Hub.

195 This study has been approved by the Ethics Committee of the University Hospital of Rennes."

196 **Financial implications of unavailable full text articles**

197 When researchers do not have access to full text "paywalled articles" through the different means

198 of access at their disposal, they can buy them individually on publisher's websites (pay-per-

199 view). However, this extra cost presents the disadvantage of being borne directly by the

200 institution or laboratory, and sometimes by the researchers themselves. Extra costs of unavailable

201 full text "paywalled articles" were calculated both in US dollars and as the percentage of gross

202 domestic product (GDP) per capita at purchasing power parity (PPP). For each "paywalled

203 article", the cost of the pay-per-view of each article was recovered from the publisher's website

204 in US dollars. When the price was in euros, it was converted to US dollars using the exchange

205 rate in use on April 5th, 2018. The cost of unavailable full text articles in each institution was

206 calculated in US dollars, and was also expressed as the percentage of the GDP per capita at

207 purchasing power parity (PPP) (current international $), using the World Development Indicators

208   from the online databases of the World Bank ("Data | The World Bank"). The GDP is the market

209   value of all officially recognized final goods and services produced within a country in a given

210   period. Using the percentage of GDP per capita at PPP allows us to assess the real financial

211   burden of providing full text articles in relation to the standard of living of each country.

Results

213   We received 26 positive responses to the 166 emails sent seeking colleagues for participation in

214   this study. *Table 1* describes institutions and characteristics of the 27 countries included in the

215   present study. Four were Hinari group A (Cameroon, Democratic Republic of Congo, Senegal,

216   and Togo), whereas four were Hinari group B (Egypt, Tunisia, Jordan, and Pakistan) and 19

217   others were not Hinari eligible. Among institutions located in Hinari group B eligible countries,

218   only the University El-Manar (Tunisia) applied to obtain Hinari resources.

Access to full text articles

220   Among the 200 articles studied, 85 full texts (42.5%) were freely available on publishers'

221   websites ("publisher OA" articles), whereas 115 (57.5%) full texts were available only with

222   subscriptions ("paywalled articles"). See *Supplemental Information 3* for the list of the 115

223   "paywalled articles".

224   Figure 1 presents the number of full texts of the 115 "paywalled articles" available in each

225   institution using institutional and Hinari access. It must be emphasized that the number of

226   available full texts using institutional and Hinari access showed substantial heterogeneity,

227   scattered between 0 (0%) full texts and 109 (94.8%). An average of 53.8 (46.8%) full text

228   "paywalled articles" (SD=31.5) were available (*Table 2*). Half of the institutions had access to

229   less than 59 (51.3%) full text "paywalled articles" (IQR=49).

230   Regarding "alternative ways", 82 e-mails of corresponding authors were found via PubMed or

231   via the Publisher website, and online reprint requests were sent to them. Thirty-one responses

232   were received (43.9% success rate), allowing us to obtain 26.96% of "paywalled articles" using

233   online reprint requests. No full texts of paywalled articles were found on the open archive PMC

234   (paywalled articles included in this study were very recent and still under publisher embargoes,

235   prohibiting self-archiving in OA repositories), and only 13 (11.30%) were found on social

236   academic networks and internet via Google Scholar.

237   To complete the search for unavailable full texts using institutional and Hinari access,

238   researchers could use "alternative ways" (PubMeD Central, RG, Google Scholar and ORR).

239   As presented in *Table 2*, by using complementary "alternative ways", an average of 73.3 of the

240   115 (63.7%) full text "paywalled articles" were available (SD=22.2). The range of the number of

241   available full texts varied among the institutions studied from 37 (32.2% for the Pakistan

242   Institute of Community Ophthalmology and the State University of Milagro) to 111 (96.5% for

243   Leiden University Medical Center) of the 115 "paywalled articles".

244   Used alone, Sci-hub allows the recovery of 108 full texts (93.9%) of 115. Despite its illegal

245   nature, researchers may be tempted to use this website, to try to find the unavailable full texts

246   using institutional/Hinari access and "alternative ways". Interestingly, using Sci-Hub as a

247   complement to institutional/Hinari access and "alternative ways" allowed the recovery of an

248   average of 109.8 (95.5%) full texts (SD=1.8). Thus, the range of the number of available full

249   texts varied very slightly from 108 (93.9%) to 113 (98.3%) of the 115 "paywalled articles".

