Inclusion, reporting and analysis of demographic variables in chronobiology and sleep research

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Many aspects of sleep and circadian physiology appear to be sensitive to participant-level characteristics. While recent research robustly highlights the importance of considering participant-level demographic information, it is not clear to what extent this information is available in the large body of already published literature. Here, we investigated study sample characteristics in the published sleep and chronobiology research over the past 40 years. 6,777 articles were identified and a random sample of 20% was included. The reporting of sample size, age, sex, gender, ethnicity, level of education, socio-economic status, and profession of the study population was scored, and any reported aggregate summary statistics for these variables were recorded. We found that while >90% of studies reported age or sex, all other variables were reported in <10% of cases. Sex balance greatly changed over the years, from a ~3:1 male to female ratio in the 1990s to a near-equal representation in the 2010s. We found that the majority of studies report at least sex or age, while other variables are typically not reported. Reporting quality is highly variable, indicating an opportunity to standardize reporting guidelines for participant-level characteristics to facilitate meta analyses.

Keywords: demographics, ethnicity, sex, research participants, reporting, publishing, meta-science
Word count: X

Introduction

Many aspects of sleep and circadian physiology appear to be sensitive to characteristics of the studied population, most notably sex (Anderson & FitzGerald, 2020; Cain et al., 2010; Mong et al., 2011; Redline et al., 2004; Santhi et al., 2016), age (Benloucif et al., 2006; Bliwise, 1993; Desforges, Prinz, Vitiello, Raskind, & Thorpy, 1990; Duffy, Zitting, & Chinoy, 2015; Espiritu, 2008; Li, Vitiello, & Gooneratne, 2018; Mander, Winer, & Walker, 2017; Redline et al., 2004) and ethnicity (Ahn et al., 2021; Eastman, Molina, Dziepak, & Smith, 2012; Eastman, Tomaka, & Crowley, 2016; Goldstein, Gaston, McGrath, & Jackson, 2020). More generally, there is a large literature on individual differences on sleep and circadian physiology (Baehr, Revelle, & Eastman, 2000; Burgess & Fogg, 2008; Chellappa, 2021; Dongen, Vitellaro, & Dinges, 2005; Horne & Östberg, 1977; Kerkhof, 1985; Santhi et al., 2012; Tankova, Adan, & Buela-Casal, 1994), demonstrating the need to consider participant-level data.

The extent to which a scientific field's findings are generalisable depend very much on the representativeness of a given study sample. A recent study reviewed the reporting and analysis of sex in biological sciences research (Woitowich, Beery, & Woodruff, 2020). The authors found that while sex inclusion has significantly increased over the past 10 years (Beery & Zucker, 2011), sex-based analysis has not improved, despite recent policies and funder mandates (Clayton & Collins, 2014). The term "gender data gap" has recently been introduced, demonstrating that women have historically been excluded from biomedical research (Criado-Perez, 2020).

The lack of diversity in biomedical and clinical research and understudy of minorities in the presence of existing health inequities exacerbates these inequities (Oh et al., 2015).

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The authors made the following contributions. Selma Tir: Data curation, Investigation, Software, Visualization, Writing – original draft, Writing – review & editing; Rhiannon White: Investigation, Writing – original draft, Writing – review & editing; Manuel Spitschan: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Project administration, Software, Writing – original draft, Writing – review & editing.

While research findings converge on participant-level demographic characteristics affecting outcomes, it is not clear to what extent this information is available in the large body of already published literature, nor to what extent it is even reported. Here, we address the question of participant-level demographic characteristics (age, sex, gender, ethnicity, level of education, socio-economic status, and profession of the study population) and reporting thereof in chronobiology and sleep research. Here, we extracted the study sample characteristics in a total of 1355 randomly sampled publications across the 8 top (ranked by the Journal Impact Factor) chronobiology and sleep research and subjected them to a comprehensive analysis.

