Utilization and Harmonization of Adult Accelerometry Data: Review and Expert Consensus

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Abstract

Purpose—To describe the scope of accelerometry data collected internationally in adults; and, to obtain a consensus from measurement experts regarding the optimal strategies to harmonize international accelerometry data.

Methods—In March 2014 a comprehensive review was undertaken to identify studies that collected accelerometry data in adults (sample size N 400). Additionally, twenty physical activity experts were invited to participate in a two-phase Delphi process to obtain consensus on: unique research opportunities available with such data; additional data required to address these opportunities; strategies for enabling comparisons between studies/countries; requirements for implementing/progressing such strategies; and, value of a global repository of accelerometry data.

Results—The review identified accelerometry data from >275,000 adults from 76 studies across 36 countries. Consensus was achieved after two rounds of the Delphi process; 18 experts participated in one or both rounds. Key opportunities highlighted were the ability for cross-country/cross-population comparisons, and the analytic options available with the larger heterogeneity and greater statistical power. Basic socio-demographic and anthropometric data were considered a pre-requisite for this. Disclosure of monitor specifications, and protocols for data collection and processing were deemed essential to enable comparison and data harmonization. There was strong consensus that standardization of data collection, processing and analytical procedures was needed. To implement these strategies, communication and consensus among researchers, development of an online infrastructure, and methodological comparison work were required. There was consensus that a global accelerometry data repository would be beneficial and worthwhile.

Conclusion—This foundational resource can lead to implementation of key priority areas and identifying future directions in physical activity epidemiology, population monitoring and burden of disease estimates.

Keywords

INTRODUCTION

Regular participation in moderate- to vigorous-intensity physical activity has well established benefits for both physical and mental health (49). More recently, the detrimental health impacts of sedentary time (too much sitting) (68), and the potential benefits of light intensity activities have been identified (43, 51). These advances in understanding activity across a broadened and more differentiated spectrum have, in large part, been due to advances in activity monitor technology (48), which address several of the limitations associated with self-report measures (21). Wearable, accelerometer-based activity monitors that collect date and time stamped posture and/or activity information are becoming increasingly available and affordable. Correspondingly, they are becoming more widely used in observational (including surveillance) and intervention studies as a measure of physical activity and sedentary time *levels* (i.e. total volumes). Furthermore, the time

resolution of data collected from such devices has also provided important insights into the accumulation *patterns* of physical activity and sedentary time across the day.

Most of these insights have so far been gained from individual studies. Analysis of pooled international accelerometry data (plus other relevant variables) may, however, facilitate more in-depth understanding of (a) the levels and patterns of activity across the intensity spectrum; (b) the impact of physical activity, physical inactivity and sedentary time on physiological, psychological, and health outcomes; (c) the correlates and determinants of these behaviors; and, (d) how these levels and patterns, health associations, and correlates and determinants, as described above, may vary between sub-groups and populations. For brevity, from here onwards the terminology "physical activity" and "activity" will be used as umbrella terms to cover the whole spectrum of physical activity variables (including the whole intensity spectrum from sedentary, through to light-, moderate- and vigorous-intensity activity).

In 2008 the International Children's Acceleromtery Database (ICAD) project (http://www.mrc-epid.cam.ac.uk/research/studies/icad/) was launched which, for the first time, pooled Actigraph (Actigraph LLC, Pensacola, FL) accelerometry data (epoch-level) and harmonised accompanying data on children 5–18 years (63). The database, which holds information on ~26,000 children from 20 studies worldwide, has allowed new analyses to generate a clearer understanding of predictors of activity, activity-disease associations and the types and levels of activity that should be promoted to maximize health benefit (e.g. (22, 47)). The ICAD project shows that international groups are prepared to collaborate and share data in a pooled archive, with data access procedures in place following submission of analysis proposal, open to all researchers in the world. This project has also provided insights into some of the benefits (e.g. large sample sizes and increased heterogeneity in activity and accompanying data) and challenges (e.g. varying protocols and measures for the activity or accompanying data) associated with such pooling efforts. Researchers have now expressed an interest to extend pooling to include adults, different accelerometer models/versions and a broader range of accompanying data (including data relating to correlates, determinants and health outcomes, as well as to the accelerometer technology and study design).