250   Moreover, for Pakistan Institute of Community Ophthalmology and State University of Milagro,

251   complementary use of Sci-Hub allowed them to recover 108 full texts of 115 instead of 37. As

252   shown in Figure 2, when considering access by continent (a) or by income level (b), using

253   complementary "alternative ways" tightens the gaps between continents and between countries

254   of low and high income level. Using Sci-Hub as a complement to institutional/Hinari access and

255   "alternative ways" totally eliminates the inequalities of access to "paywalled articles" by

256   continent or income level.

257   **Financial implications of unavailable full text articles**

258   Extra costs of unavailable full text "paywalled articles were assessed after using

259   institutional/Hinari access, after using institutional/Hinari access and "alternative ways", and

260   after using institutional/Hinari access, "alternative uses", and Sci-Hub (*Table 3*).

261   Using institutional/Hinari access, the average extra cost (in US dollars) of unavailable full text

262   "paywalled articles" would be $2,790.8. However, this extra cost varies greatly from one

263 institution to another: from $258 (Leiden University Medical Center) to $5,240.9 (State
264 University of Milagro and Pakistan Institute of Community Ophthalmology). Using alternative
265 ways in addition to institutional/Hinari access, extra costs would be reduced by an average of
266 $1,918.6. Interestingly, complementary use of Sci-Hub reduces the average extra cost of
267 unavailable full texts even more, dividing this average extra cost of unavailable full texts by 14
268 ($198.4 instead of $2790.8 using institutional/Hinari access and "alternative ways"). Likewise,
269 the average extra cost expressed as the percentage of GDP per capita at PPP is reduced more
270 than ten-fold (2.4% instead of 25.4%) for the 27 institutions studied. This extra cost is thus
271 substantial in some institutions, e.g. in Togo, where it is at 18.8%.

Discussion

273 In order to describe the difficulty in accessing scientific literature, a number of studies only
274 focusing on one country have been conducted, mostly in the USA, to assess the availability of
275 journals or books in university libraries (Nisonger, 2011). Other studies have been conducted to
276 analyze global access and use of digital resources in research, mainly in African universities
277 (Harle, 2009; Malapela & de Jager, 2017; Bruijns et al., 2017). To the best of our knowledge,
278 only one study in 2011 previously evaluated the accessing of recent full text "paywalled
279 articles", and included seven institutions located in Africa, North and South America, Asia, and
280 Europe (Voronin, Myrzahmetov & Bernstein, 2011). Furthermore, the problem of accessing
281 medical information in low-income countries is still being openly discussed (Aronson, 2004;
282 Godlee et al., 2005; Goehl, 2007; Himmelstein et al., 2018). We believe that our study provides
283 the most complete comparative study examining worldwide access to recent full text articles. In
284 addition, it is the first to study the financial implications of limited access to scientific literature
285 and the first to assess Sci-Hub's performance as an alternative to legal institutional access. The
286 field of ophthalmology was chosen because, for several years, our research team has been
287 focusing its research on bibliometrics in the field of ophthalmology.

288 Our study nevertheless has a number of limitations. The number of countries studied is relatively
289 low, particularly Hinari eligible countries, which can be explained by the difficulty in finding
290 researchers in the field of ophthalmology in most of the Hinari group A and B eligible countries.
291 Indeed, when we looked for collaborators to participate in this study, we found very few
292 researchers in the field of ophthalmology located in these countries (personal data). Moreover,

293   institutions studied in each country are inevitably not representative of the overall situation in the

294   country, and requesting participation from all the institutions in a country is impossible.

295   Nevertheless, to minimize the differences between institutions, only those located in capital cities

296   or belonging to the most populated cities in their countries were chosen. Finally, it was not

297   possible to obtain an average value of access to full text "paywalled articles" by country and to

298   calculate correlations between the number of accessible full texts and socio-economic parameters

299   (e.g. GDP per capita). For the same reasons, it was impossible to assess whether the use of

300   Hinari resources significantly changed the number of available full text "paywalled articles".

301   Furthermore, we wanted to compare the results obtained with the three ways of accessing full

302   text "paywalled articles". Our data included the average number of full texts available and the

303   average extra costs, in US dollars and expressed as the percentage of GDP per capita at PPP. We

304   found that using institutional/Hinari access; using institutional/Hinari access and "alternative

305   ways"; and using institutional/Hinari access, "alternative ways", and Sci-Hub were significantly

306   different at $p<.05$ (p-value$<.001$). However, as the ways of accessing full text "paywalled

307   articles" were not independent (because of the cumulative effect that binds them), these

308   statistical results were not taken into account. We deliberately limited the search to articles

309   published in 2017-2018 to include only very recent articles. This allowed us to access the latest

310   findings which are thus presumed to be more informative for clinicians and researchers than

311   older ones. Nevertheless, due to embargo periods, we must note that including articles published

312   over a wider time period could have led to more frequent inclusion of articles freely available on

313   publishers' websites ("publisher OA" articles) and articles using "alternative ways".