Methods

Procedure. Journal articles published between 1979 and 2019 (odd years) in the top eight sleep and chronobiology journals were considered. The listing of possible target journals was based on a previously established list of journals implementing a hybrid strategy by consulting the Web of Science Master Journal List, domain-relevant expertise in sleep and chronobiology and consulting with a senior researcher with >25 years of experience in the field (Spitschan, Schmidt, & Blume, 2020). From this previously derived list, we selected eight journals were selected based on their five-year Impact Factor, and included *Journal of Pineal Research* (ISSN: 0742-3098 / 1600-079X; 2018 5-year IF: 12.197), *Sleep* (0161-8105 / 1550-9109; 5.588), *Journal of Sleep Research* (0962-1105 / 1365-2869; 3.951), *Sleep Medicine* (1389-9457 / 1878-5506; 3.934), *Journal of Clinical Sleep Medicine* (1550-9389 / 1550-9397; 3.855), *Journal of Biological Rhythms* (0748-7304 / 1552-4531; 3.349), Behavioral Sleep Medicine (1540-2002 / 1540-2010; 3.162), and *Chronobiology International* (0742-0528 / 1525-6073; 2.998). While *Sleep Medicine Reviews* also features in the list of journals, we did not include it as it primarily publishes reviews.

Article inclusion. 6,777 articles were identified through a MEDLINE search by the journal and including odd years. A random sample of 20% was initially selected for screening. Inclusion requirements included conducting original research in the English language, reporting human data, and recruiting volunteers. As such, animal studies, bibliographies, case reports, comments, conference proceedings, editorials, guidelines, letters, retracted publications, reviews, errata and corrigenda were excluded.

Review and article extraction. All included articles were reviewed for eligibility and coded by RW. The reporting of sample size, age, sex, gender, ethnicity, level of education, socioeconomic status, and profession of the study population was scored binarily (0 = not reported, 1 = reported), and any reported aggregate summary statistics for these variables were recorded. Funding source, geographical location and clinical focus of the article were examined, as well as whether data were analyzed by including any of the demographic variables as covariates.

Data were coded in an Excel Spreadsheet and analyzed in R Studio (version 4.0.5). Reporting of funding, geographical location, and number of sub-studies for each article were investigated for the sample of articles that passed all eligibility criteria.

Pre-registration. We pre-registered our protocol (specified using the PRISMA-P template (PRISMA-P Group et al., 2015; Shamseer et al., 2015)) on the Open Science Framework (https://osf.io/cu3we/).

Materials, data and code availability. All data underlying this manuscript are available on a public GitHub repository (https://github.com/hcvnl/sleep_circadian_demographics_data). The article was written in R (R Core Team, 2020) using RMarkdown and papaja (Aust & Barth, 2020), employing a series of additional R packages (Arnold, 2021; Attali & Baker, 2019; Auguie, 2017; Bates & Maechler, 2021; Borchers, 2021; Edwards, 2020; Henry, Wickham, & Chang, 2020; Kaplan & Pruim, 2021; Müller & Wickham, 2021; Pruim, Kaplan, & Horton, 2021; Pruim, Kaplan, & Horton, 2017; Sarkar, 2008; Sarkar & Andrews, 2019; Wei & Simko, 2017; Wickham, 2007, 2016, 2019, 2021; Wickham & Bryan, 2019; Wickham, François, Henry, & Müller, 2021; Wickham & Hester, 2020; Wilke, 2021; Xiao, 2018; Xie, 2015) and is fully reproducible.

Results

Number of analysed articles. Out of 1355 articles, we included and extracted data from 1152 (85%). The distribution of years in which the articles were published is non-uniform and we included and extracted data from more recent articles (Fig. 1). In addition, the representation of journals in the final list of articles is non-uniform, not least as the included journals will have not have been available from the entire data collection period (1979 and onwards). We also examined reasons for exclusion amongst the articles that we did not include and extract data from. These are given in Figure 2.

Funding. Funding sources were reported by 62% of studies, while funding number was also reported in 69% of these cases (Fig. 3). Overall, funding by the United States' National Institutes of Health (NIH) represented 19% of the reported funding agencies. 92% of the studies funded by the NIH also reported funding number. The second most represented funding agencies were the Australian National Health and Medical Research Council (NHMRC) and the Canadian Institutes of Health Research (CIHR).