However, differences between monitor types, models, calibration methods, attachment procedures and wear locations, deployment strategies, monitor setup, and data processing procedures of existing studies, together with further developments in measurement methodology, pose evolving challenges in this research field (48). To better understand and to begin to address these challenges, this article reports on:

    A. a comprehensive review describing the scope of accelerometry data collected internationally in adults; and,

    B. an expert consensus, via a two-phase Delphi process, regarding optimal strategies to harmonize international accelerometry data.

It is intended that the data reported in this article will provide a foundational resource for implementing key priority areas and identifying future directions for pooling and

harmonizing accelerometry data, which could substantially progress the field of physical activity epidemiology.

PART A: Comprehensive Review

The first part of this manuscript provides the results of a comprehensive review, reporting on the amount of accelerometry data collected internationally in adults, the types of monitors used, the wear location, the study designs, the sampling frames and other study-specific information.

METHODS

Search strategy—Three different search strategies were employed. A PubMed electronic literature database search was undertaken on the 7th March 2014, using the search syntax "acceleromet* AND adult* AND physical activity". Second, authors' own literature databases were screened for publications which matched the inclusion criteria but were not identified from the PubMed database search, as was authors' knowledge of unpublished studies with completed or on-going data collection.

Inclusion and exclusion criteria—Studies that used an accelerometer-based activity monitor that measured activity across the movement intensity spectrum with a sample size of N 400 adults (18+ years) were eligible to be included. We excluded: non-human studies; studies with a mean age <18 years; non time-stamped pedometer (steps-only) studies; heart-rate monitoring only studies; studies which purposely recruited a specific population (i.e. populations with functional or cognitive limitations, pregnant women, military and athlete groups, students, and patients [studies involving overweight/obese adults and those at high risk for diabetes were included]); methodological studies (i.e. reliability, validity and feasibility studies); laboratory studies; sleep only studies; and, studies not relating to physical activity.

Data extraction—Data were extracted using a standardized form which included study name, country, monitor type/model, anatomical site worn, N, age, gender, study design, sampling frame/strategy and timing of data collection. For multi-phase studies, only data of the first phase providing accelerometry data were extracted. In cohorts with an age range covering childhood/adolescence and adulthood the total age range was provided, but N was derived for adults only, given the focus of this review. When needed, more than one information source was used per study, to enable complete data extraction. For studies sourced from published documents, any information not provided in the corresponding document was determined by contacting the corresponding author. Data extraction from published manuscripts were performed by one author (K.Wi.) and double-checked by a second author (G.N.H.). Included studies were stratified into national population-based studies and other (which includes non-national population-based studies, birth or twin studies, intervention studies, and case-control studies).

RESULTS

Supplemental Digital Content Table 1 provides an overview of all 76 included studies providing accelerometry data in adults. [See Table, Supplemental Digital Content 1, Overview of all identified studies with accelerometry data in adults.] Sixty one published studies were identified, with 39 of these identified via the PubMed literature database search, and 22 sourced from authors' literature databases (some of them published after the 7th March 2014). Fifteen additional studies were identified through authors' knowledge of studies in progress.

The 76 included studies represented studies in 36 different countries, across 6 different continents (Africa (5), Asia (4), Europe (21), North America (3), Oceania (2) and South America (1)). This is illustrated in Figure 1. Here, countries with national population-based cohorts are represented in dark grey, whereas countries with any other study types (non-national population-based, birth and twin cohorts and other) are represented in light grey. Globally, accelerometry data are/will be collected in >275,000 adults. Sixteen percent of this total participant number is available from national population-based cohorts (Canada, Greenland, Hong Kong, Norway, Portugal, the UK, the US and Sweden). [See Table, Supplemental Digital Content 1, Overview of all identified studies with accelerometry data in adults.]

As shown in Figure 2a, over one third (38%) of the global pool of 277,370 adults with accelerometry data was collected using the Axivity accelerometer (Axivity Ltd, UK), with nearly one third (30%) using different versions of the Actigraph accelerometer, followed by smaller contributions from the Actiheart (CamNtech Ltd, UK), Actical (Philips Respironics, USA), activPAL (PAL Technologies Ltd, UK), and GENEActiv (Activinsights Ltd, UK) monitors. When considered by studies using the monitors (Figure 2b), more than half (51%) of studies have used an Actigraph activity monitor, with 16% using the Actiheart montor and 12% using the Actical monitor. Other monitors, including the Axivity accelerometer, were used in a minority of studies. A range of different anatomical positions have been used, including variations within monitor type (e.g. the Actigraph monitor which was worn on the hip, waist, lower back, and wrist). [See Table, Supplemental Digital Content 1, Overview of all identified studies with accelerometry data in adults.]

