Accelerometer Scoring Protocol for the IPEN-Adult Study

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Protocol developed 2011-2014 for the IPEN Adult Study.
(NIH: National Cancer Institute R01 CA127296; PI: James F. Sallis).

*This comprehensive accelerometer data screening and scoring protocol was developed in part based on over 12 years of our research team's cumulative experience with collecting, managing and processing accelerometer data in large studies. The current manual adapted many of the same protocols used in previous studies and some were developed specifically for the unique situations that presented when pooling data from numerous IPEN countries. The goal was to process accelerometer data in a standard way from 11 countries that employed varied data collection methods, accelerometer models, and had different wear time patterns. This required creating protocols for various methods and standardizing their use across IPEN countries.

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1. Accelerometer Data Collection Details by Country

While data scoring methods were standardized across all IPEN-Adult countries by centralizing the data processing at the IPEN Coordinating Center (CC), some methods related to data collection varied. Below is a table documenting the various accelerometer models, deployment methods, documentation of wearing and mail days, date format used in initialization of the accelerometers, and language settings used to assign days of week to the processed dataset. This table is for documentation only. Based on the varied methods and lack of complete documentation of wear dates provided by the countries, the CC made a decision to rescreen all accelerometer files and identify wear days based on a common protocol.

Table 1							
Country	**Code**	**Accelerometer Model(s) & percent of total**	**Deployment Method(s)**	**Documentation provided to CC**	**Rewear protocol[a]**	**Date Format & Language Setting**	**# eligible part files sent to CC**
Belgium	32	7164 (88%) GT1M (12%)	In-person	Researcher reported delivery days	No	month/day/year English (US)	1063
Brazil	55	7164 (23%) GT1M (77%)	In-person	Researcher reported delivery days & participant reported wear log	Yes	day/month/year Portuguese (Brazil)	366
Colombia	57	GT3X (100%)	In-person	Researcher reported wearing days	Yes	month/day/year day/month/year Spanish(Colombia)	251
Czech Republic	42	GT1M (62%) GT3X (38%)	In-person	Researcher reported wearing days	No	day.month.year Czech (set to Bosnia)	606
Denmark	45	GT3X (100%)	Mail	Researcher reported mailing days	No	day-month-year Danish	273
Hong Kong	85	7164 (20%) GT1M (3%) ActiTrainer (77%)	In-person	None	Yes	month/day/year English (US)	293
Mexico	52	GT3X (100%)	In-person	Researcher reported delivery days	Yes	month/day/year English (US)	674
New Zealand	64	Actical (100%)	Mail	Researcher reported wearing days	No	month/day/year English (US)	1824
Spain	34	GT1M (57%) GT3X (43%)	In-person	Researcher reported delivery days	No	month/day/year English (US)	349

Country	Code	Accelerometer Model(s) & percent of total	Deployment Method(s)	Documentation provided to CC	Rewear protocol	Date Format & Language Setting	# eligible part. files sent to CC
UK	44	GT1M (100%)	In-person & Mail	None	No	month/day/year English (US)	160
USA	01	7164/71256 (100%)	Mail	Researcher reported mailing days & participant completed logs	Yes	month/day/year English (US)	2123

2. Screening Accelerometer Data

Data screening for valid wearing time, as well as device malfunction or other abnormalities, was a key data processing step for IPEN and was implemented at 2 time points.

1) During data collection: Countries were asked to screen their data in real time to determine if enough wearing time was collected to be considered compliant with the requirement of having at least 5 days containing at least 10 wearing hours. If not enough data were collected, the protocol was to ask for a rewear for the number of days that were missing. However, some countries collected data prior to the start of the IPEN study and did not implement this data screening or rewear protocol.[a]

> The importance of screening data right away was an important quality control procedure! This was important for rewear reasons and it was imperative to screen data prior to initializing for another wearing in case the device had malfunctioned and needed to be taken out of rotation.

2) Post-data collection at the CC: Because countries had varied accelerometer data collection methods, it was crucial that all data were screened for device malfunction and valid wearing time so that only valid wearing data were scored and included in the accelerometer data files. During the screening process, anomalous data collected with faulty devices were identified and eliminated. Days where the accelerometer was collecting data but not with0 the participant because it was in mail transit or with the field researcher while conducting door-to-door recruitment, for example, were identified and eliminated. Wearing time was determined for each participant and saved for processing using MeterPlus (www.meterplussoftware.com).

> To maximize reliability, all data files from 11 countries were screened and scored at the IPEN Coordinating Center by trained and 'certified' researchers.

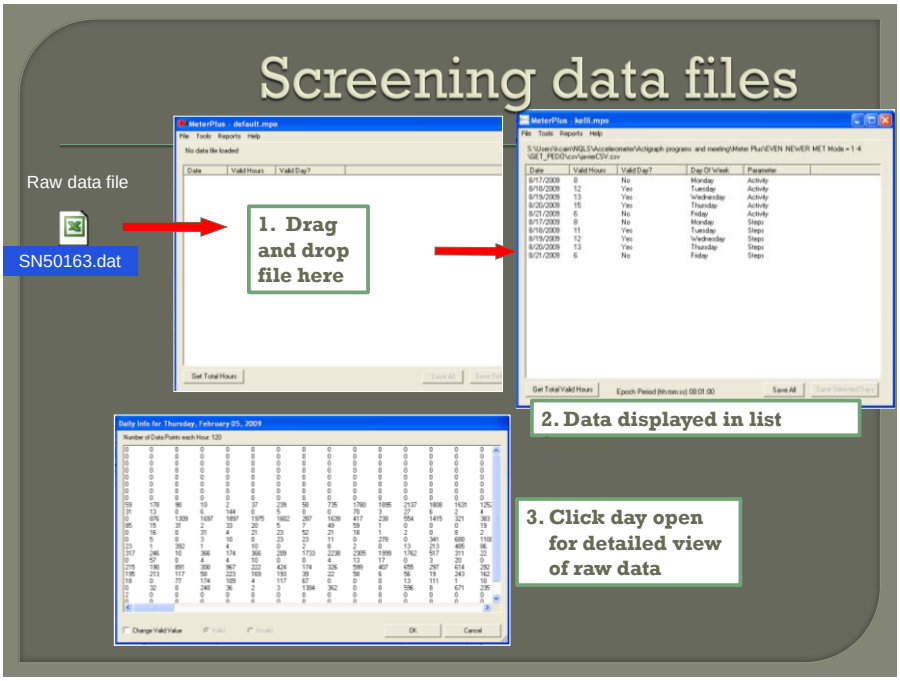
A. How to screen data in MeterPlus

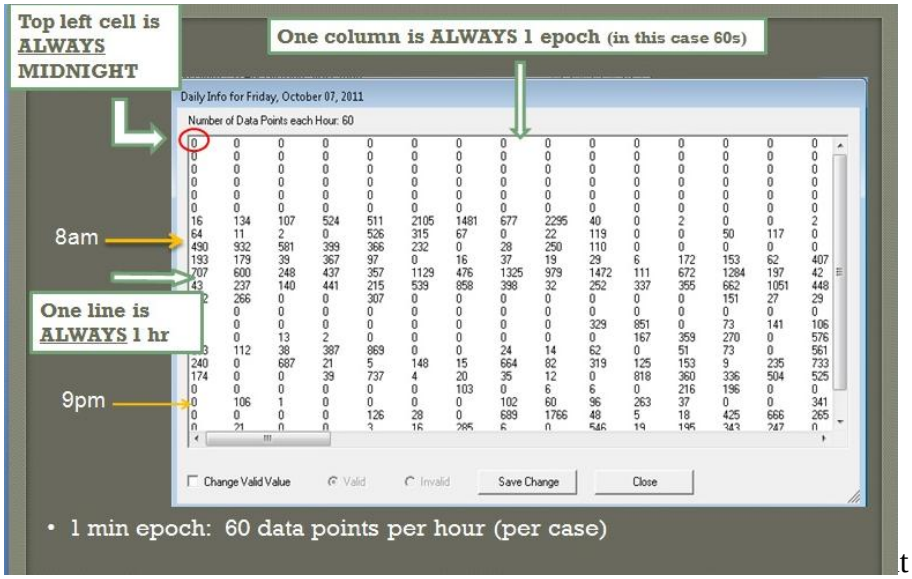
1) Drag the CSV file into the MeterPlus window.

2) Go to Reports, then Header Details to screen for errors. ***If using an older model (7164 or 71256), current memory address = 0 in the header of the file is an error!***

3) MeterPlus shows you the date range from when the meter was initialized to when it was downloaded and whether or not each day is valid. ***Double check that the date initialized is the first date reflected in MeterPlus. If it isn't, this could indicate a problem with the data file.***

4) Open each wearing day in Detailed View by double clicking. The wearing day range can be determined by using the tracking database information provided by countries or by checking the data in the absence of a record. The detailed view in MeterPlus will show you the unprocessed data points. The data patterns of wearing the Actigraph and mail time are quite different, as are patterns from devices that are not functioning properly. Often times, a mail day or a malfunction will be listed as being valid, but upon reviewing the data points, it will be clear that it is not (see sections B and C).





5) People will occasionally go to sleep with the accelerometer on. There will be movement between the two days and it is hard to determine where one day ends and another begins. Make a note of this in the Access database so cleaning of the file can occur later. More about identifying sleep wearing in Chapter 3, pages 18-19.
6) Record the number of valid days in the Access tracking database. Also record the dates of wearing and any flags for bad or repeated data or sleeping with the accelerometer.

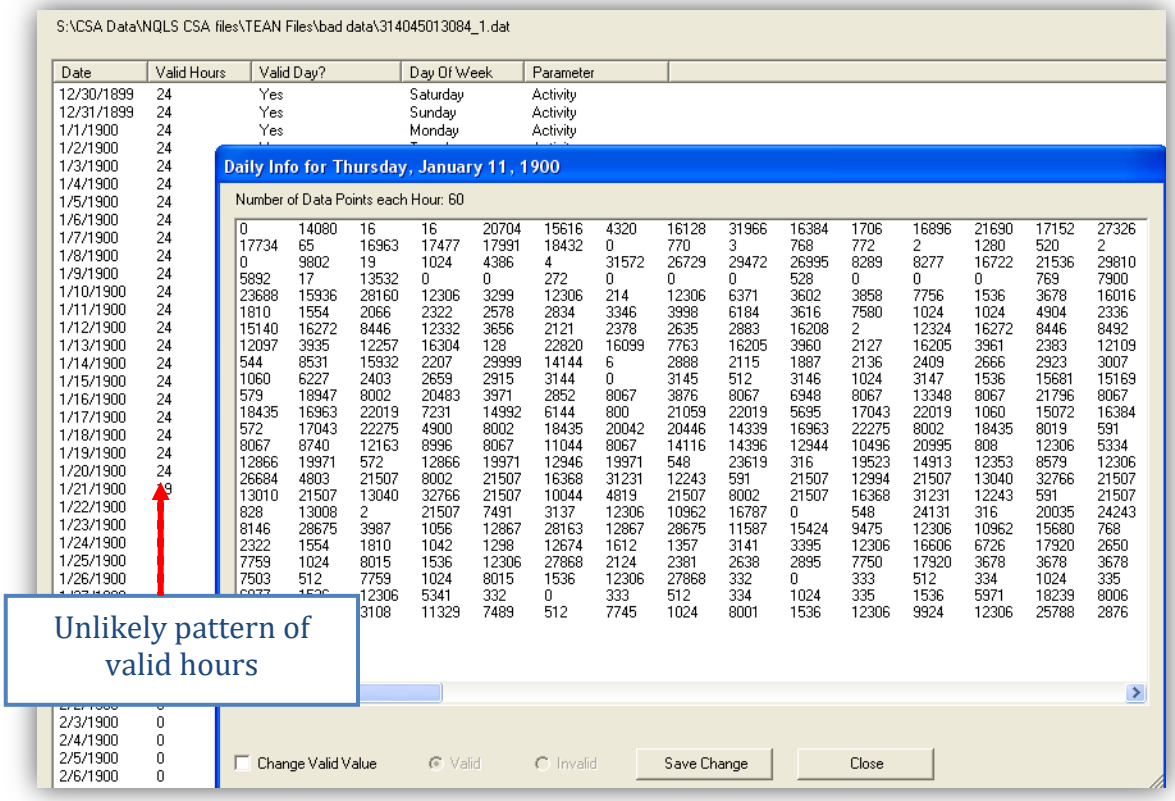
See **Appendix B** for detailed instructions on how we dealt with specific datasets with different time zones, varying deployment methods and other site-specific circumstances.