Geographical location. 93% of articles were conducted in a single country. The geographical location of the study was explicitly reported in 57% of studies. The country of study was inferred for the rest of the sampled articles. Inference was primarily based on the first author's affiliation. Overall, 53 countries were represented. 77% of articles reported multiple

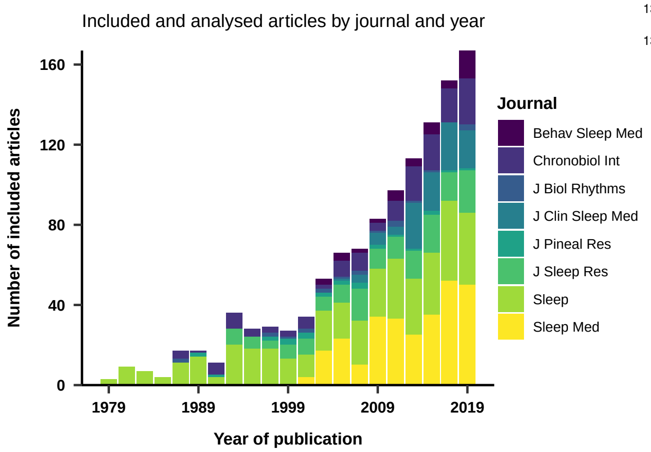

Figure 1. Included and analysed articles by year and journal. More recent articles are more represented, reflecting an overall increase in scientific output.

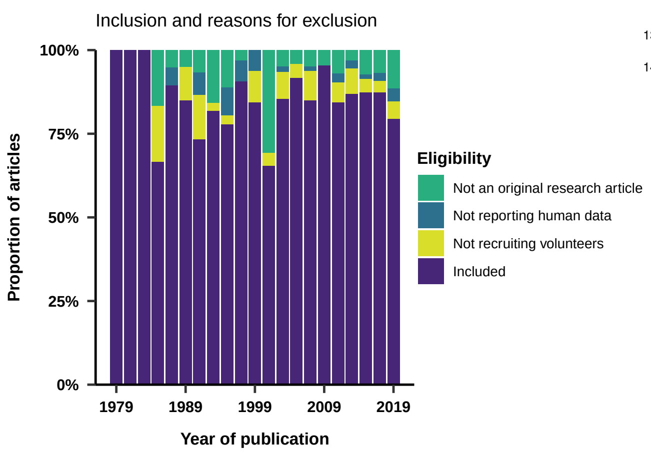

Figure 2. Normalised distributions of included and excluded articles.

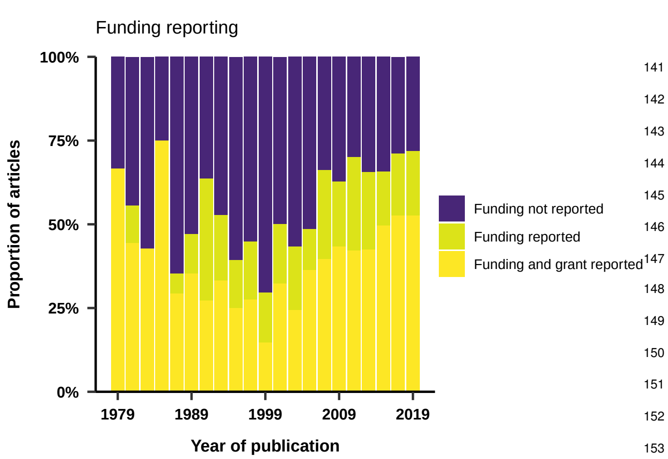

Figure 3. Reporting of funding across years.

countries of study. Figure 4 shows the distribution of study location across time with the eight most represented countries.

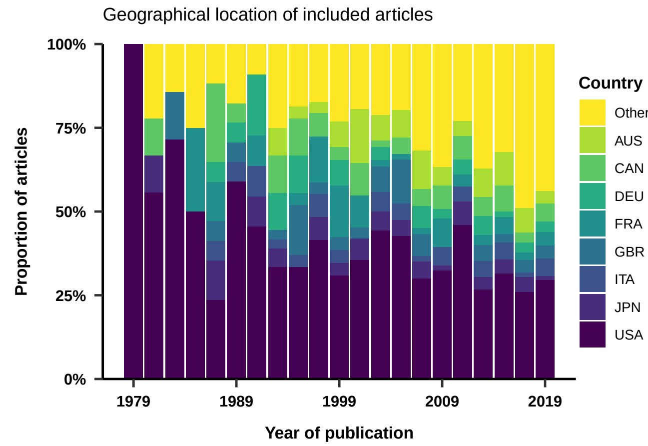

Figure 4. Gegraphical location of the studies. The eight most represented countries across the entire dataset are individually shown.