SUMMARY

In summary, this comprehensive review highlights the enormous scope and potential of accelerometry data available, with data from >275,000 participants across 76 studies (with 400 participants) and 36 countries. North-America, Europe and Oceania are well represented in terms of available accelerometry data. Most other regions are less well represented and investment in data collection in these regions will be important to understand variations between populations. Other important opportunities for future accelerometry data collection include an expansion in terms of nationally representative cohorts, which are currently only available for North-American, some European countries and Hong Kong, as well as follow-up of these national cohorts, which is currently lacking.

The analytical opportunities available with these data (both historic and in future data collections) along with the short- and long-term priorities, steps to take advantage of these opportunities, and ways to harmonize this diversity of data are discussed in Part B: an expert consensus on the harmonization of accelerometry data.

PART B: DELPHI SURVEY. Consensus from an international expert panel on the harmonization of international physical activity data derived from accelerometer-based activity monitors

In October 2012, an invitation-only meeting was held at the 4th International Congress on Physical Activity and Health (ICPAPH; Sydney, Australia) to discuss the potential opportunities to utilize the increasing amount of accelerometry data being collected internationally. As a result of that meeting (13 attendees from five countries), it was decided to run a Delphi process with the aim to achieve expert consensus on the harmonization of internationally-available accelerometry data.

METHODS

Participants—Twenty researchers (see Table, Supplemental Digital Content 2, Alphabetical list of the twenty individuals with recognized expertise in physical activity monitoring, epidemiological studies, surveillance, advocacy, and/or measurement expertise, who were invited to participate in the Delphi survey.) with recognized expertise in physical activity monitoring, epidemiological studies, surveillance, advocacy, and/or measurement expertise were invited to participate in the survey.

Process—The Delphi expert consensus process consisted of two rounds. Both rounds were administered via an online questionnaire (Limeservice: https://www.limeservice.com/en/). Consistent with Delphi principles (16, 38), responses were anonymous.

Round 1: In Round one, experts were given a brief overview of the aims of the study (as presented in the introduction) and were then asked to provide responses to the following five open-ended questions. They were also given the opportunity to provide any additional comments or observations in regard to the survey.

1. What do you consider to be the unique research opportunities for utilizing the large amount of internationally available activity monitor data?

2. Which additional data (i.e. other than activity monitor data) would this require?

3. What strategies do you think will be effective in enabling comparisons of activity monitor data between studies/countries, both for historical and future data collection?

4. What may be required to implement or progress such strategies?

5. Do you think that the development of an International Activity Monitor Database (IAMD), i.e., a global repository of objectively measured activity monitor data, would be a worthwhile/valuable investment? If no, please clarify. If yes, what would be the additional value of the IAMD?

Answers from the first round were then collated and summarized (K.Wi., S.S., G.N.H.), and used to form the second online survey (Round 2).

Round 2: In Round two, experts were asked to comment on the summary of the responses from Round 1, and, as appropriate, rank the responses provided in order of priority. Based on the responses provided, it was considered that no further rounds were required.

Ethics—The Delphi study was approved by The University of Queensland School of Population Health Ethics Committee (Australia). Participants were provided with information about the study and consent was required prior to commencing the survey. All experts who participated in the process were invited as co-authors.

RESULTS

Characteristics of the expert panel—An overview of the characteristics of the expert panel is provided in Table 1. In Round one, 14 experts participated, in Round two, 16 experts participated, with 12 experts providing data for both rounds, and 18 experts participating in either round.

Findings from the Delphi Process

1. Unique research opportunities for utilising the large amount of internationally available activity monitor data: The two key themes highlighted by the expert panel were the ability for cross-country/cross-population comparisons, and the analytic opportunities available with the larger heterogeneity and the greater statistical power. More specifically, the unique research opportunities for utilising the large amount of internationally available accelerometry data, as agreed by absolute consensus (100% of experts), were identified as:

- The estimation and comparison of the prevalence of physical activity (levels and patterns), as well as trends over time (surveillance), around the world and in different contexts, including in populations that are typically under-represented.