B. Device malfunction/anomalous data

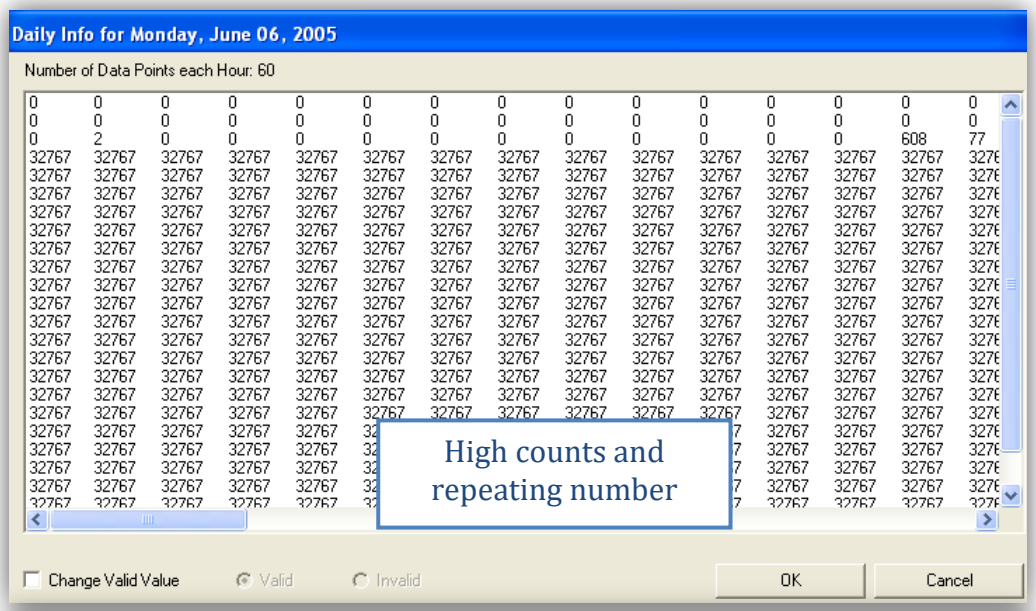
1) Older generation Actigraphs (7164/71256)

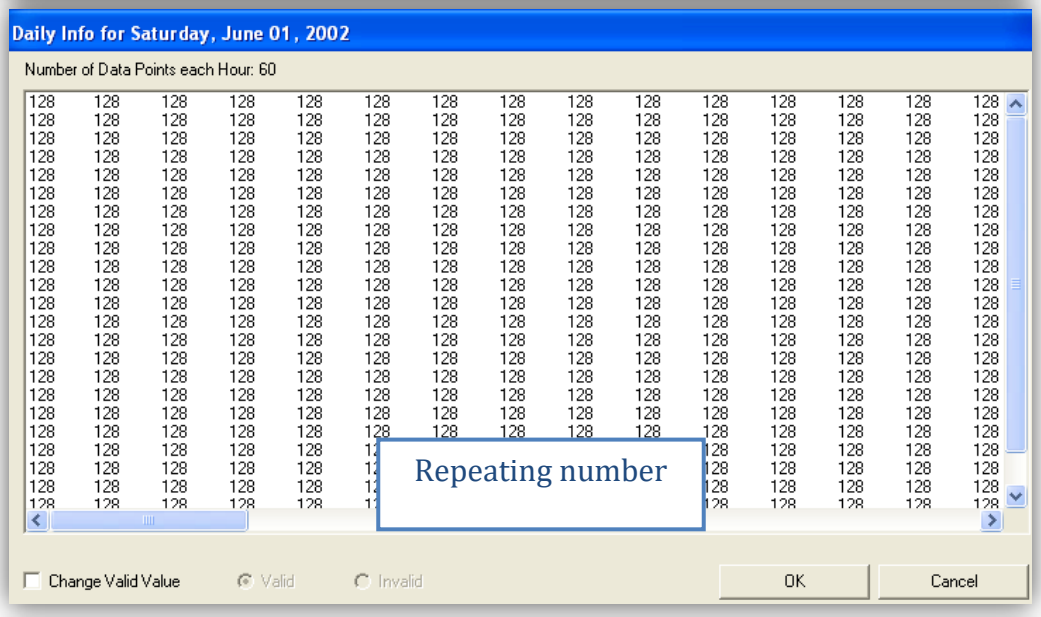
i. Anomalous data patterns

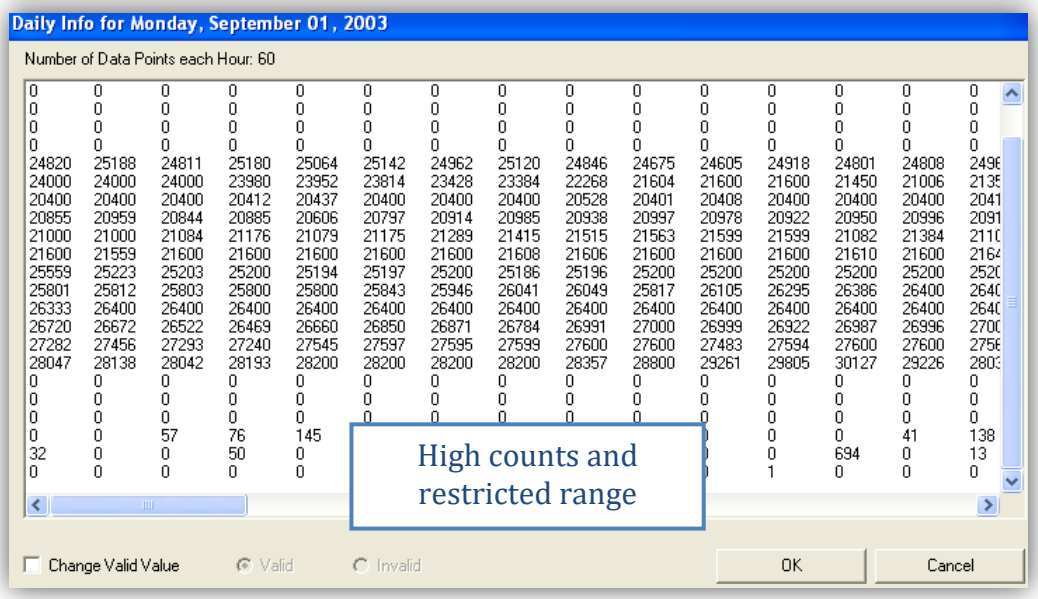
The most common anomalous data patterns in the older generation Actigraphs were counts over 16,000, repeating number, and counts within a restricted range. If all days were showing 24 valid hours in the MeterPlus screening window, this was a red flag that these days may have contained anomalous data. See examples below of anomalous data patterns. In these instances, data were not considered valid.



High valid hours could indicate anomalous data caused by device malfunction or 24-hour wearing (see Page 18)

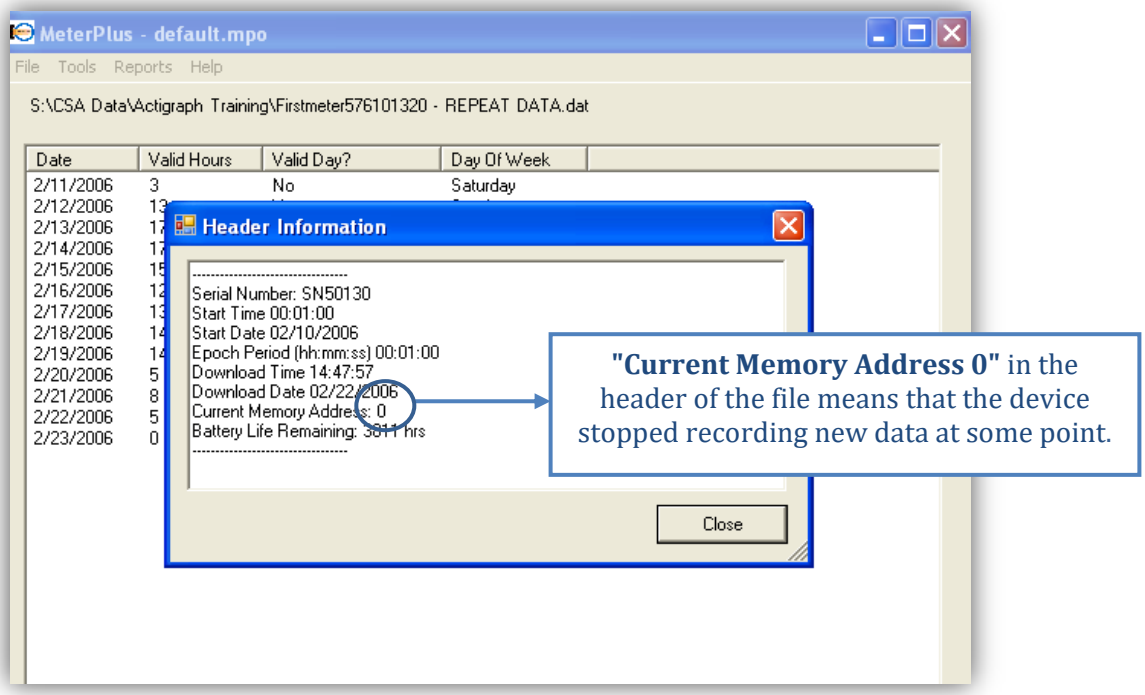

Daily Info for Monday, June 06, 2005
Number of Data Points each Hour: 60
High counts and repeating number
Change Valid Value
Valid
Invalid
OK
Cancel


Daily Info for Saturday, June 01, 2002
Number of Data Points each Hour: 60
Repeating number
Change Valid Value
Valid
Invalid
OK
Cancel

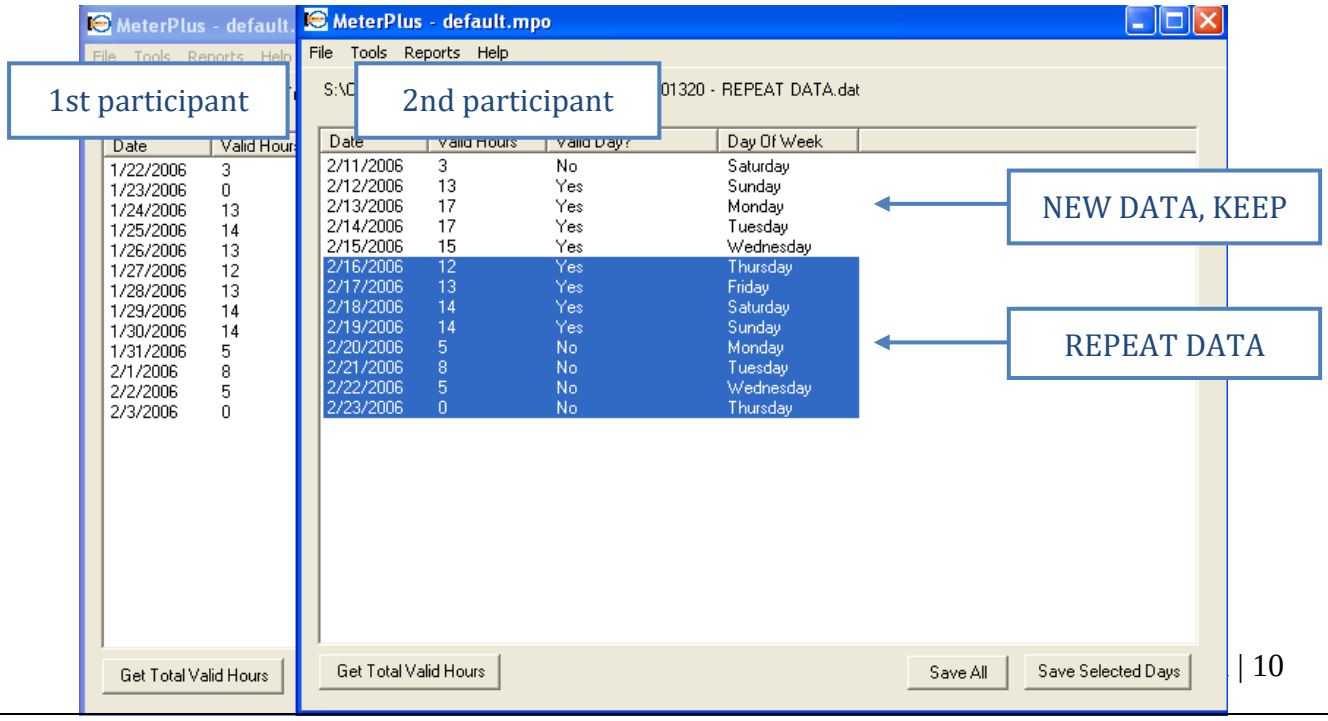

Daily Info for Monday, September 01, 2003
Number of Data Points each Hour: 60
High counts and restricted range
Change Valid Value
Valid
Invalid
OK
Cancel

ii. Repeat data

When the battery temporarily loses connection in the 7164/71256, the accelerometer stops recording new data. The main indicator of this error is "current memory address: 0" in the file header. The data that were previously recorded on the device **are not overwritten** during the new data collection period and would be downloaded again along with newly collected data. The IPEN CC determined at what point the accelerometer stopped collecting new data by comparing to data from the previous participant. Data collected *prior* to the repeated data were considered valid and saved.



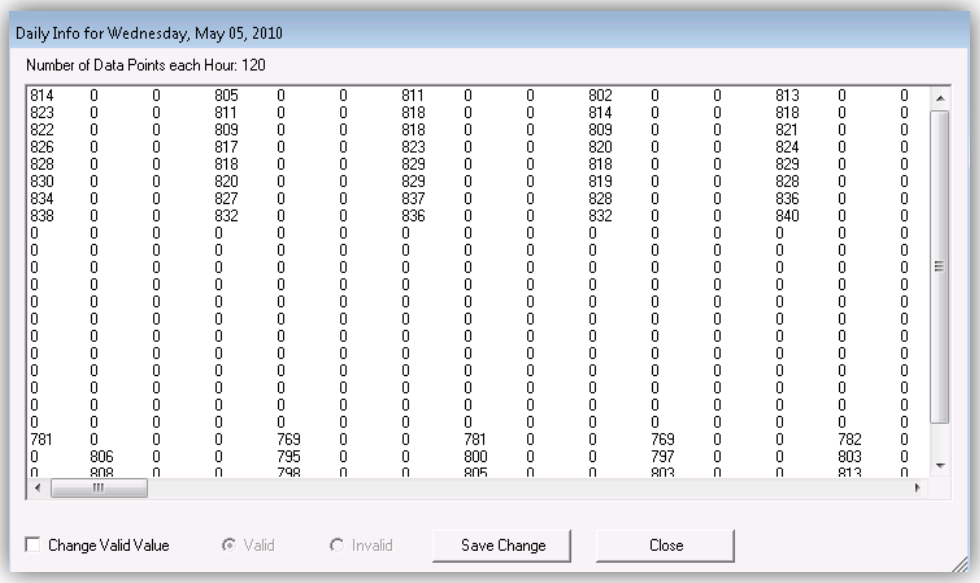
Below is an example of 2 data files from same Actigraph unit, but with data from 2 different participants. The data start repeating on 2/16/2006.