Sample size. Sample size was reported in 92% of studies, while 98% investigated a single sampled population.

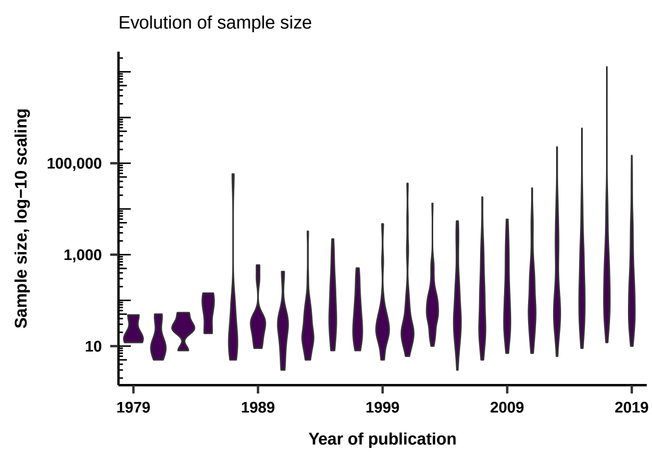

Figure 5. Sample size of the recruited volunteers as a function of publication year. Numbers are computed on a log-10 scale.

Age. 93% of articles reported a variable describing age. Overall, the average mean age of the study populations was 39 years old. We examined the extent to which the mean age across studies differed widely as a function of publication year (Fig. 6), and found that the mean age is much more widely varied in later years, likely reflecting the extent of considering study samples that are more varied in age.

Sex. Sex was reported in 89% of the studies. In Figure 7, we show the proportion of studies that recruited male subjects, female subjects, both sexes or did not specify the sex of the participants. 13% of the studies reporting sex only recruited male participants, while 10% only employed females. Out of the studies focusing on a single gender, 1% of the male studies focused on a sex dependent feature, while 2% of the female studies did. 4% of studies reported age by sex.

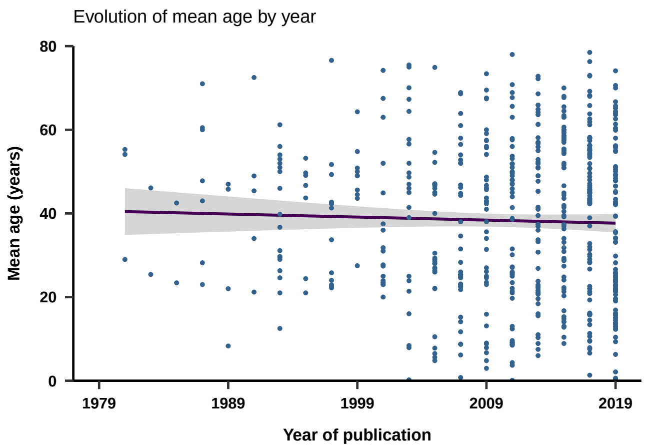

Figure 6. Evolution of mean age in included studies as a function of publication year. Fit shown is a linear fit.

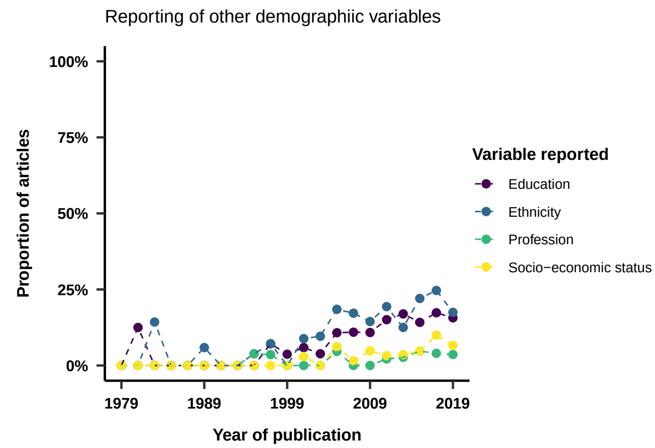

Figure 8. Reporting of education, ethinicity, profession and socio-economic status.