- More statistically powerful etiological analyses on dose-response associations with health outcomes, including: detection of more subtle associations; consistency of associations across populations; and, gene-environment interactions.

- More comprehensive and powerful analyses of the correlates/determinants of physical activity and identification of target groups for future intervention.

2. Collection of data in addition to the accelerometry data: In the first round of the Delphi survey, the participant responses regarding the additional data that should be collected in addition to the accelerometry data fell into nine different categories. During the second round, participants were asked to indicate which of these categories they considered essential to be included in data pooling. For any categories deemed non-essential, participants indicated the level of scientific priority and feasibility of harmonization. Table 2 provides an overview of all nine categories, with categories presented in order of priority (i.e. most essential listed first).

In summary, there was strong agreement on the necessity of basic socio-demographic and anthropometric data, and the majority of participants also rated health status and occupational classification data as essential to pool. Half or less than half of participants deemed data on death registration, cardio-metabolic profile, function (physical, cognitive, fitness), the environment, and biological tissue sample data as essential. However, while these items were deemed non-essential, participants rated their scientific priority as relatively high (median 3 for each category), indicating that adding these data would be of significant value. The dependence between data necessity and research aims was raised, with surveillance applications generally requiring less information to be pooled. Most items rated as highly essential were perceived to be relatively feasible to harmonize between studies. In contrast, participants indicated that less essential items may be less feasible to harmonize and pool. Notably, the questions relating to scientific priority and feasibility of harmonization (for data which was considered non-essential) were not compulsory, and therefore not all experts provided responses for these (Table 2). For categories such as death registry information, differences in data quality between countries/studies were acknowledged as a consideration. Other categories, such as environmental data, were rated as non-feasible given the high volume of work required to process and harmonize such data. Cost and potential deterrence of studies participating in a pooling effort were other salient characteristics raised, especially for categories such as biological tissue sample data.

3. Effective strategies enabling comparisons of activity monitor data between studies/ countries: In general, there was a strong consensus that standardization of monitor calibration, data collection, data processing and data analytical procedures are needed. Disclosure of monitor information, and protocols for data collection and processing were deemed essential to enable comparison, with access to raw (i.e. unprocessed waveform) data preferred.

3a. Historically collected data: Following responses from the first round of the survey, two different approaches were broadly proposed for historically collected data, specifically:

1. Centralized re-processing of the highest resolution of data with uniform methodology based on a developed consensus.

2. De-centralized re-processing by the original researchers on their own data with uniform methodology, relative to the different research questions of interest and meta-analysis of results.

Participants were asked which approach was preferable and why. As shown in Table 3, the vast majority of experts preferred centralized re-processing of data, followed by a preference for a mixed approach (i.e. providing either option for the researcher), then for de-centralized data reprocessing. Table 3 also summarizes the perceived benefits, caveats and facilitating utilities needed for each of the proposed approaches, as indicated by the experts.

Four additional strategies were identified as important for enabling comparisons of the historically collected data. In order of priority, these were:

1. the availability of raw signal data instead of proprietary data processing and outputs (e.g. "counts"), where possible (and transparency where not);

2. development of criteria to determine which types of monitor data can be pooled;

3. disclosure of data collection protocols; and,

4. standardization of cut-points within each monitor type/model.

3b. Future data collection: The panel (n=16) identified five main strategies to enable comparison of monitor data collected in the future. The two main priorities identified were:

- the development, public availability and ensured implementation of standardized protocols, tools and analytical methods; and,

- the use of raw signal data (rather than outputs resulting from proprietary data processing).

Secondary priorities identified were:

- obtaining better wear compliance;

- ensuring data collection in representative samples; and,

- convergence in terms of monitor types used.

4. Requirements for implementation of these strategies: In general, three key requirements for the implementation of these strategies were highlighted:

- communication and consensus among researchers;

- the development of an online infrastructure; and,

- methodological comparison work.

For the *online infrastructure*, user-friendliness and high-speed access; capacity to host a database (with adequate data storage space) and data sharing agreements; and, capacity for centralized data processing and analysis, were identified as potentially important characteristics. Modifying or adapting existing accelerometry data processing systems (e.g. MOVE-e-Cloud [Newcastle University, UK], DataSHaPER [http://www.datashaper.org], MeterPlus [Santech Inc, USA], KineSoft [KineSoft, Loughburough, UK: http://www.kinesoft.org]), which are already available or in development was generally preferred, as this was deemed more efficient, robust and financially viable.