2) Newer generation Actigraphs (GT1M, GT3's, Actitrainer)

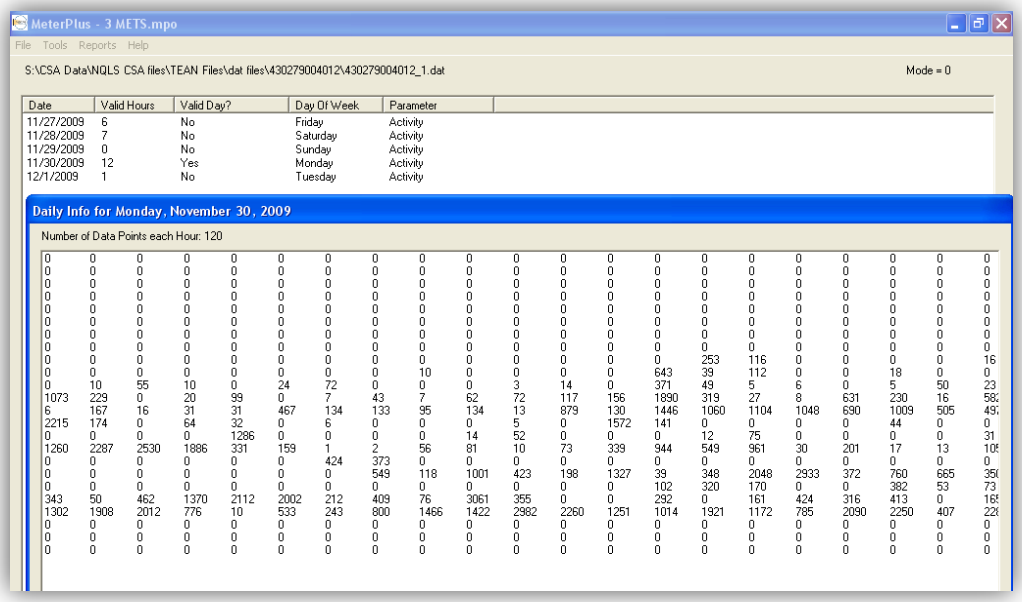
i. Anomalous data patterns

Anomalous data occurred less frequently with the new generation Actigraphs; however, it did happen. The most common anomalous data pattern was counts within a restricted range with an unusual repetitive pattern that is arranged in columns (every 3rd minute, for example, see below). In these instances, the data were not considered valid.



ii. Faulty battery

Another malfunction found in the GT models was with faulty batteries that stopped recording new data after a few days despite the devices showing a full charge prior to initialization. When identified during data collection, units were tested to see if the problem could be replicated and if so they were sent to ActiGraph for repair.



3) Acticals

i. Converting Actical data files

The first step in processing the data files collected with the Actical was to convert them to a format that worked in MeterPlus. Here is the protocol:

a) Open the Actical file in Notepad and replace the header information with the following Actigraph formatted header:

---------- Data File Created By Actical date format M/d/yyyy----------
Serial Number: Actical serial number
Start Time 00:00:00
Start Date 6/1/2010
Epoch Period (hh:mm:ss) 00:00:02
Download Time 14:44:31
Download Date 6/1/2010
Current Memory Address: 47096
Current Battery Voltage: 4.09 Mode = 0

The first value below this bottom line of the header should be the beginning of data.

b) Modify the information that is highlighted (e.g., serial number, start time, start date, epoch length, download date, mode) so that it is accurate. Download Time, Current Memory Address and Current Battery Voltage are not important to modify. For a list of Actigraph modes, refer to page 33 of the MeterPlus User's Manual. It is very important that the mode is correct to get accurate results.

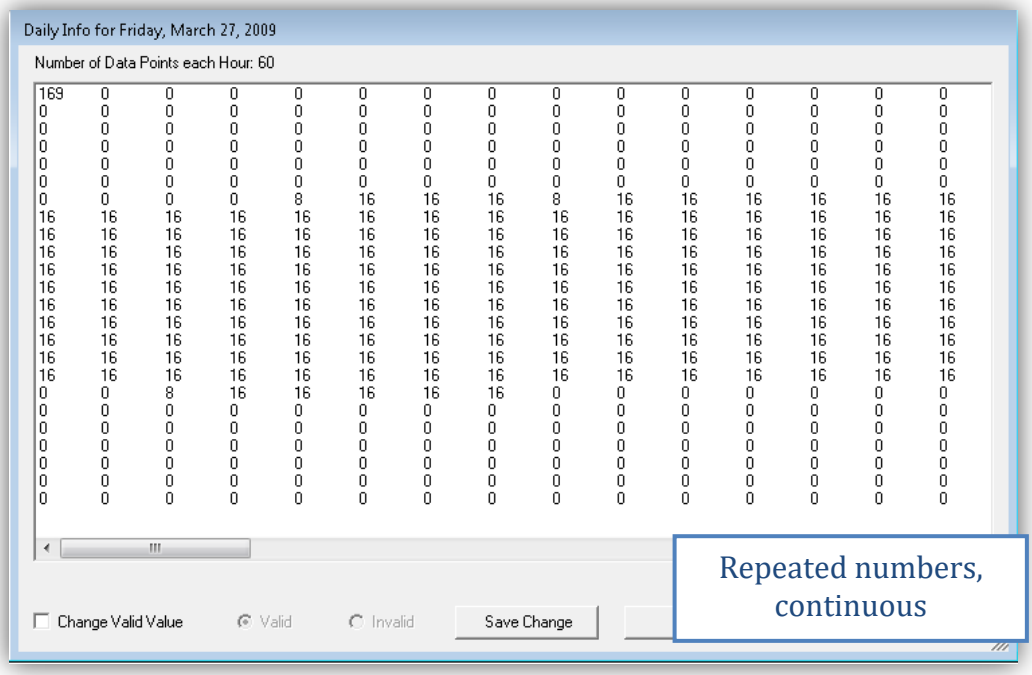
c) Make sure the correct date format is in the header of the file and save the file.

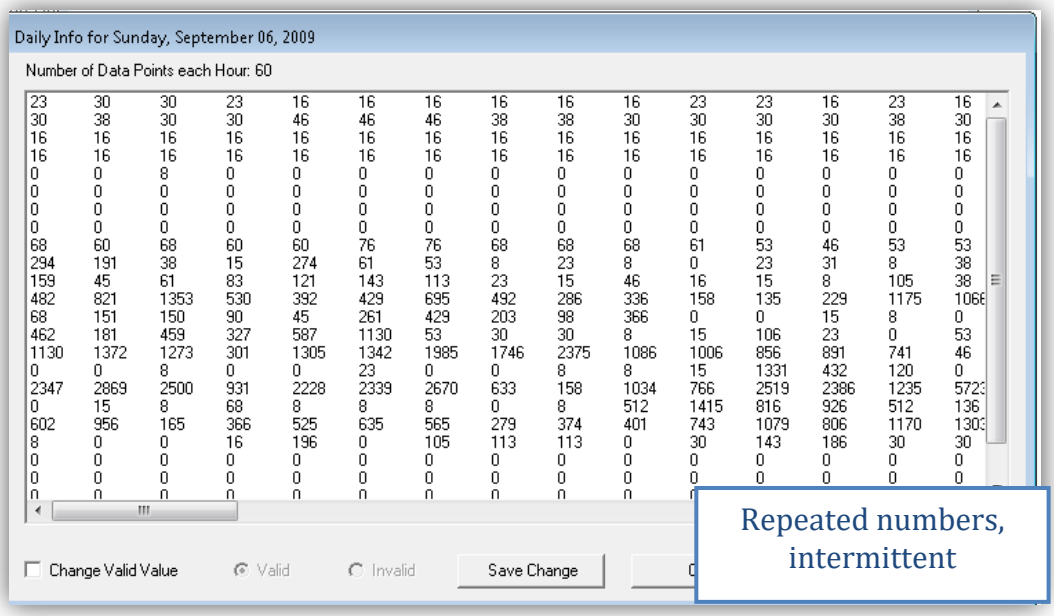
d) Rename the file with a .dat extension by replacing "AWS" with "dat".

e) If the files are anything but Mode=0 (one data type), run them through the DATtoCSV converter to create CSV files (see Section 2.2 of User's Manual). The mode=0 DAT files or the CSV files can be processed through MeterPlus.

ii. Anomalous data patterns

Anomalous data patterns identified in the Actical were related to repeating numbers. Examples are below. In these instances, the data were considered not valid.





C. Wearing time identification

Because accelerometers record "counts" during times when the device is collecting data but not being worn by participants (e.g., mail or delivery time), identifying true wearing time was a key step in the processing of accelerometer data in IPEN-Adult. Identifying wearing time required manual screening of the data because non-wearing days often recorded data in patterns that MeterPlus categorized as "valid". Therefore, screening the count data was necessary to identify the data patterns associated with mailing. Time that initialized accelerometers spent in the hands of researchers during delivery or pick-up days often show a

data pattern similar to participant wearing time, therefore documentation of in-person delivery and pick-up dates was requested from countries using in-person delivery and/or retrieval protocols. Wear time logs completed by participants were requested when available as well as documentation of known mail days. Countries varied in the documentation that was available so protocols were tailored for each country.

1) Mailing Protocols

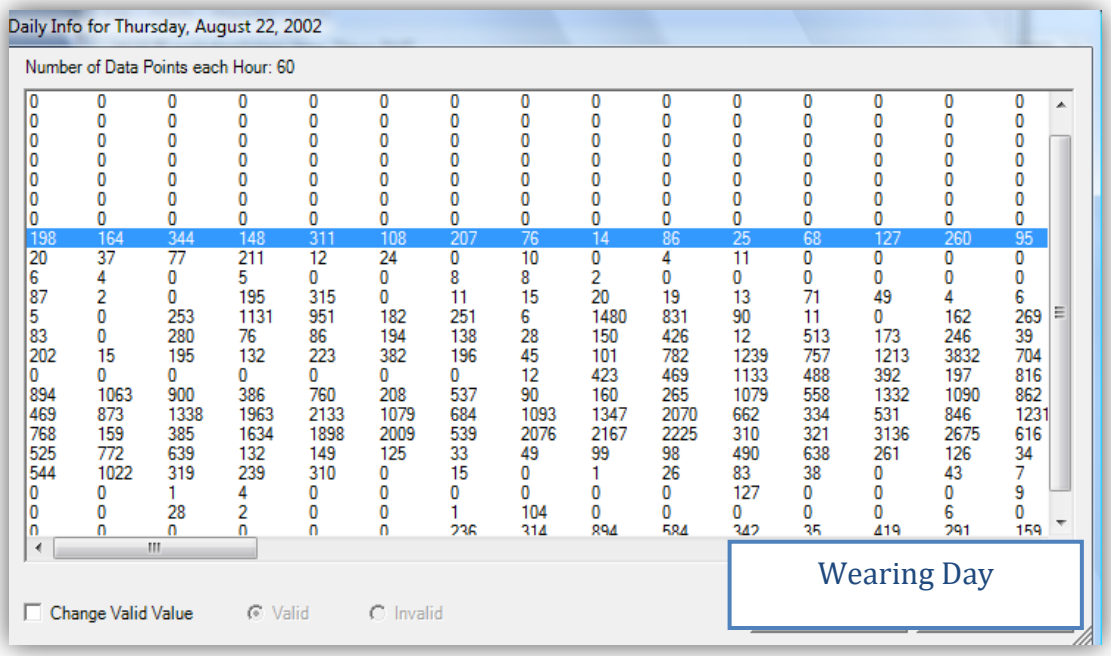
The following IPEN-Adult countries used mailing protocols to deploy their accelerometers: Denmark, New Zealand, UK and the USA. All countries except the UK provided documentation of mailing days (Denmark, USA) and/or participant- or researcher-reported wearing days (New Zealand, USA) to assist with the identification of wearing time and mail time.