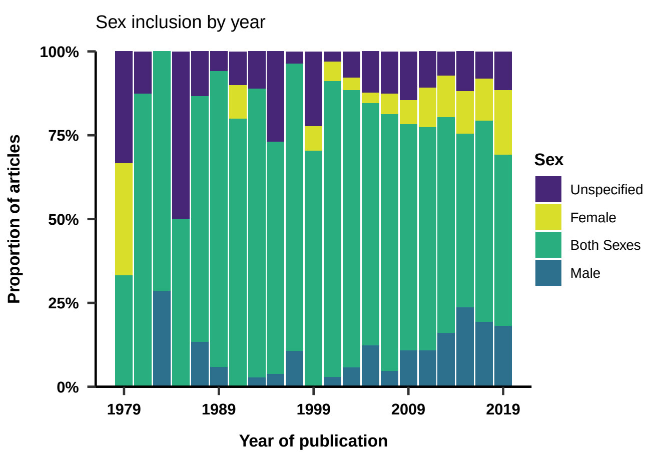

Figure 7. Sex inclusion by year. Proportion of studies that recruited male subjects, female subjects, both sexes, or did not specify the sex of the participants.

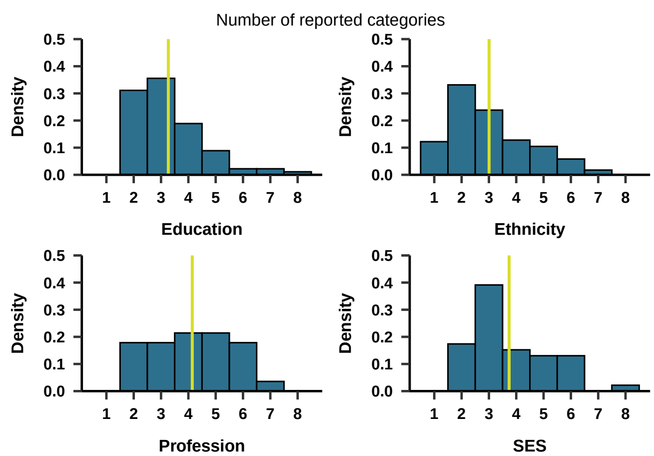

Figure 9. Number of categories reported for education, ethnicity, profession and socio-economic status.

Ethnicity, education, profession and socio-economic status. We also examined the reporting of other demographic variables, including ethnicity, education, profession and socio-economic status. Other demographics variables were reported in 12% of studies for education, 15% for ethnicity, 2% for profession, and 4% for socio-economic status. Figure 8 shows the distribution of this reporting across the years. Qualitatively, we see an increase of reporting additional demographic variables over time. In Figure 9, we show the number of categories reported for each variable amongst those articles that included it in a histogram.

Study focus. 3% of articles focused on a sex dependent feature, while 50% investigated a clinical feature. 1% of studies focused on twins, 1% on pregnant women, 2% on shift workers and 4% on university students.

Analysis disaggregation. We also examined the extent to which articles reported subgroup analyses of the data based on one or more of the reported demographic variables. Over time (Fig. 10), we see a distinct evolution of the extent to which subgroup analyses of the study sample were performed. The most common subgroup analyses involve disaggregting by sex and age, or both.