314   Our study nonetheless provides a global vision of the difficulty involved in accessing scientific

315   literature around the world, highlighting the shortcomings of institutional access, which can have

316   significant financial consequences for researchers seeking to overcome them. Our study also

317   shows that the use of the website Sci-Hub helps to overcome these shortcomings and financial

318   consequences.

319   The open access (OA) movement has been progressively making more articles openly available.

320   However, articles behind paywalls ("paywalled articles") are still more numerous than "publisher

321   OA" articles in our study (57.5% and 42.5%, respectively). These results are in agreement with

322   the most recent studies, which estimate that, in biology and medicine, 39.1% to 50% of articles

323   published are "publisher OA" articles (Boudry & Durand-Barthez, 2017; Bosman & Kramer,

324   2018). We found that researchers in ophthalmology working in the 27 institutions included in

325   this study can access only an average of 46.8% (with very large disparities, varying from 0% to

326   94.8%) of full text "paywalled articles" using their institutional and Hinari access. Furthermore,

327   half of the 27 institutions studied can offer access to just over 50% of full text "paywalled

328   articles", a value very close (56%) to that determined in 2011 for seven institutions located in

329   Africa, North and South America, Asia, and Europe (Voronin, Myrzahmetov & Bernstein, 2011)

330   showing that the situation has not improved in recent years. As previously pointed out by

331   Machin-Mastromatteo (Machin-Mastromatteo, Uribe-Tirado & Romero-Ortiz, 2016), this shows

332   that, "many universities are unable to acquire subscriptions for years, because they are seriously

333   hindered by budget limitations and the lack of interest and policies from the state for supporting

334   research and access to scientific resources". Researchers in ophthalmology working in the less

335   privileged institutions are thus in very poor situations. Indeed, although they use "alternative

336   ways" (i.e. PubMeD Central, RG, Google Scholar and ORR) to recover full texts, they are forced

337   to use Sci-Hub if they want to access a sufficient number of full text articles necessary to

338   conduct their research satisfactorily. Researchers cannot afford these articles because their yearly

339   budget for accessing articles without using Sci-Hub is too high, with sums of money up to

340    $3,597 (institutions in Pakistan or Ecuador), or more than 200% of the GDP per capita at PPP

341   (202.3% in Ecuador).

342   Results of the present study showed that "alternative ways" might help researchers access full

343   text "paywalled articles". We would like to draw particular attention to the usefulness of online

344   reprint requests (ORR). Although ORR does not immediately provide access and is a laborious

345   procedure which depends on many factors that vary between individuals, ORR are quite efficient

346   for obtaining full text "paywalled articles" (Kanthraj, 2010). Applied to our set of "paywalled

347   articles" they allow free access to the full texts of 31 (26.96%) of 115, which is not negligible.

348   An effort should be made to make them more widely known, particularly in less privileged

349   countries, where they are the least used (Burrows, 1996). Another way to promote the use of

350   ORR would be to have publishers and Pubmed make an extra effort to communicate, free of

351   charge, corresponding authors' email addresses (only 37 emails were found on the PubMed

352   website, and 81 were accessible free of charge on publisher websites). Indeed, some publishers

353   disclose corresponding authors' email addresses only on the full text of articles attainable only

354   through subscription, making it impossible to use ORR. Widely used globally (Bohannon, 2016),

355   Sci-Hub raises many questions about the future of scientific publication (Russell & Sanchez,

356   2016; McNutt, 2016; Machin-Mastromatteo, Uribe-Tirado & Romero-Ortiz, 2016; Strielkowski,

357   2017). Our results showed that using Sci-Hub makes it possible to drastically reduce the

358   inequalities of access to "paywalled articles" in the institutions studied, in terms of number of

359   accessible full texts and the money spent to buy them on publishers' websites. As already

360   pointed out by Bendezù-Quispe *et al*. and Machin-Mastromatteo *et al.*(Bendezú-Quispe et al.,