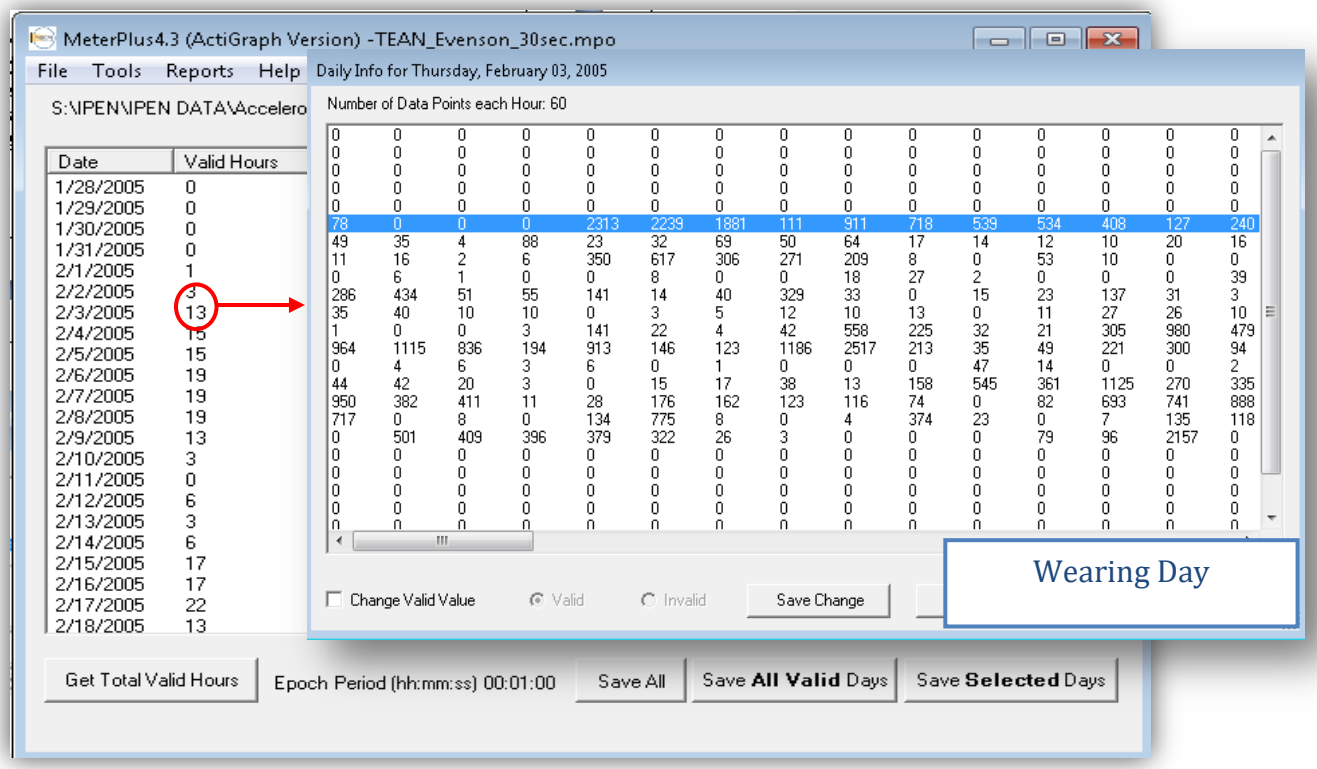
In an IPEN substudy, we found that 1/3 of non-wear "mailing" days in the 7164 showed ≥10 valid hours using a 60-minute nonwear definition. This is why manually screening data when mailing protocols are used was essential! Researchers at the CC were certified as being reliable in identifying mailing days using the following protocols.

i. Differentiating mail days vs wearing days

It can't be assumed that all valid days are wearing days when using mailing protocols, therefore count-level data along with information about carrier method, length of mail transit/distance between research office and participants, and documentation of the first mailing day were considered (when available).

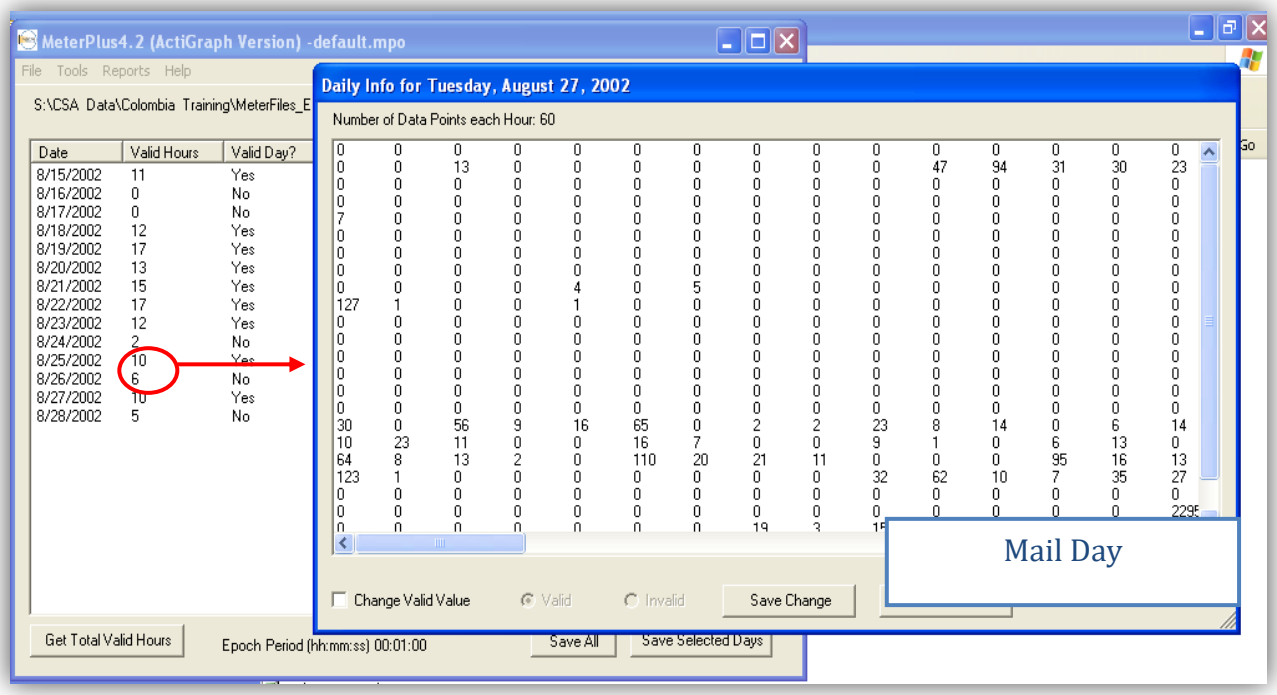
Examples of typical wearing time data patterns (60 second epoch):

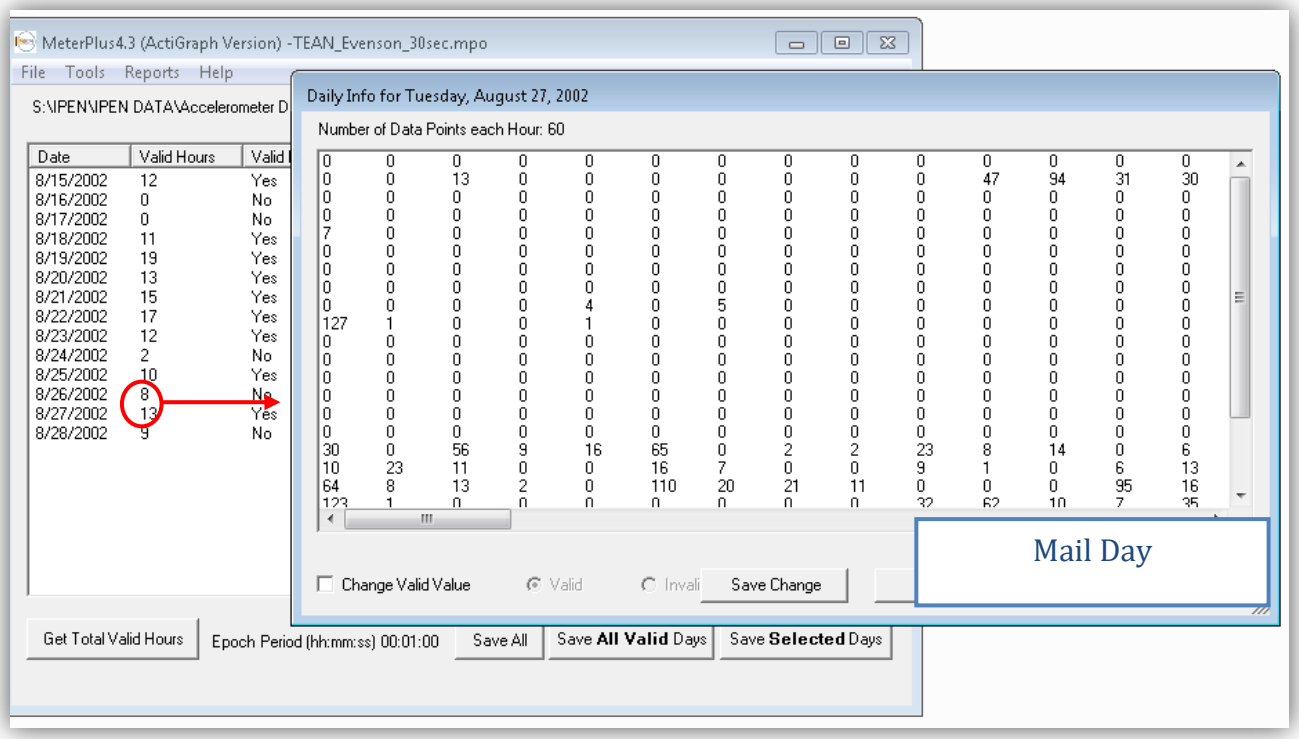




These examples of typical wearing days show rows of zero counts during sleep and the activity starts in the morning. There are low counts throughout but they are sporadic and they're not consecutive. This is a very typical wearing time pattern.

Examples of mail time data patterns (*note these days have 10 and 13 valid hours*):





These examples show ≥10 valid hours in MeterPlus, but opening the count-level data show that they are likely mail days. There are low counts and an abundance of zeros that do not follow the typical wear time pattern. Also, these days are after the cluster of wearing time, separated by a non-valid day, and 1 day prior to download. These are all indicators of mail time.

2) In-person delivery protocols

The following IPEN-Adult countries used in-person delivery and/or retrieval protocols to deploy their accelerometers: Belgium, Brazil, Colombia, Czech Republic, Hong Kong, Mexico, Spain and the UK. All countries except Hong Kong and the UK provided documentation of delivery/retrieval days (Belgium, Brazil, Mexico, Spain) and/or participant- or researcher-reported wearing days (Brazil, Colombia, Czech Republic) to assist with the identification of wearing time and delivery/retrieval time.

When accelerometers were retrieved up in-person and the device was still collecting data, the pick-up day WAS NOT counted as a valid wearing day even if there were enough valid hours. Because the devices were collecting data after the participant handed it over to the researcher, the data collected was a mix of participant movement and researcher movement.

3) Questionable wearing time

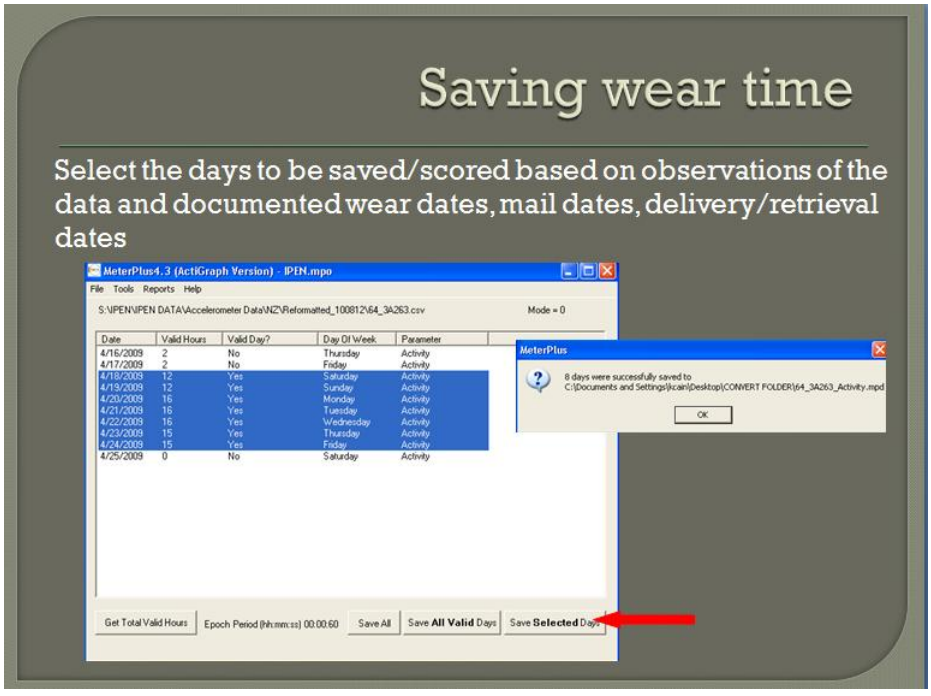
The protocol was to determine wearing days based on the data, and to use other documentation as supporting materials. In some cases, participant-reported wear logs or researcher-documented delivery dates were utilized to make the final determination about wearing days when the data patterns were ambiguous or unclear. However, in cases where the CC researchers were not confident in making these decisions (usually because

documentation was not available), the files were set aside for a manager to review and make final decisions. For consistency, the same manager reviewed all questionable files across all the countries. There were a few guidelines used in this review process:

a. Pay special attention to the first and last days that may look like wearing day to insure that they are not mail or carrying days. Compare these days to participant's other days of wearing to see if data has the same pattern. If pattern looks different, DO NOT SAVE DATA. ***This rule specifically pertains to participants that show more than 7 days of data and there is no log.***
b. If the first or last day would be the participants 6th or 7th day:
   i. If the day could be wearing but doesn't exactly look like other days and proceeded or followed immediately by a mail day→DO NOT SAVE THAT DAY
   ii. If the day could be wearing but doesn't exactly look like other days and mail time is distinct from wearing time (i.e. 5 days after wearing you see three days of mail)→SAVE THAT DAY.
   iii. If slightly questionable wearing day (i.e. the pattern is different than their other wearing days) is sandwiched between log-validated wearing days→SAVE.

4) Saving wearing time

Once wearing days were identified, the next step was to save these days into a reformatted file for scoring in MeterPlus (called an "mpd") for eventual batch processing.



ALL WEARING DAYS were saved, even if they were not valid 10-hour days! This gave us the most flexibility to rescore or test a different valid day criteria.