For *methodological comparison work*, standardization and harmonization of methods and procedures for data collection, processing and analysis were deemed important. The following two components were highlighted as key requirements:

- Convergent validity studies (particularly free-living) to establish models to equate outputs from different monitors, anatomical sites, decision rules, etc. A global web-based dashboard is needed to map what has been done and what needs doing, as this is work in progress.

- An international consensus process, potentially in the form of an International Taskforce, to define, publish and publicize internationally agreed standards for collection and processing of data.

Strong support was identified for the organization of an international consensus to set standards as mentioned above, acknowledging that this would be a worthwhile but challenging process. Considerations raised included the necessity of scrutinising agreed standards before implementation to ensure they result in valid activity parameters, to allow for multiple standards for different purposes, to involve a sufficiently wide range of experts, to avoid overly strict standards imposing on researchers' creativity and to ensure that standards are updated to keep pace with changing technology.

Participants indicated that convergent validation research would benefit from a well-structured approach, potentially in the form of a separately funded programme of coherent and coordinated studies. A global web-based dashboard would need to clearly characterize the knowledge already gathered; including quantification of uncertainty, as well as what is still unknown. Some participants anticipated that the potential increase in the use of wrist-worn monitors collecting raw acceleration signals may diminish the need for convergent validity studies in the future.

5. Value of an International Activity Monitor Database (IAMD), i.e. a global repository of objectively measured activity monitor data: There was full (100%) consensus that an International Activity Monitor Database (IAMD) would be beneficial and worthwhile, but that the success of this would be dependent on several factors, including:

- the development/existence of strong international standards for data collection, management, and analysis which are published and easily accessible;

- sufficient quality control, and good governance;

- perception from data contributors that their contribution is worthwhile; and,

- perception that the benefits for researchers in general are greater than the resources required to develop an IAMD.

5a. Priorities and aims of an IAMD: Three key *short-term priorities* were proposed:

1. The development of goals and strong international standards and protocols for data collection, management, analysis and quality assurance. This could be facilitated through a working group holding consultations at various international conferences.

2. Securing funding to start with a demonstration project involving a limited number (e.g. 10) of studies/countries involved, which has a relatively simple objective as a proof of principle, before increasing complexity. Such a demonstration project could, for example, only include a few accelerometry brands and primarily focus on mapping between those.

3. Commence examination of the equivalence between monitors, anatomical sites, etc., as well as harmonization of variable naming conventions.

Four key *long-term priorities* were proposed:

1. Securing the funding to support an IAMD and to ensure its long-term sustainability.

2. Creating a widespread appreciation among researchers of the importance of following the international standards and protocols for data collection, management, analysis and quality assurance, as developed in the short term, and of providing their data to an IAMD. This could be facilitated by ensuring easy data access for investigator-driven research use, such as in the NHANES dataset (http://www.cdc.gov/nchs/nhanes.htm).

3. Building international capacities and recruiting multiple countries, following examples such as the International Physical Activity and the Environment Network (IPEN) project (44).

4. Keeping a strong emphasis on quality control throughout this process.

Several potential mechanisms were suggested to enable high quality control and wider scrutiny of the whole process. These included utilities to ensure easy accessibility to the internationally established standards and protocols; the development of minimum criteria for information sharing at each level of the process (e.g. logs of routine calibration checks for raw data); sharing information and protocols (e.g. syntaxes) in the public domain; and setting up a data monitoring council. Methodologically, moving on to more generalized inference on body movement including all accelerometry data was considered a long-term priority. Other types of bio-signals (such as temperature, heart rate, breathing etc.) could be included in the inference of generalized body movement information in the long run, to keep up with new measurement approaches.

5b. Potential funding sources for an IAMD

Short-term funding: A variety of potential sources were identified by participants as options for short term funding. These included national funding bodies, some of which provide specific international network/collaboration grants, such as the Wellcome Trust (UK), Bupa Foundation (Australia), US National Institutes of Health, the Leverhulme Trust (UK), Economic and Social Research Council (ESRC, UK) and large philanthropic groups. Funding from individual countries as well as international funding sources, such as European project funding and the World Health Organization, were also proposed. The possibility of partial cost absorption by local departments in the initial stages was suggested as well. Finally, as many funders typically do not like to fund international studies, the idea to focus the IAMD database to a certain health outcome to increase attractiveness to specific funders was also brought forward.