361   2016; Machin-Mastromatteo, Uribe-Tirado & Romero-Ortiz, 2016), our data show that Sci-Hub

362   can help clinicians in ophthalmology working in less privileged institutions or countries

363   worldwide by allowing them to obtain essential information and respond appropriately to patient

364   care needs. Without this option, they would not be able to cope with the demands of their

365   profession. Nonetheless, as shown by (Bohannon, 2016; Machin-Mastromatteo, Uribe-Tirado &

366   Romero-Ortiz, 2016), Sci-Hub is not only used in less privileged countries, and a correlation has

367   been shown between the number of downloads per 1,000 inhabitants on Sci-Hub and the Gross

368   Domestic Product (GDP) per inhabitant (Greshake, 2016). As examples, the United States is the

369   fifth largest downloader after Russia, and a quarter of the Sci-Hub requests came from the 34

370   members of the Organization for Economic Co-operation and Development, the wealthiest

371   nations with, as shown in this study, the best journal access. The use of Sci-Hub by these

372   countries can be defined as a use "by convenience" rather than necessity (Bohannon, 2016; Hoy,

373   2017; Lawson, 2017), and could easily decrease by improving library interfaces (Faust, 2016). In

374   the long term, Sci-Hub might disrupt the whole system of academic publishing because it harms

375   publishers due to the lost profits generated by its use (Strielkowski, 2017). In order to limit such

376   losses, publishers could be tempted to increase their subscription rates (Russell & Sanchez,

377   2016), which have been steadily increasing in recent years (Hoy, 2017; Himmelstein et al.,

378   2018), which may lead to cancellations or reduction of subscriptions by institutions worldwide

379   (Schiermeier & Mega, 2017). This would have the effect of further accentuating inequalities.

380   Publishers could also be tempted to further generalize "gold OA" (authors pay article processing

381   charges (APC) to publish their articles) as the default publication model (Novo & Onishi, 2017;

382   Strielkowski, 2017). This model is not beyond criticism because it favors the existence of

383   predatory publishers (Beall, 2012). It also generates inequalities between authors who have funds

384   to pay APC (whose cost is often prohibitive) and those who do not (Danda, 2014), despite many

385 publishers providing discounts at the request of the authors or according to their geographical
386 location. Some publishers have reacted by bringing lawsuits against Sci-Hub to shut down the
387 site (Kemsley; Greco, 2017). So far, these attempts have been unsuccessful, and it is likely that
388 future attempts will lead to the same outcome (Hoy, 2017). It now seems that Sci Hub will cease
389 to operate only if and when the conditions that make it essential disappear (Lawson, 2017), i.e.
390 that access to the articles through legal channels will not be as unequal as we have shown in this
391 study. To achieve this, in addition to the suggestion mentioned above, several paths can be taken:
392 including more countries in the Hinari program (particularly upper-middle income countries)
393 (Bendezú-Quispe et al., 2016); promoting Green OA (self-archiving in OA repositories) by
394 setting up institutional or national OA policies (Kirsop & Chan, 2005; Machin-Mastromatteo,
395 Uribe-Tirado & Romero-Ortiz, 2016), (e.g. as it has been done recently in France) (Boudry &
396 Durand-Barthez, 2017); and implementing subscription–based access for a reasonable price. This
397 has already been done in other areas, particularly in the field of music, "offering individual
398 subscription-based access to all articles from all imaginable databases for a price that most
399 scientists in any corner of the world could afford" (Strielkowski, 2017).

Conclusions

401 Regardless of the solutions chosen, it is urgent that the scientific community as well as decision-
402 makers, mobilize effectively to limit these inequalities of access to scientific "paywalled articles"
403 in order to solve this problem which has persisted for far too long, and finally free researchers
404 from this daily dilemma: Sci-Hub or not Sci-Hub?

405 **Warning:** "Sci-Hub does not restrict itself to only openly licensed content. Instead, it retrieves
406 and distributes scholarly literature without regard to copyright regimes. Readers should note that,
407 in many jurisdictions, use of Sci-Hub may constitute copyright infringement. Users of Sci-Hub
408 do so at their own risk. This study is not an endorsement of using Sci-Hub, and its authors and
409 publishers accept no responsibility on behalf of readers. There is a possibility that Sci-Hub users
410 — especially those not using privacy-enhancing services such as Tor — could have their usage
411 history unmasked and face consequences, both legal or reputational in nature." (Himmelstein et
412 al., 2018).