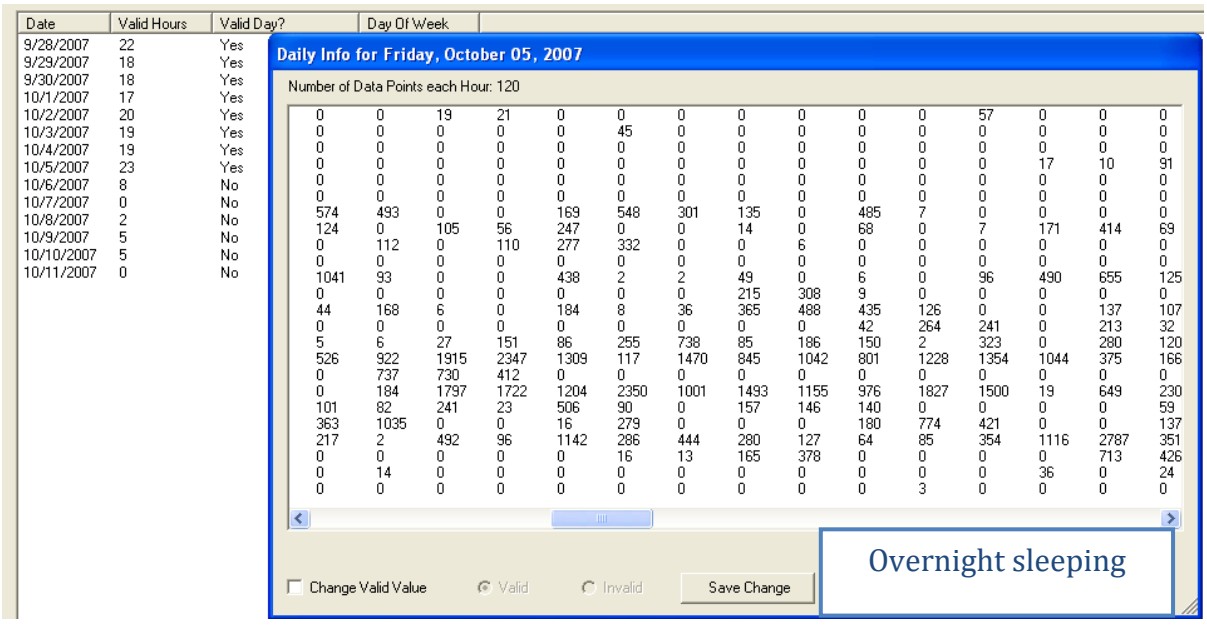
3. Identifying and Cleaning Data Collected during Sleep

Although the instructions were to remove the accelerometer prior to going to bed at night, some IPEN participants wore the monitor 24 hours a day, including during sleeping. These participants have inflated sedentary and wear time estimates because sleep can be active enough to not always be identified as non-wear using the IPEN definition (60+ minutes consecutive zero counts). We have found that sleep is frequently categorized as sedentary, sometimes light or moderate, activity. In a comparison of average activity estimates between participants who removed the accelerometer for night time sleep and those who did not, we found that the latter group recorded 281.5 minutes more sedentary, 26.8 minutes more light and 2.4 minutes more moderate per day on average. Standard time filters in MeterPlus could have been used to eliminate sleep times but cultural (and individual) differences (e.g., active night life, shift workers) made it impossible to identify common sleep hours across participants in 11 countries.

Therefore, sleep times needed to be identified on a day-by-day, participant-by-participant, basis and counts >0 during sleep periods needed to be manually replaced with '0's so these sleep periods would appropriately be categorized as non-wear.

A. Identifying 24-hour wearing days

MeterPlus would usually show 20-24 valid hours on days when the accelerometer was worn for the entire day and night. This pattern was typically, but not always, seen on more than 1 day. The count data would mostly be concentrated in the waking hours of the day, but would show scattered counts throughout typical sleeping hours.



During screening, each day was reviewed for wear and non-wear periods as well as likely times when sleep occurred. The following guidelines were used to identify sleep days:

1. Day must not have distinct non-wearing period (all 0 counts for at least 6 hours)
2. Day must have an easily identifiable pattern of wearing for at least 15 hours.
3. During sleeping hours (for most people, over night) there must be a different pattern of counts lasting at least 4 hours.
4. Counts during sleep period are generally <100cpm but some can reach 500 cpm as long as in a non-consecutive pattern. It is also possible to have isolated counts >1000 during sleep.

When identified during screening, these files were flagged and the sleeping dates noted in the tracking database for eventual cleaning.

B. Identifying sleep periods

Once the likely sleep periods were identified, the pattern of counts during this period was reviewed. The guidelines below were used to designate sleep start and end times.

1. Sleep start time: look for 15+ minutes of consecutive 0's to identify sleep has started. Start searching in the late evening and continue to the first hours of the next day.

2. End (wake) time: look for 10+ minutes of consecutive non-zero counts, or 4 minutes with counts > 600 within any 5 minute block. If wake time is difficult to determine, look for 8+ minutes during any 10 minute block with non-zero values AND at least 2 counts >250.

These guidelines were subject to judgment if the above rules resulted in identification of unlikely sleep times or pattern. For example, a sleep period lasting 12+ hours or ending at 3am and seeming to start again 30 minutes later. This could have been a night waking for bathroom, etc. and was considered part of the

C. Cleaning data files

Once sleep start and wake times were identified, all non-zero counts during these time periods were manually replaced with '0's. Files were then are saved as CSVs with "_C" at the end of the file name and processed according to IPEN guidelines.

D. Prevalence of 24 hour wearing

24-hour wearing was identified in all 11 countries. Below is a table showing the prevalence per country. Spain participants had the most (13.6%) and the Czech Republic had the least (1.2%).

Table 2			
Country	Participants	Files with at least one 24-hr wear day	Prevalence of 24-hr wearing
Belgium	1060	43	4.1%
Brazil	352	5	1.4%
Colombia	250	14	5.6%
Czech Republic	603	7	1.2%
Denmark	273	12	4.4%
Hong Kong	288	12	4.2%
Mexico	668	29	4.3%
New Zealand	1810	146	8.1%
Spain	339	46	13.6%
UK	153	4	2.6%
USA	2118	60	2.8%
TOTAL	7914	378	4.8%

4. Data Processing Methods

A. Model

Within IPEN-Adult, a variety of models were used in different countries, and some countries used more than one model (see table below).

Table 3			
Model	Countries that used	N	% of total IPEN cases
7164/71256	Belgium, Brazil, Hong Kong, UK, US	3184	41.2%
GT1M	Belgium, Brazil, Czech Republic, Spain, UK	1040	13.4%
ActiTrainer	Hong Kong	229	3%
GT3X	Colombia, Czech Republic, Denmark, Mexico, Spain	1484	19.2%
Actical	New Zealand	1798	23.2%

1) Actigraph generation differences

We conducted studies to determine if a correction factor was necessary to allow us to use different Actigraph models in a pooled dataset. Some evidence from laboratory studies

suggest that the different models are comparable when Freedson (1998) MVPA cut points are applied (John 2010, Corder 2007); however it has also been suggested that there is less comparability on the lower end of the spectrum (Kozey 2010, Rothney 2008). Our studies in free living adults and youth are showing that the single axis data *are* comparable between the new models (i.e. GT1M vs GT3X/GT3X+ vs ActiTrainer) but are *not comparable* between the old (7164) and new models in sedentary, light or moderate intensity (<100 cpm for sedentary and Freedson for light and moderate). When the Low Frequency Extension (LFE) is applied to the data from the GT3X, the differences are no longer significant (Cain 2015). However, we weren't able to apply the LFE in IPEN because with the GT3X models, the filter is applied DURING initialization, and we did not have advance knowledge of the impact of the filter so data were collected with the normal filter. This was a limitation in the interpretation of physical activity differences among IPEN countries.

2) Actigraph – Actical differences

A substudy conducted by the IPEN group along with colleagues in New Zealand have shown that data collected with the Actical are also not comparable to the Actigraph and alternative cut points have been recommended to improve comparability (see page 23).

B. Epoch length

Accelerometers collect acceleration data 30 times every second and then sums across a period of time, referred to as an "epoch." The resulting value is referred to as a "count". For IPEN, a 60-second epoch was used which is consistent with the calibration studies that most cut points were derived from in adults. Some countries using the newer generation devices collected data using shorter epochs to allow for more flexibility for within-country analyses. However, these data were "reintegrated" to 60 seconds to be consistent across all IPEN-Adult countries.

C. Filter

Because data were collected before ActiGraph introduced the Low Frequency Extension, and/or we understood the pros and cons to using it, all data collected with the new generation Actigraphs used the Normal filter.

D. Nonwear definition

Based on a few studies and our own in-house validation study, we have concluded that 60 minutes of consecutive zeros maximized the detection of sedentary behavior – at least for adults. People can sit very still (no movement registered on the meter) for at least an hour. A shorter nonwear definition will under-estimate sitting time by misclassifying sedentary time as nonwear. For IPEN, it was more important to maximize 'sensitivity' for sedentary time and not to maximize 'specificity' between non-wear and sedentary; therefore it was very important that 'non-wear days' were manually detected and excluded from analyses.

One study (Choi 2012, MSSE) showed that their algorithm (90 minutes with a formula for allowances in the 30 minute upstream/downstream) performed better than the Troiano algorithm

(60 minutes with 2 consecutive minutes for an allowance) in seniors, but studies haven't been conducted comparing non-wear definitions *without* allowances which is what MeterPlus uses.

E. Valid day definition

For compliance, a valid day contained at least 10 valid hours. This is consistent with many studies in adults and should provide a reasonable estimation of usual activity patterns. Participants varied in the number of days the accelerometer was worn so we saved any number of valid wearing days between 1 – 15 days.

F. Valid participant

For a participant to be considered valid to be included in most analyses, they had to have at least 4 valid days of wearing time. Participants with less than 4 days were excluded.

Table 4		
Country	Participant files excluded for <4 valid days (compared to having 1 valid day)	% files excluded (compared to having 1 valid day)
Belgium	10	0.9%
Brazil	17	4.9%
Colombia	0	0%
Czech Republic	103	21.3%
Denmark	1	0.4%
Hong Kong	17	5.9%
Mexico	10	1.5%
New Zealand	237	13.2%
Spain	7	2.1%
UK	14	9.4%
US	46	2.2%

G. Cut points

1) Moderate-to-vigorous physical activity (MVPA)

IPEN-Adult used the Freedson adult cut points (Freedson 1998) for the MVPA threshold. This is a commonly used and accepted cut point for use with ActiGraph data.

2) Sedentary

The 100 counts per minute cut point (Matthews 2008, Evenson 2008) was used in IPEN-Adult.

Below are the exact values entered into MeterPlus for ActiGraph scoring:

- Sedentary 0-100
- Light 101-1951
- Moderate 1952-5724
- Hard 5725-9498
- Very hard 9499-20,000 *

Summed for MVPA

** "out of range" cut point (20,001-100,000) was created and used as a screen for anomalous data. Once anomalies were ruled out, very hard was revised to be 9499-100,000.*

3) Actical MVPA cut point development

For the omni-directional Actical data, new moderate and vigorous intensity cut points were developed to enable comparison between the ActiGraph-Freedson and Actical estimates. Given that activity 'counts' are arbitrary units defined by the mechanical and/or electrical characteristics of the device and the filtering algorithm, Actigraph and Actical counts are not comparable and cut points do not readily translate between devices (Esliger 2006, Paul 2007). To develop the IPEN Actical cut points, data were collected from 37 subjects in a free-living setting in the US while simultaneously wearing an Actical and GT3X+ Actigraph on the same belt for 3 days. Data were converted to a 60 second epoch and the Normal filter was applied to the GT3X+ data. The between-subject bias and correlation in the percentage of time spent in moderate and vigorous activity was calculated for a range of potential Actical cut points (using ActiGraph-Freedson estimates as the criterion). The optimal Actical cut points, which balanced minimal mean bias with maximal between-subject correlation, were 730-3399 cpm for moderate (mean bias = 0.3 ±3.3%, r = 0.589) and ≥3400 cpm for vigorous intensity (mean bias = 0.0 ± 1.6%, r = 0.216). These cut points were applied to the IPEN sample of Actical data from New Zealand to obtain daily minutes of moderate and vigorous intensity physical activity. This paper has been submitted for publication (Duncan, submitted). Comparable cut points for sedentary and light activity were not developed, therefore, New Zealand was excluded from analyses involving accelerometer-derived sedentary estimates. Below are the exact values entered into MeterPlus for Actical scoring:

Summed for MVPA

- Moderate 730-3399
- Vigorous 3400-20,000 *

** "out of range" cut point (20,001-100,000) was created and used as a screen for anomalous data. Once anomalies were ruled out, vigorous was revised to be 3400-100,000.*

H. Date format

Because of the varied date formats across countries, it was difficult to correctly identify dates in the header when both the month and day were plausible values. For example, 5/3/2016 would be May 3, 2016 in the US, but March 5, 2016 in Brazil. Therefore, the IPEN CC requested all countries to initialize and download accelerometers using the US data format for consistency. *Date format can easily be changed on computers by changing date and time formats in Regional and Language*

settings on the computer to the appropriate region. See Table 1 on page 5 for details. However, when files were transferred with a non-US date format, settings on CC computers were changed prior to screening data so MeterPlus would accurately identify wearing dates.