Long-term funding: In general, suggestions for <u>*long-term funding*</u> predominantly involved international funding bodies, some of which focus on advancing global health, such as the World Health Organization, the NIH Fogarty International Center, the United Nations, the European Union, large philanthropic groups, as well as international consortia of research councils, with industry funding being another proposed candidate.

5c. Governance of an IAMD: Other large international projects, including multi-country self-report data collection initiatives, were recommended as important models to follow when organising an IAMD (e.g. International Physical Activity Questionnaire (IPAQ, https://sites.google.com/site/theipaq/); WHO STEPS chronic disease risk factor surveillance

and the Global Physical Activity Questionnaire (GPAQ, http://www.who.int/chp/steps/en/index.html)). An important common element in each of these projects is that they involve substantial manpower and require a dedicated team of full time staff. Securing funding for a Coordinating Centre which provides sufficient resources and support staff was therefore suggested. In addition, installation of an Advisory Board, consisting of a strong group of high-level, well-connected experts, to oversee the development of the IAMD was proposed. In general, the governance structure would need representation of researchers from multiple countries involved. Capacity building resources enabling face-to-face meetings were recommended as they may provide a lot of momentum to the project.

DISCUSSION

This article reported on the findings from a comprehensive review describing the scope of accelerometry data collected internationally in adults, as well as conclusions from an expert consensus regarding the most optimal strategies to harmonize international accelerometry data.

The review – which included data from both published and ongoing studies – highlighted the now considerable amount of accelerometry data available internationally, with data collected from >275,000 participants across 36 countries. As such, it provides an important resource for identifying not only opportunities with the existing data, but also evidence gaps which could direct future data collection priority areas/countries. The review also highlighted the multitude of accelerometer-based activity monitors, models, and attachment procedures used across studies. Of note is that although comprehensive, it was not a systematic review and it is possible that relevant studies may have been missed.

The expert consensus provided strategies and short- and long-term priorities, as well as potential funding sources for addressing the current challenges in comparing the data across studies and populations. A key strength of the consensus was the inclusion of experts (median of 18 years of expertise in physical activity) across a diverse range of physical activity interest areas. However, it should be noted that not all experts in the field were contacted for inclusion in the Delphi process, which may have resulted in some key considerations, strategies, priorities, and/or funding sources being misrepresented in terms of priorities or even remaining unidentified. For example, one consideration not made explicit during the Delphi process is the wide variety of calibration procedures that have been used for different monitor types (e.g. locomotion calibration, multiple activity type calibration) – the majority of which are laboratory-based studies, with some studies using free-living protocols. Harmonization of existing data without reprocessing will require the use of scoring approaches that were derived from the same type of calibration studies.

Notably, some of the strategies identified through the consensus are already occurring. This includes data pooling (such as in the International Children's Accelerometry Database: ICAD (63) and the DEDIPAC European knowledge hub: https://www.dedipac.eu/); and, standardization (such as through the Sensor Methods Collaboratory (70), the Sittonomy (9)), and the Database of Genotypes and Phenotypes (dbGaP: http://www.ncbi.nlm.nih.gov/gap). Given the rapid evolution of both monitor technology and methodology, regular revision

(e.g., every three years) of the key priorities and most optimal strategies to harmonize international accelerometry data is recommended.