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518

Figure 1

Number of full text "paywalled articles" available (n=115) for each of the 27 institutions included in the study

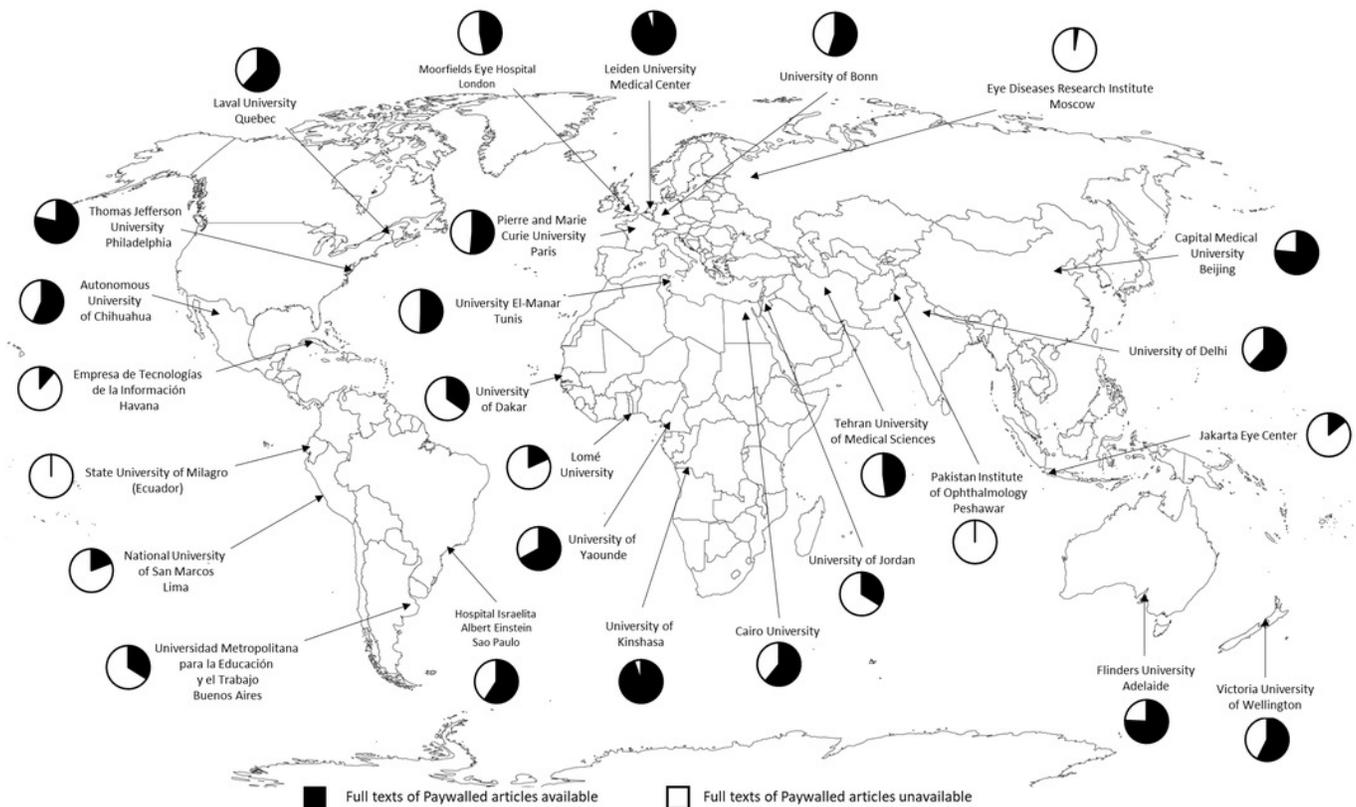
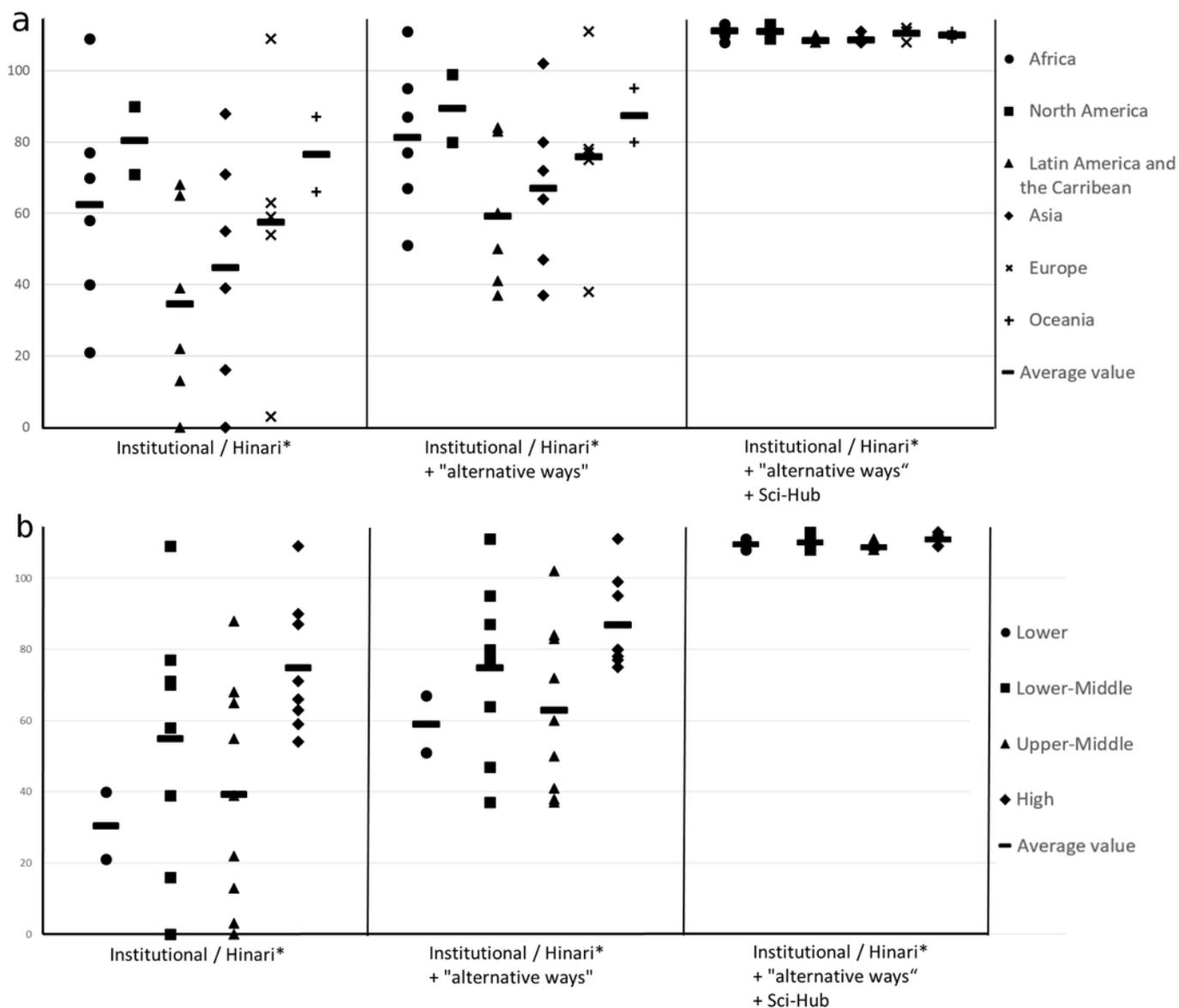