Discussion

Taking an inventory of represented study samples reveals the representativeness of our collective knowledge

The ability to generalise findings from the scientific literature to wide and diverse populations of people hinges upon the representativeness of the study sample with respect to demographic categories. The question to what extent the composition of a given study sample can make the generalisability of findings difficult or impossible has received attention in the field of psychology, where many articles published in prominent journals reflected participants from WEIRD (Western, Educated, Industrialized, Rich, and Democratic) contexts (Henrich, Heine, & Norenzayan, 2010; Muthukrishna et al.,

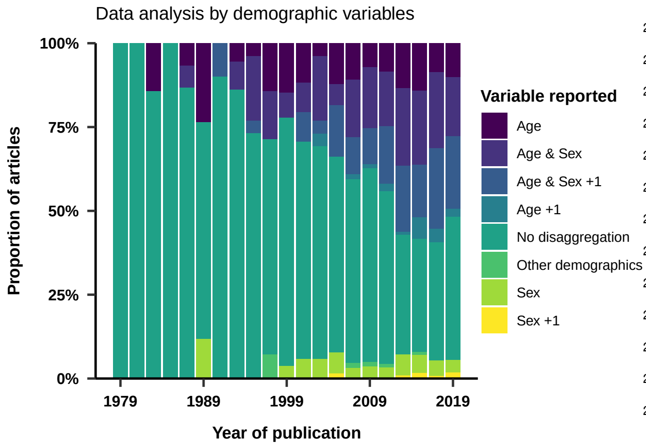

Figure 10. Use of study population characteristics as variables in the analysis.

2020). In other fields, analyses similar to the one in the present review have been published (Jones, St. Peter, & Ruckle, 2020; O'Bryant, O'Jile, & McCaffrey, 2004; Sifers, 2002), but to our knowledge, this review represents a first look at these question of participant demographics in chronobiology and sleep research.

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The need to consider individual differences

In the clinical domain, the need to time therapy based on a patient's individual circadian rhythm has more recently become the focus of the emerging field of chronotherapy or chronotherapeutics (Adam, 2019; Dijk & Duffy, 2020; Greco & Sassone-Corsi, 2020; Hill, Innominato, Lévi, & Ballesta, 2020).

Limitations of the current review

We now turn to possible limitations of this review and the included analyses and discuss how they might introduce bias in our findings. First, we consider the possibility that the article selection procedure may have introduced biases. Our review only concerned articles from a subset of eight specialized journals. As a consequence, the included articles were necessarily published in these journals, ignoring relevant articles published in other specialised journals (such as those included in the list of candidate journals), and articles published in other, including interdisciplinary journals. This raises the question to what extent we may have missed a section of the literature that would have been relevant to include here. As an alternative strategy, we considered randomly sampling a subset of chronobiology and sleep research articles produced by a general search (e.g. on search from "sleep OR chronobiology" on MEDLINE), but considered this to be too permissive. Our strategy of selecting a subset of candidate journals provided a reasonable trade-off, as well as sampling from a range of field-specific outlets.

Due to the non-uniform distribution of publication years of the included articles (Fig. 1), variables derived from published papers and visualized and/or analyzed by year will have varying uncertainty, with reported percentages from publications of the earlier years being most uncertain. The fact that early years are represented with fewer articles, however, is a not a function of our data set, but of the exponential groth of scientific output (Bornmann & Mutz, 2015; Parolo et al., 2015; Powell et al., 2017).

Towards standardised reporting of demographic variables: From checklists to schemas?

There are guidelines and/or checklists for standardizing reporting of participant characteristics, such as CONSORT (Schulz, Altman, Moher, & CONSORT Group, 2010) or STROBE (Elm et al., 2007) (an extensive data base for health research reporting guidelines is provided by the Equator Network, https://www.equator-network.org/). Some biomedical journals (e.g. Robinson, McMichael, & Hernandez, 2017) specifically state demographic reporting requirements in the author instructions. Similarly, some organisations may make recommendations of specific reporting items for specific types of study (Veitch & Knoop, 2020).

These guidelines and/or checklists are largely focused on *what* is reported and not *how* it is reported. There is, *a priori*, however, no reason to not develop and use a standardized and machine-readable schema for reporting participant characteristics. The FAIR principles state that data should be findable, accessible, interoperable and reusable (Wilkinson et al., 2016), and one way of realising these criteria is the use of data schemas which could prescribe categories of data and common naming schemes for reporting participant characteristics. Importantly, however, "what gets counted counts" (D'Ignazio & Klein, 2020), and it will be imperative to understand to what extend such any data schema may be exclusionary (e.g. by enforcing gender binaries), and whether any specific demographic variable is truly important (following the principle of data minimization).

Conclusion

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