In summary, the accelerometry data collected across the globe provides a key opportunity to further understand the distribution, determinants, health impacts and burden of disease for physical activity across the intensity spectrum, as well as how these may vary between subgroups and populations. By identifying the scope of the data available, and obtaining an expert consensus on the strategies, priorities, and potential funding sources, this article provides a foundational resource to maximize this opportunity.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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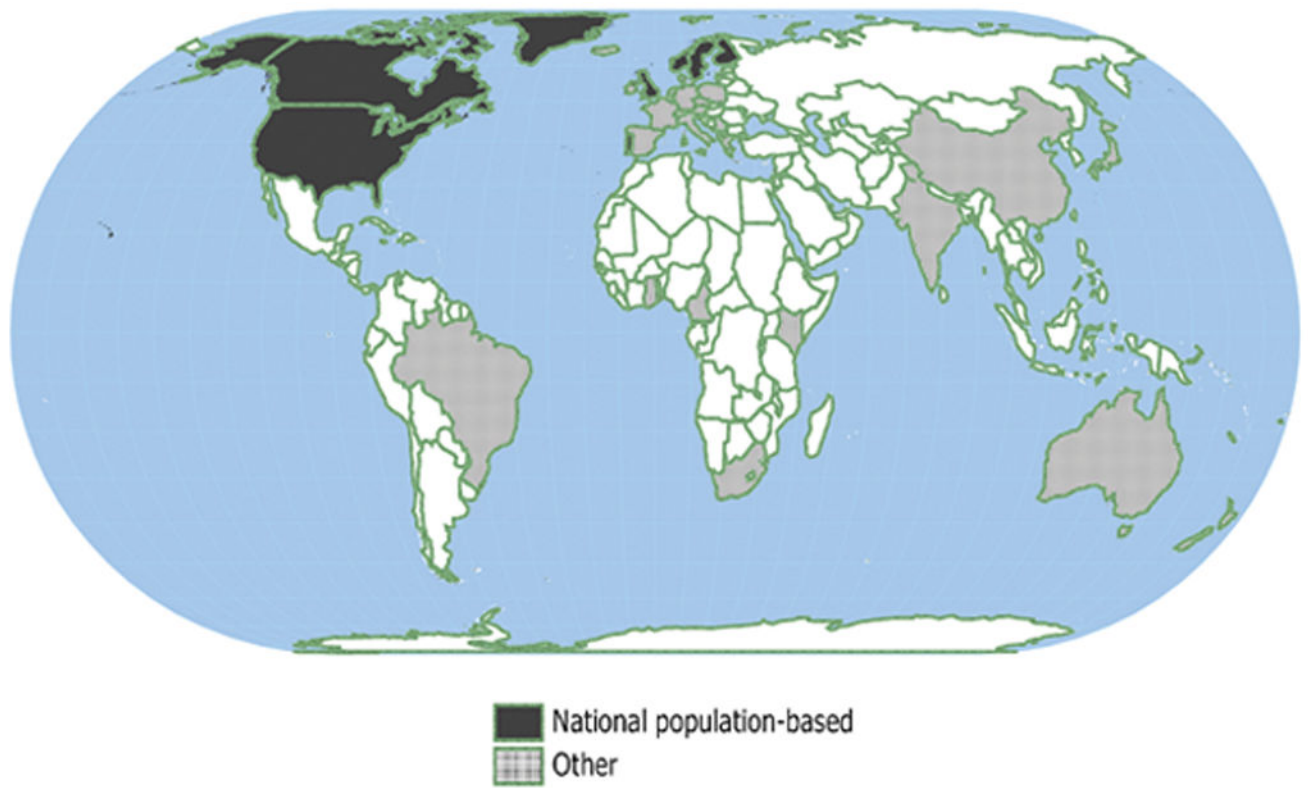
Figure 1.
Global overview of countries with accelerometry data (N 400) in adults. Countries with national population-based cohorts are represented in dark grey (all with N >1000), whereas countries with any other study types (i.e. non-national population based, birth and twin cohorts and other) are represented in light grey.
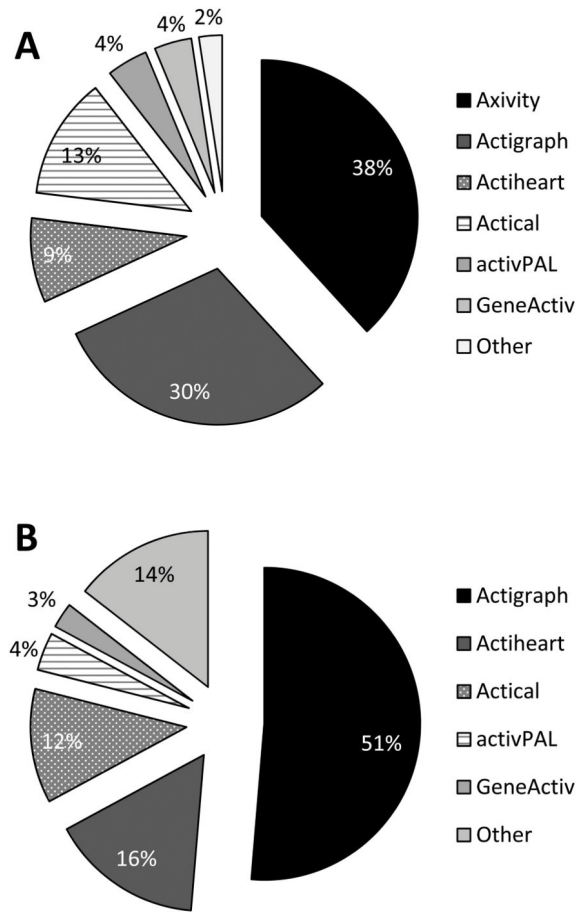
Figure 2.
Contribution by sample size (A) or by study (B) of the different monitor types to the global pool of accelerometry data.