I. Preparing Rewear Files for Scoring

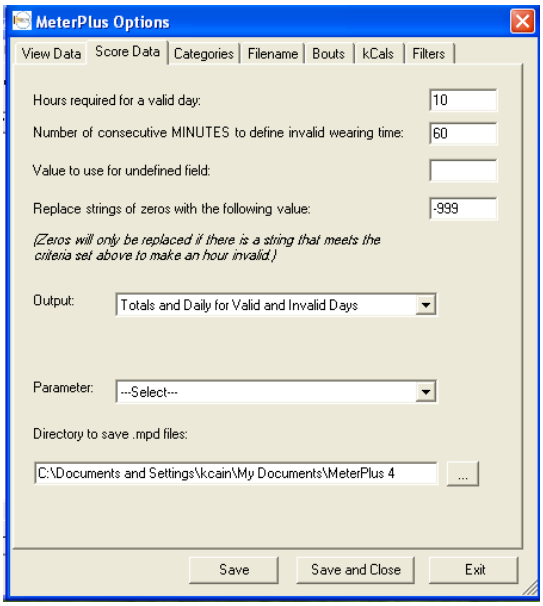
If a participant had more than one accelerometer file because of a rewear, the data for each wearing was combined prior to batch scoring following this protocol:

- Open the re-wear MPD file in Notepad, indicated by a "(2)" at the end of the file name (314509001029_2.mpd).
- Make a note of the number of days in this file (Header: NumberOfDays,).
- Copy all of the data after the header which starts with a date (DATE, 08-18-2003) by selecting the text and hitting Control-C. Close file.
- Open the original file in Notepad (314509001029_1.mpd). Paste (Control-V) the data from the re-wear file at the end of this file.
- Change the NumberOfDays in the header to reflect the data added from the re-wear file. For example, if 3 days of re-wear data are added to 4 days in the original file, change the NumberOfDays, 4 to NumberOfDays, 7.
- Save the new file containing data from both wearings in the same format.
- Move the re-wear MPD file to a folder within the country called Rewear Files - DO NOT USE.

J. Configuring MeterPlus to Clean Data

Below are the parameters programmed into MeterPlus for cleaning and scoring of data.

Hours required for a valid day: **10**
Number of consecutive MINUTES to define invalid wearing time: **60**
Value to use for undefined field: **[blank]**
Replace strings of zeros with the following value: **-999**
Output: **Totals and Daily for Valid and Invalid Days**



K. Scoring data

Once all MPD files were created for each country, MeterPlus scored all data in a batch to apply cut points and aggregate individual files into one CSV file. Physical activity outcome variables, such as average MVPA per valid day, were calculated from the variables MeterPlus created.

6. Compliance Rates by Country

As mentioned previously, countries screened their data for valid wearing time and transferred files that contained *any* valid wearing time. The IPEN Coordinating Center staff re-screened all files for consistency in wearing time (compliance) and malfunction/anomalous data identification. The results of the CC screening process are below. *Note that these results do not include ID-matching with various other data types (e.g., survey, GIS) so participant n's are going to vary across IPEN papers. Also note that these compliance rates are based on accelerometer files that were already screened for wearing time at individual sites so do not account for participants who did not provide accelerometer data or dropped from the study.*

Table 5					
Country	**Participant files re-screened by Coordinating Center**	**Files rejected by CC**	**Participant files available for scoring**	**Compliance rate for 1 valid day (n)**	**Compliance rate for 4 valid days (n)**
Belgium	1063	3	1060	100.0% (1060)	99.1% (1050)
Brazil	366	16	350	98.6% (347)	94.3% (330)
Colombia	251	28	223	100.0% (223)	100.0% (223)
Czech Republic	606	109	497	97.2% (483)	76.5% (380)
Denmark	273	0	273	100.0% (273)	99.6% (272)
Hong Kong	293	7	286	100.0% (286)	94.1% (269)
Mexico	674	8	666	99.7% (666)	98.5% (656)
New Zealand	1824	14	1810	99.3% (1798)	86.2% (1561)
Spain	349	10	339	99.1% (336)	97.1% (329)
UK	160	7	153	97.4% (149)	88.2% (135)
USA	2123	5	2118	99.8% (2114)	97.6% (2068)
TOTAL	**7982**	**207**	**7775**	**99.5% (7735)**	**93.5% (7273)**

7. Quality Control

The IPEN CC developed accelerometer protocols and databases for investigators in each country to follow. Additional quality control measures were implemented throughout data collection (when possible).

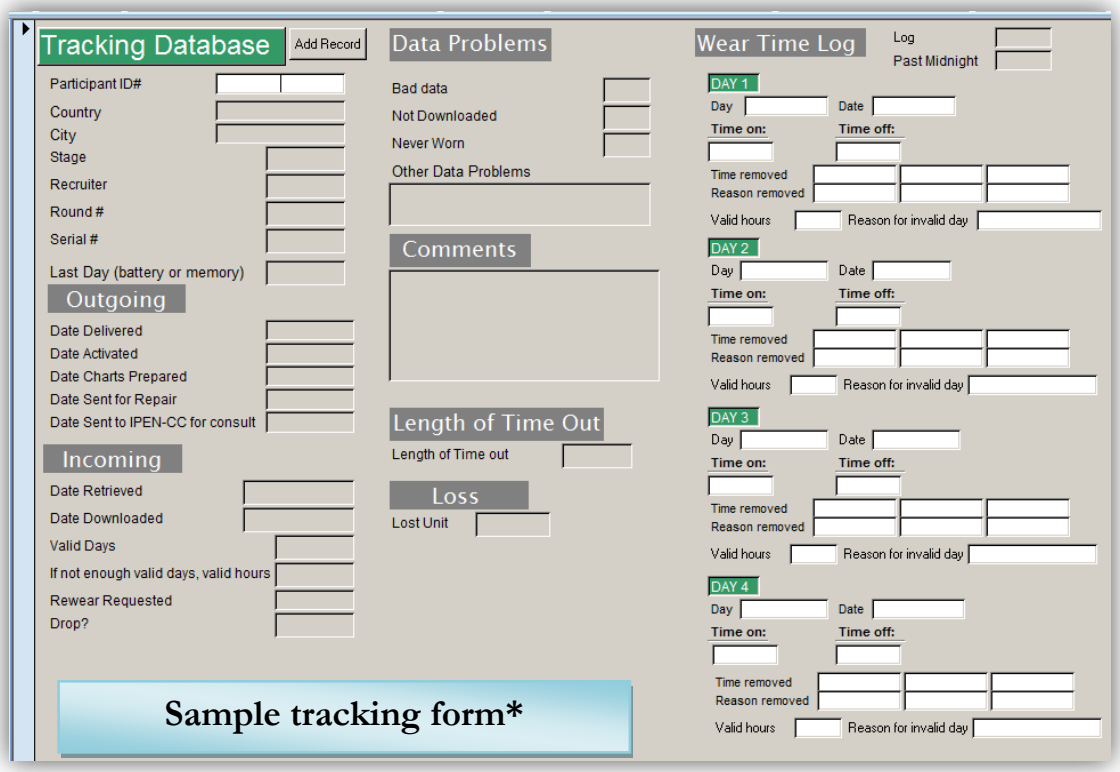
A. Quality control at data collection sites

1) Tracking database

The CC developed an Access database to track inventory of accelerometer devices, track deployment of all devices to each participant, and to monitor recruitment efforts. This database was made available to all countries.

The most important feature of the database that was used in screening and cleaning accelerometer files was the tracking of deployment by participant. We refer to this as the tracking database. A new record was created every time a device was delivered or mailed to a participant and was identified by participant ID number. Below were the variables in the tracking database. A sample screenshot of this database form is also below.

- Participant ID number
- Actigraph or Actical serial number
- Recruiter/data collector identifier
- stage/wave of data collection, including re-wear
- round (number of times an ActiGraph has been deployed)
- date delivered or mailed
- date activated/initialized
- date battery and/or memory will run out (useful for prompting)
- date received
- date downloaded
- # valid days from screening process
- actual dates worn (as verified from log or seen in data; will help with scoring later)
- Day 1 date (these variables are helpful to spot trends in compliance issues)
- Day 1 day of week
- Day 1 valid or not
- reason if not valid (e.g., put on too late, took off too early)
- Day 1 comments
- ….repeated for however many days you need
- Comments
- Actigraph not downloaded because participant dropped, etc. (yes/no)
- Actigraph lost (yes/no)
- Actigraph not worn at all (no data to save) (yes/no)
- Actigraph worn overnight or other odd patterns in data (comment)
- Anomalous data (all one value, 32767 values, all 5 digit counts)
- Other data problems (comment)
- Re-wear needed (yes/no)



2) IPEN file naming

We created a consistent convention to identify files at the IPEN CC and to assure we had unique participant ID numbers across countries. This file name was also the participant ID number used in survey and GIS databases.

We **required** each country to add their unique Country Code to the beginning of each accelerometer filename with the participant's ID followed by an underscore (e.g., 55_xxxx).

We **suggested** using a 12-character file/ID name for survey, accelerometer and other relevant files:

- Country code (2 characters) followed by "_" = IPEN CC provided unique code (see Table 1).
- Walkability code (1 character; 1=low walkability; 2=high walkability).
- Neighborhood, Tract or City code (6 characters; use the smallest unit available).
- ID number within neighborhood, census tract or city (3 characters).

Sample filename: 55_1583642001			
55=Brazil	1=Low Walkability	583642=Census Tract	001= ID within Census Tract

B. Quality control at CC

1) Data screening certification

Research assistants at the CC went through training to become certified to screen and score accelerometer files to identify anomalous data, 24-hour wear time, valid wearing days, etc. The purpose was to assure consistency and reliability in this process.

The certification consisted of a 1-day training on the basics of accelerometers, IPEN accelerometer collection and scoring methods, the use of MeterPlus, and particular attention was paid to identifying data patterns of various situations (wear time, malfunction, mail time, etc.). Each research assistant then initialized an accelerometer, wore it for a few days, downloaded and screened their own data to give them first-hand knowledge of the entire process.

To become officially certified, each research assistant screened at least 20 accelerometer files making notes about the validity of each day of data, and creating MPD files for each. Each batch of certification files included examples of typical wearing patterns with mail time on each end of wearing time, intermittent wearing time throughout a long period of time, device malfunction (complete and partial days), sand questionable wearing time. Valid wearing time decisions were compared to those of our "gold standard" in-house accelerometer expert. If there were discrepancies, additional training and examples were provided until complete agreement was reached. Researcher assistants were then considered "certified" to independently screen accelerometer data.

2) Master ID file

Each country provided a Master ID file that contained a row for each participant and included the following variables:

- ID#
- City
- Neighborhood
- Administrative unit
- Walkability (high/low)
- SES (high/low)
- Quadrant (high/high, high/low, low/high, low/low)
- Accelerometer file (yes/no)
- Survey (yes/no)

This file was cross-referenced with the accelerometer files that were transferred to the CC to identify missing files, or mismatches that indicated a mislabeled participant ID or misnamed accelerometer file. These files served as the starting point for matching and merging all data (accelerometer, survey, GIS) into one file.

8. References

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Choi L, Ward SC, Schnelle JF, Buchowski MS. Assessment of wear/nonwear time classification algorithms for triaxial accelerometer. *Med. Sci. Sports Exerc*. 2012 Oct;44(10):2009.

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Appendix A . Accelerometer model descriptions

7164: This was the oldest model and used to be referred to as the CSA or MTI monitor. It had a 22-day memory when used with 60s epoch and collecting activity data only. If collecting step counts or using a 30s epoch, the memory was reduced to 11 days. It ran on a coin battery that lasted approximately 6 months. This model was initialized and downloaded using an RIU reader and either DOS or Windows based Actisoft software. This model required periodic calibration using a separate piece of equipment. This model was prone to developing a battery holder malfunction (3-4% of initializations) that caused the device to stop collecting new data. The internal device is a uniaxial piezoelectric cantilever beam sensor that detected dynamic accelerations.

71256: This was a newer version of 7164 with memory increased to 91 days (60s epoch and activity only). Otherwise, the same as 7164.

The GT1M and GT3X (look is identical)

GT1M: The GT1M was introduced in 2005 and used new accelerometer technology capable of detecting both static and dynamic accelerations (Dual-axis Microelectro-Mechanical-System (MEMS) accelerometer). It had a rounded casing and was initialized and downloaded using a USB connection and Actilife software (all new models worked with Actilife). It had a rechargeable battery that lasted about 14 days. It had 1MB of memory (340 days with 60-second epoch, less with smaller epochs or additional data). With this model it was possible to collect step counts and horizontal plane data in addition to single-plane vertical activity data.

GT3X: Introduced in 2009, the GT3X used similar accelerometer technology to the GT1M. The rechargeable battery lasted 21 days and had 4MB of flash memory (later models had 16MB). There were more options for additional data collection (e.g., tri-axis data and inclinometer) and vertical axis data appear to be comparable with the GT1M.

GT3X+: This was one of the newest versions of ActiGraph. It collected data in raw format with the epoch and filtering applied post-download. The user could specify the sampling rate up to 100 Hertz. The rechargeable battery lasted 40 days and it had 512MB of memory. New data collection option was the ambient light sensor.