Figure 2

Number of full text "paywalled articles" available by continent (a) and by income level (b) using institutional and Hinari access, "alternative ways" (PubMeD Central, RG, Google Scholar, and ORR), and Sci-Hub. * If available.

Institutions included in the study presented by continents (listed alphabetically).

Institution	Country / continent	World bank classification by income level
University of Yaounde	Cameroon	Lower-middle
University of Kinshasa	Democratic Republic of the Congo	Lower-middle
Cairo University	Egypt	Lower-middle
University of Dakar	Senegal	Low
Lomé University	Togo	Low
University El-Manar, Tunis	Tunisia	Lower-middle
Laval University	Canada	High
Thomas Jefferson University, Philadelphia	United States of America	High
Universidad Metropolitana para la Educación y el Trabajo, Buenos Aires	Argentina	Upper-middle
Hospital Israelita Albert Einstein, Sao Paulo	Brazil	Upper-middle
Empresa de Tecnologías de la Información, Havana	Cuba	Upper-middle
State University of Milagro	Ecuador	Upper-middle
Autonomous University of Chihuahua	Mexico	Upper-middle
National University of San Marcos, Lima	Peru	Upper-middle
Capital Medical University, Beijing	China	Upper-middle
University of Delhi	India	Lower-middle
Jakarta Eye Center	Indonesia	Lower-middle
Tehran University of Medical Sciences	Islamic Republic of Iran	Upper-middle
University of Jordan	Jordan	Lower-middle
Pakistan Institute of Community Ophthalmology, Peshawar	Pakistan	Lower-middle
Pierre and Marie Curie University, Paris	France	High
University of Bonn	Germany	High
Leiden University Medical Center	The Netherlands	High
Eye Diseases Research Institute, Moscow	Russian Federation	Upper-middle
Moorfields Eye Hospital, London	United Kingdom	High
Flinders University, Adelaide	Australia	High
Victoria University of Wellington	New Zealand	High