Table 1

Characteristics of the 18 experts who contributed to either Round 1 or Round 2 of the Delphi Process

Characteristic	%, or median (range)
Women, %	14.3%
Institutional location, %	
United Kingdom	35.7%
United States	28.6%
Australia	21.4%
Other	7.1%
Research Field (multiple choices allowed)[*], %	
•Measurement	80%
•Epidemiology	73%
•Interventions	73%
•Policy	26%
•Other	53%
Years as physical activity researcher, median (range)[*]	18 (5 to 40)

[*] data only available for 15 participants

Table 2

Additional data, other than accelerometry data, required (most essential listed first)

Additional data	Proportion of participants who deemed this information essential (%; n=16)	When not deemed essential [a]	
		Scientific priority (median; 1=low; 5=high)	Feasibility of harmonization (median; 1=low; 5=high)
Basic socio-demographic data such as age, sex, race/ethnicity, country, and socio-economic status (i.e. income, education, employment status)	94%	/	/
Anthropometric data (i.e. weight, height, waist circumference)	88%	4 (n=1)	4 (n=1)
Health status data (i.e. diabetes, cardiovascular disease, cancer)	75%	4 (n=1)	4 (n=1)
Occupational classification data (i.e. type of occupation)	63%	3.5 (n=2)	4 (n=1)
Death registry information/cause of death data	50%	3.5 (n=2)	2 (n=2)
Cardio-metabolic biomarker data (i.e. blood biomarkers, blood pressure)	44%	4 (n=5)	3.5 (n=4)
Data on function (i.e. physical, cognitive, fitness)	31%	4 (n=4)	2.5 (n=4)
Built environment / Geographic Information Systems (GIS) data	19%	4 (n=7)	2 (n=7)
Biological tissue sample data (other than blood samples)	6%	3 (n=8)	2 (n=7)

[a]Questions on scientific priority and feasibility of harmonization were only asked if the information was deemed non-essential. These latter two questions were not compulsory: the lower n's for some responses indicate the degree of missing data.

Table 3

Preferred approach, and perceived benefits and caveats of the approach, as well as utilities needed to enable comparisons of historically collected accelerometry data (N=16)

	Centralized	De-centralized	Mixed approach	No opinion
Percentage	63%	13%	19%	6%
Perceived benefits	• Uniformity and standardization of methodology • Higher feasibility • More robust quality control • More time-efficient • Flexibility in terms of re-processing (i.e. no additional burden on participating studies)	• Flexibility in terms of additional/novel variable output • More realistic	• Tailoring to data sharing preference of data owners - i.e. enabling inclusion of studies experiencing issues with sharing of raw data • Tailoring to data complexity – e.g. "counts" only data (with lower data volume transfer) would enable centralized approach	/
Perceived caveats	• Detail in methodology not taken into account • Methodological standard not evolving with improvements in monitor methodology • Too great of a constraint on research process (e.g. if output measures are specific to certain research questions, or novel ways of data analysis develop which were not anticipated in initial centralized processing) • Substantial man-power needed	• Lower quality control • No funding for processing, so big burden of voluntary work • Lack of transparency in processing decisions	• Only feasible if processing approach can be implemented consistently between studies using the centralized and non-centralized approach	/
Facilitating utilities needed	• Cloud-computing to enable large dataset transfer	• Provision of processing protocols and codes/tools for uniform de-centralized processing (e.g. via internet or supplementary information in papers)	• Provision of processing protocols and codes/tools for uniform de-centralized processing (e.g. via internet or supplementary information in papers)	/