ActiTrainer: This device is similar to the GT1M with its two-axis solid state accelerometer. It had an external display showing heart beats per minute, calories burned, and distance traveled. It had a rechargeable battery and 64 days of memory,

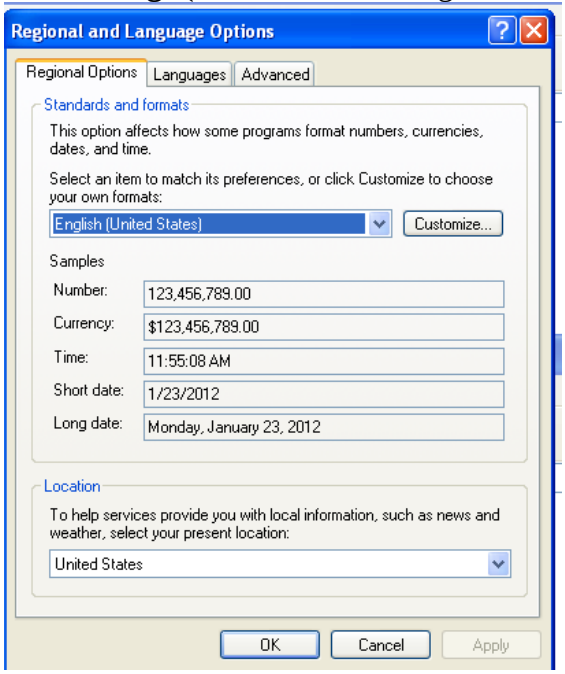
as well as the ability to specify time intervals to record data in workout mode. Single axis data have been shown comparable to the GT1M.

Actical: The Actical was manufactured by a different company than the ActiGraph, Respironics. It was an omni-directional accelerometer with a seismic mass cantilever beam mechanism. Although the sensor was omni-directional, it was positioned within the Actical in such a way that when it is worn on the hip, the monitor was most sensitive to vertical accelerations. The Actical ran on a coin battery similar to the 7164. Older models could not record data in an epoch shorter than 15 second and had memory of 256k, but newer models can record data in any epoch length as well as raw data.

Appendix B. MeterPlus settings for each country

Belgium

Date settings (Control Panel→Regional and Language Settings→English (U.S)



Time Zone settings: leave as is

NOTES

- Complete when checking header details
  - Meter Serial #, accel model (1=7164, 3=GT1M), will know by what it says in header details and by serial number (1xxxx=GT1M, 7xxxx=GT3X)
  - Mode. If devices is 7164 and there isn't mode information put -777
  - Date Activated, date downloaded
- Drop off and pick up protocol
  - Initialized day after participant received meter.
    - Some of the meter files have the first wear date in the file name, this can be used as reference but still open all days
  - Picked up in person about 7 days later (varied so screen those days carefully)
    - Look for pick up/download movement after final wear day. If there is no movement (of at least 1 hour) then we have to assume that the final wear day is also the pickup day→DO NOT SAVE.
    - If the day the meter was downloaded looks like a wear day→DO NOT SAVE (had to be a pick up day)
- MODE 2- Belgium had mode 2 meters so followed Mode 2 protocol above and created MPDs.

Brazil

Date settings (Control Panel→Regional and Language Settings→Portuguese (Brazil

Time Zone settings: leave as is

NOTES

- Confirm the following fields from header details
  - Meter Serial number
  - Date Activated
  - Date Downloaded
- Add the following information from the header details
  - Accel Model
  - Mode
- Use the Date Delivered, Date Retrieved and log information to create MPD.
- Rewears will be indicated in the CSV with "_2" and in the database with a 2 in the stage field. Clean these separately.
- Complete entire IPEN MPD Creation Section as you would in the Meter Scoring Database.
- If meter was not worn, put a 1 in Never Worn (Data Problems field)
- If you see typos in any of the fields you confirm, fix them (Meter Serial number, dates, etc). Do not worry about log information unless completely discrepant from the data. Set these files aside to be confirmed with the country.

Colombia

Date settings (Control Panel→Regional and Language Settings→Spanish (Colombia)

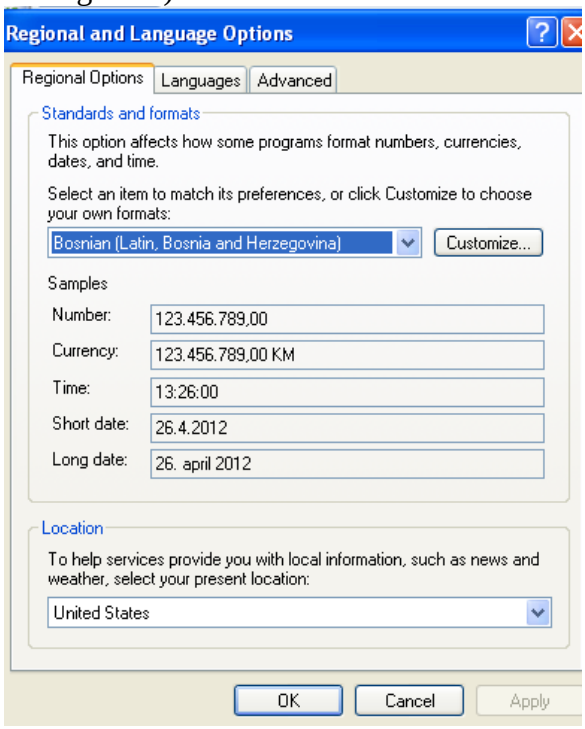
Time Zone settings: leave as is with no change to time zone

NOTES

- Use files in CSV folder (not DAT)
- Used only the last digits as participant ID for Meter Cleaning Database.
- **Be careful with the dates as they will change because of the date format being set to Spanish (Colombia). Enter date fields in the database in Spanish format except for wearing dates saved enter in US format.**
- CountryComments-Wearing days as noted by country (be careful of date format as it varies between US format and Colombia format). Valid days as noted by country. If wearing days and valid days are the same then just the dates are listed. If not it is identified which is which (i.e wearing days: 1.10-7.10, Valid days: 2.10-7.10). If needed the date that the meter was downloaded while the PT had the meter is indicated.
- Stage- Rewears are already in one CSV file so if this field has a 2 it indicates that meter was downloaded and given back to participant. Do not save this day (date will be indicated in CountryComments)
- MODE-Complete when checking header details.
- Date activated-complete when checking header details
- Date Downloaded-imported incorrectly, update when checking header details

Czech Republic

Date settings (Control Panel→Regional and Language Settings→Bosnian (Latin, Bosnia, and Herzegovina)-this is set to Bosnia because if set to Czech the date is illegible in Access.



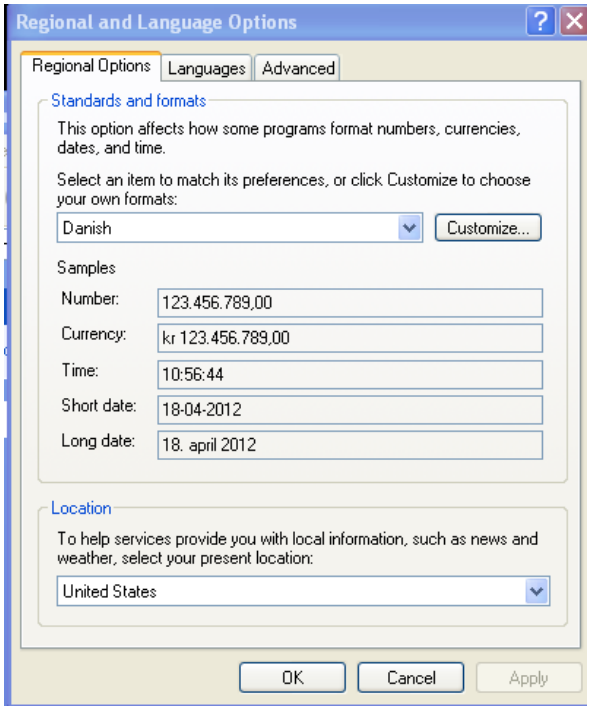
Time Zone settings: leave as is

NOTES

- Complete when checking header details
  - Meter Serial #, Mode, Model (see header detail→GT1M=3, GT3X=4)
  - Date Activated, Date downloaded
- Pick up and drop off protocol
  - Meters were picked up and dropped off in person.
  - Meters were initialized 3-5 days prior to delivery to participants, starting measuring right after delivery for 8 consecutive days→carefully screen first days
    - The date in CountryComments is the date that the country indicated was the Participants first wear day. Use this as a guide but screen all days.
  - Look for pick up/download movement after final wear day. If there is no movement (of at least 1 hour) then we have to assume that the final wear day is also the pickup day→DO NOT SAVE.
  - If the day the meter was downloaded looks like a wear day→DO NOT SAVE (had to be a pick up day)

Denmark

Date settings (Control Panel→Regional and Language Settings→Danish



Time Zone settings: leave as is

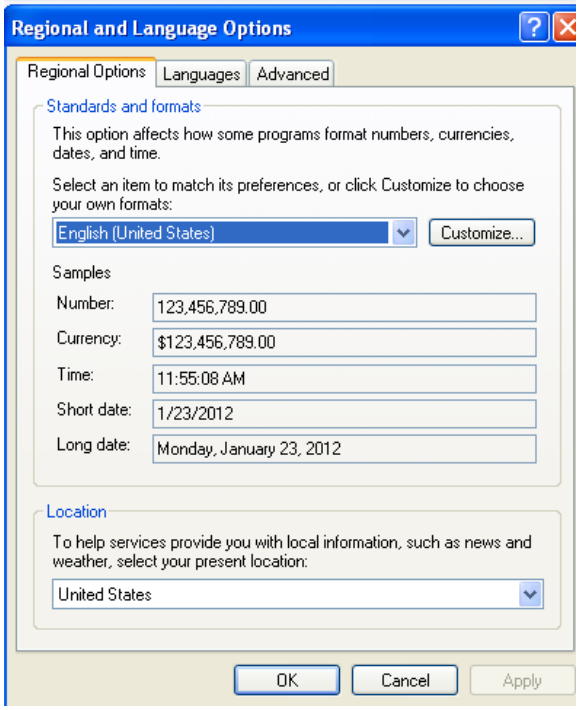
NOTES

- Complete when checking header details
  - Date downloaded, Mode
- Confirm when checking header details
  - Meter Serial number , Model (GT3X=4)
- Mail and pick up protocol
  - Initialized to start generally 1 day before first wear date (same as date sent)-screen 1st days carefully
  - Pick up protocol varied but all by mail
    - Look for pick up/download movement after final wear day. If there is no movement (of at least 1 hour) then we have to assume that the final wear day is also the pickup day→DO NOT SAVE.
    - If the day the meter was downloaded looks like a wear day→DO NOT SAVE (had to be a pick up)
    - Pay special attention to the first and last days that may look like wearing day to insure that they are not mail days. Compare these days to participants other days of wearing to see if data has the same pattern. If pattern looks different, DO NOT SAVE DATA. ***This rule specifically pertains to participants that show more than 7 days of data and there is no log.***

- If the first or last day would be the participants 6th or 7th day:
    - If the day could be wearing but doesn't exactly look like other days and proceeded or followed immediately by a mail day→DO NOT SAVE DATA
    - If the day could be wearing but doesn't exactly look like other days and mail time is distinct from wearing time (i.e. 5 days after wearing you see three days of mail)→SAVE DATA.
  - If slightly questionable wearing day (i.e. the pattern is different than their other wearing days) is sandwiched between log-validated wearing days→SAVE THAT DAY.

Hong Kong

Date settings (Control Panel→Regional and Language Settings→English (U.S)



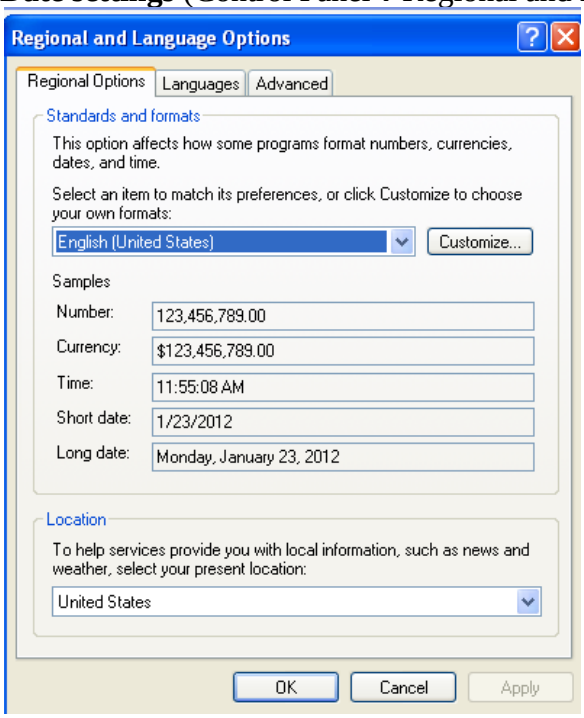
Time Zone settings: leave as is

NOTES

- Complete when checking header details
  - Meter Serial #
  - Mode
    - If devices is 7164 and there isn't mode information put -777
  - Date Activated
  - Date downloaded
- Confirm model
  - Serial number begins with 5 and doesn't say it is a GT1M in the header then it is a 71256 and model=2 (this will probably have to be changed for all 71256 meters)
- Drop off and pick up protocol
  - Initialized to start before left for appointment so carefully screen first days.
  - Picked up in person
    - Look for pick up/download movement after final wear day. If there is no movement (of at least 1 hour) then we have to assume that the final wear day is also the pickup day→DO NOT SAVE.
    - If the day the meter was downloaded looks like a wear day→DO NOT SAVE (had to be a pick up day)

Mexico

Date settings (Control Panel→Regional and Language Settings→English (U.S)