Number of full text "paywalled articles" available using institutional and Hinari access, "alternative ways" (PubMeD Central, RG, Google Scholar, and ORR), and Sci-Hub.

* : if available. ** : confidence intervals were calculated considering the sample size studied (200), with a margin of error of 5%. Institutions are sorted by continent, countries are listed alphabetically.

Institution	Institutional / Hinari* n (%)	Institutional / Hinari* +"alternative ways" n (%)	Institutional / Hinari* +"alternative ways"+ Sci-Hub n (%)
University of Yaounde (Cameroon)	77 (67)	95 (82.6)	113 (98.3)
University of Kinshasa (Democratic Republic of the Congo)	109 (94.8)	111 (96.5)	113 (98.3)
Cairo University (Egypt)	70 (60.9)	87 (75.7)	110 (95.7)
University of Dakar (Senegal)	40 (34.8)	67 (58.3)	111 (96.5)
Lomé University (Togo)	21 (18.3)	51 (44.3)	108 (93.9)
University El-Manar, Tunis (Tunisia)	58 (50.4)	77 (67)	112 (97.4)
Laval University, Quebec (Canada)	71 (61.7)	80 (69.6)	109 (94.8)
Thomas Jefferson University, Philadelphia (United States of America)	90 (78.3)	99 (86.1)	113 (98.3)
Universidad Metropolitana para la Educación y el Trabajo. Buenos Aires (Argentina)	39 (33.9)	60 (52.2)	108 (93.9)
Hospital Israelita Albert Einstein, Sao Paulo (Brazil)	68 (59.1)	84 (73)	109 (94.8)
Empresa de Tecnologías de la Información, Havana (Cuba)	13 (11.3)	41 (35.7)	108 (93.9)
State University of Milagro (Ecuador)	0 (0)	37 (32.2)	108 (93.9)
Autonomous University of Chihuahua (Mexico)	65 (56.5)	83 (72.2)	110 (95.7)
National University of San Marcos, Lima (Peru)	22 (19.1)	50 (43.5)	108 (93.9)
Capital Medical University, Beijing (China)	88 (76.5)	102 (88.7)	111 (96.5)
University of Delhi (India)	71 (61.7)	80 (69.6)	108 (93.9)
Jakarta Eye Center (Indonesia)	16 (13.9)	47 (40.9)	108 (93.9)
Tehran University of Medical Sciences (Islamic Republic of Iran)	55 (47.8)	72 (62.6)	108 (93.9)
University of Jordan (Jordan)	39 (33.9)	64 (55.7)	109 (94.8)
Pakistan Institute of Community Ophthalmology, Peshawar (Pakistan)	0 (0)	37 (32.2)	108 (93.9)
Pierre and Marie Curie University, Paris (France)	59 (51.3)	77 (67)	111 (96.5)
University of Bonn (Germany)	63 (54.8)	75 (65.2)	111 (96.5)
Leiden University Medical Center (The Netherlands)	109 (94.8)	111 (96.5)	112 (97.4)
Eye Diseases Research Institute, Moscow (Russian Federation)	3 (2.6)	38 (33)	108 (93.9)
Moorfields Eye Hospital, London (United Kingdom)	54 (47)	78 (67.8)	111 (96.5)
Flinders University, Adelaide (Australia)	87 (75.7)	95 (82.6)	111 (96.5)
Victoria University of Wellington (New Zealand)	66 (57.4)	80 (69.6)	109 (94.8)
Mean	53.8 (48.6)	73.3 (63.7)	109.8 (95.5)
Standard deviation	31.5	22.2	1.8
Confidence interval**	+/- 8.1	+/- 11	+/- 16.5
Min	0 (0)	37 (32.2)	108 (93.9)
Max	109 (94.8)	111 (96.5)	113 (98.3)
Median	59 (51.3)	77 (67)	109 (94.8)
Inter quartile range (IQR)	49	36	3

Extra cost of full text "paywalled articles" unavailable using institutional/Hinari access; using institutional/Hinari accesses and "alternative ways"; and using institutional/Hinari access and "alternative ways" and Sci-Hub.

* : if available. Extra cost indicates the sum of the price of unavailable full texts bought individually on publishers' websites in US dollars, or between brackets expressed as percentage gross domestic product (GDP) per capita at purchasing power parity (PPP) (current international $).

Institution	Institutional / Hinari*	Institutional / Hinari* +"alternative ways"	Institutional / Hinari* +"alternative ways"+ Sci-Hub
University of Yaounde (Cameroon)	1636.3 (45.3)	799.0 (22.1)	30 (0.8)
University of Kinshasa (Democratic Republic of the Congo)	322.2 (5.6)	165.9 (2.9)	58 (1.0)
Cairo University (Egypt)	1940.2 (17.4)	1176.0 (10.6)	162 (1.5)
University of Dakar (Senegal)	3475.1 (135.4)	2181.0 (85.0)	190.8 (7.4)
Lomé University (Togo)	4378.1 (293.6)	3016.1 (202.3)	279.6 (18.8)
University El-Manar, Tunis (Tunisia)	2638.3 (22.8)	1788.1 (15.4)	160.8 (1.4)
Laval University, Quebec (Canada)	2296.4 (5.1)	1831.8 (4.1)	235.6 (0.5)
Thomas Jefferson University, Philadelphia (United States of America)	962 (1.7)	579.4 (1.0)	58 (0.1)
Universidad Metropolitana para la Educación y el Trabajo. Buenos Aires (Argentina)	3568.2 (17.9)	2644.8 (13.3)	279.6 (1.4)
Hospital Israelita Albert Einstein, Sao Paulo (Brazil)	2035.2 (13.5)	1313.8 (8.7)	220.8 (1.5)
Empresa de Tecnologías de la Información, Havana (Cuba)	4573.4 (84.0)	3391.6 (62.3)	279.6 (5.1)
State University of Milagro (Ecuador)	5240.9 (47.0)	3597 (32.3)	279.6 (2.5)
Autonomous University of Chihuahua (Mexico)	2116 (12.2)	1333.6 (7.7)	162 (0.9)
National University of San Marcos, Lima (Peru)	4229.8 (32.5)	3034.6 (23.3)	279.6 (2.1)
Capital Medical University, Beijing (China)	1150.7 (7.4)	512.9 (3.3)	118 (0.8)
University of Delhi (India)	2229.1 (33.9)	1778.5 (27.1)	279.6 (4.3)
Jakarta Eye Center (Indonesia)	4657.6 (40.1)	3201.6 (27.6)	279.6 (2.4)
Tehran University of Medical Sciences (Islamic Republic of Iran)	2706.9 (13.6)	2001.3 (10.0)	279.6 (1.4)
University of Jordan (Jordan)	3446 (38.1)	2526.6 (27.9)	279.6 (3.1)
Pakistan Institute of Community Ophthalmology, Peshawar (Pakistan)	5240.9 (100.1)	3597.0 (68.7)	279.6 (5.3)
Pierre and Marie Curie University, Paris (France)	2608.4 (6.3)	1775.9 (4.3)	176.8 (0.4)
University of Bonn (Germany)	2325.7 (4.8)	1749.7 (3.6)	118.8 (0.2)
Leiden University Medical Center (The Netherlands)	258 (0.5)	124 (0.2)	88 (0.2)
Eye Diseases Research Institute, Moscow (Russian Federation)	5134 (20.7)	3561.1 (14.4)	279.6 (1.1)
Moorfields Eye Hospital, London (United Kingdom)	2579.8 (4.5)	1495.2 (2.6)	118 (0.2)
Flinders University, Adelaide (Australia)	1270.4 (2.8)	918.9 (2.0)	146.8 (0.3)
Victoria University of Wellington (New Zealand)	2330.6 (6.00)	1707.9 (4.4)	235.6 (0.6)
Mean	2790.8 (37.5)	1918.6 (25.4)	198.4 (2.4)
SD	1458.2 (60.6)	1064.5 (41.5)	83.7 (3.7)
Min	258 (0.5)	124 (0,2)	30 (0.1)
Max	5240.9 (293.6)	3597 (202.3)	279,6 (18.8)