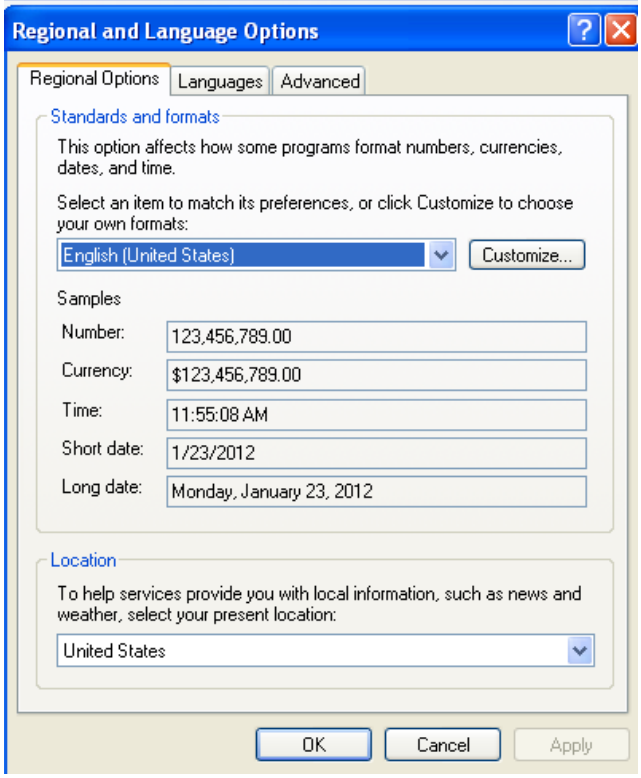
Time Zone settings: leave as is

NOTES

- Complete when checking header details
  - Date Activated, Date downloaded, Mode
- Confirm when checking header details
  - Meter Serial number, Model (GT3X=4)
- Deliver and pick up protocol
  - Drop off and pick up in person
  - Meter started before PT received device so pay attention to Date Sent→DO NOT SAVE
  - Some participants kept the same meter after meter was checked for enough valid days/hours. This date is noted in Country Comments box→DO NOT SAVE
  - This is noted in the stage field, stage=1 if they left the meter with the PT, stage=2 if they did not leave the meter with the PT.
  - Date Received or retrieved→DO NOT SAVE
  - Rewears that received different meters are noted with a "R" in the participant# and in the file name. The dates for these file may be a little mixed up, so screen the data carefully.
  - All dates were changed to US format, some may have notes that they were in Mexico format in the country comments. Some files were not noted that they had a date issue, so if file doesn't load in MeterPlus, open CSV and check date format.

New Zealand

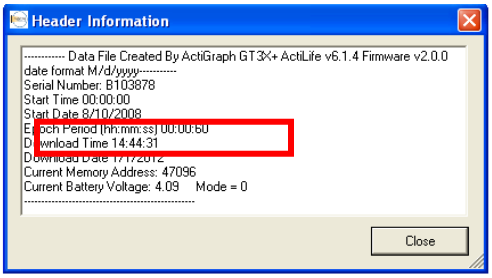
Date settings (Control Panel→Regional and Language Settings→English (U.S)



Time Zone settings: leave as is

NOTES

1. Complete when checking header details:
   - Meter serial #
   - Model =5
   - Date Activated (start date)

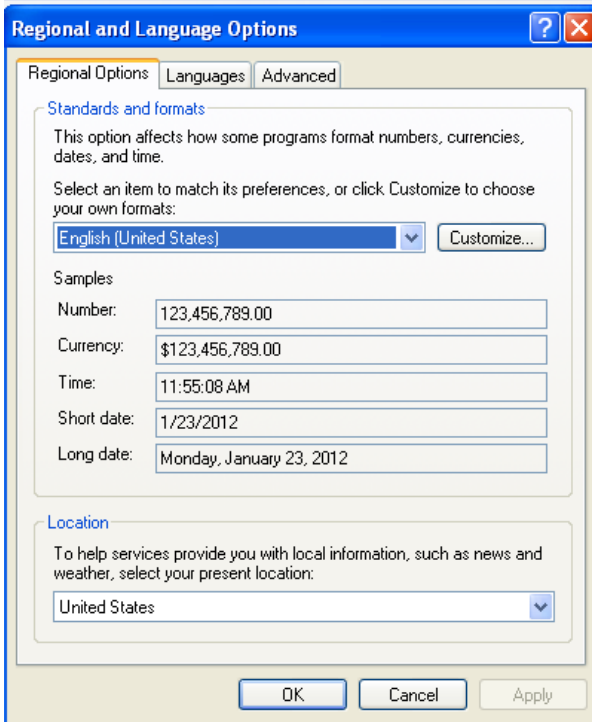


1. Check every day to make sure actually wearing. Look only at the days between 'date sent' and 'date received.' Use it as a guide paying particular attention to the first and last dates.
2. Save ALL wearing days, not only 10+ hour days

a. PAY ATTENTION because of the settings most mail/nonwear days will appear as having enough valid hours until you open them so it is VERY important to open all days.
b. Pay special attention to the first and last days that may look like wearing day to insure that they are not mail or carrying days. Compare these days to participants other days of wearing to see if data has the same pattern. If pattern looks different, DO NOT SAVE DATA. ***This rule specifically pertains to participants that show more than 7 days of data.***
c. If the first or last day would be the participants 6^{th} or 7^{th} day:
    i. If the day could be wearing but doesn't exactly look like other days and proceeded or followed immediately by a mail day→DO NOT SAVE DATA
    ii. If the day could be wearing but doesn't exactly look like other days and mail time is distinct from wearing time (i.e. 5 days after wearing you see three days of mail)→SAVE DATA.
d. If slightly questionable wearing day (i.e. the pattern is different than their other wearing days) is sandwiched between log-validated wearing days→SAVE THAT DAY.
e. If the day the meter was downloaded looks like a wear day→DO NOT SAVE (had to be a pick up day)
    i. Look for pick up/download movement after final wear day. If there is no movement (of at least 1 hour) then we have to assume that the final wear day is also the pickup day→DO NOT SAVE.

Spain

Date settings (Control Panel→Regional and Language Settings→English (U.S)



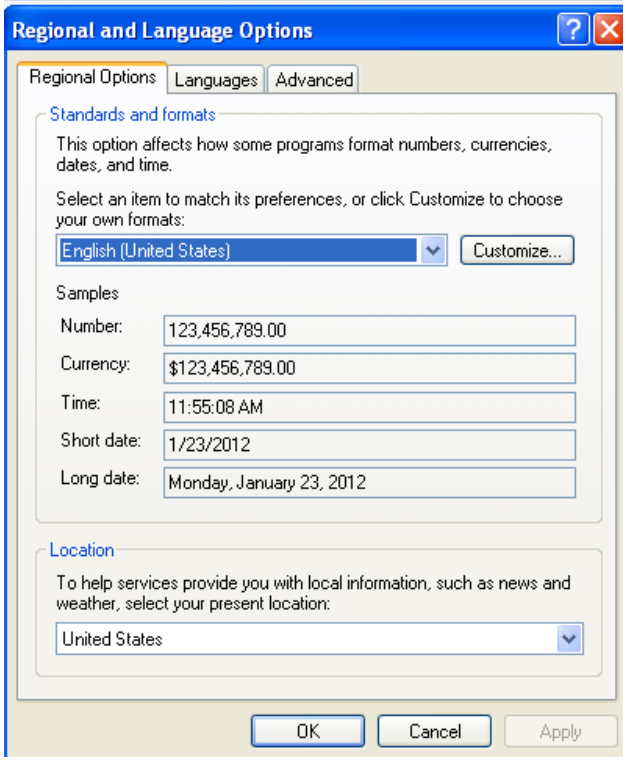
Time Zone settings: leave as is

NOTES

- Verify and complete when checking header details
  - Verify Serial #=meter serial number
    - GT1M Serial numbers do not match header details (Spain renamed them).
  - Verify Accel model (3=GT1M, 4=GT3X), will know by what it says in header details and by serial number (4/7xxxx=GT1M, 9xxxx=GT3X)
  - Complete Mode, Date Activated, Date downloaded (verify with the actual last day of the data b/c the download date was changed on some of the files when converted)
- Drop off and pick up protocol
  - Initialized day after participant received meter.
    - Initialized for random times, a lot of the time later in the day so the first day won't be a full day but still save if matches other wearing.
  - Picked up in person about 7 days later (varied so screen those days carefully)
    - Look for pick up/download movement after final wear day. If there is no movement (of at least 1 hour) then we have to assume that the final wear day is also the pickup day→DO NOT SAVE.
    - If the day the meter was downloaded looks like a wear day→DO NOT SAVE (had to be a pick up day)

UK

Date settings (Control Panel→Regional and Language Settings→English (U.S)



Time Zone settings: leave as is

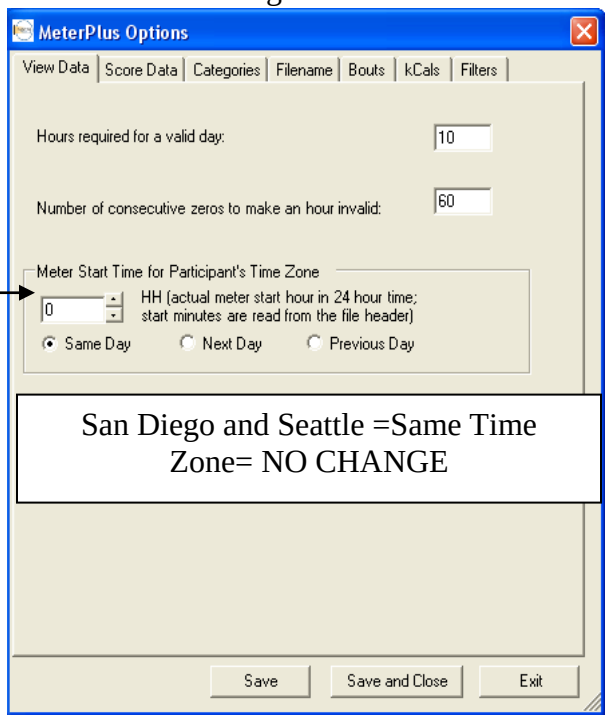
NOTES

- **No logs/dates provided so follow these rules:**
  - Participants with ID numbers between 44_0589 and 44_0843 had their accelerometer delivered **by mail**. They were sent by 'next day delivery' and initialized to start recording at 6am in the morning on the day following receipt. For example, if the meter was posted on a Monday it would be received in the post on Tuesday and the meter would start recording at 6am on Wednesday. (n=81)
  - Participants with ID numbers between 44_0001 and 44_0588 had their accelerometer delivered **in person**. They were initialized to start recording at 6am in the morning the following day. For example, if the meter was delivered on a Monday it would start recording at 6am on Tuesday. (n=79)
  - All devices were returned by mail use protocol for mail return (see #7a-d).

USA

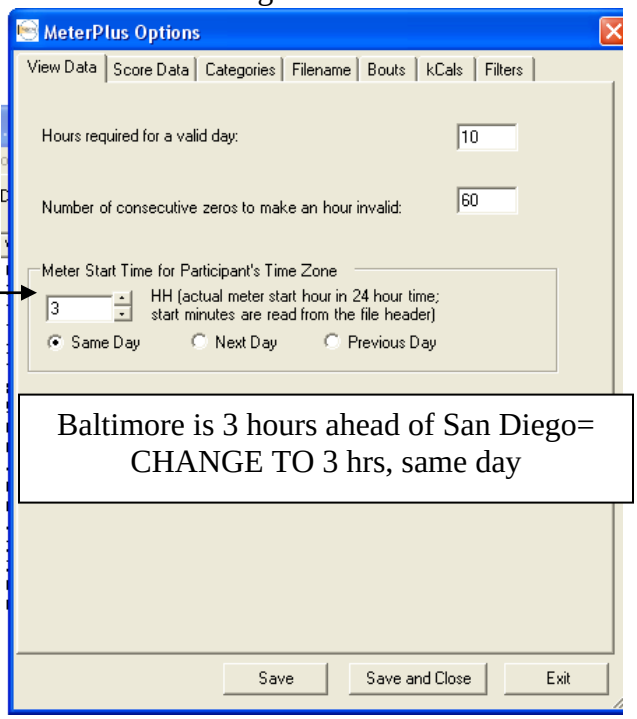
Date settings: leave as is. (MM/DD/YYYY)
Time Zone settings:

Sent from San Diego to Seattle



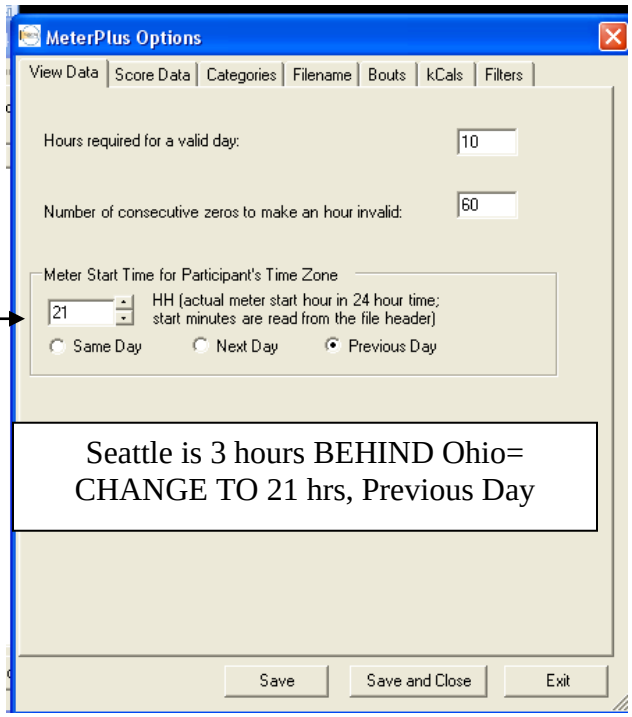
San Diego and Seattle =Same Time Zone= NO CHANGE

Sent from San Diego to Baltimore



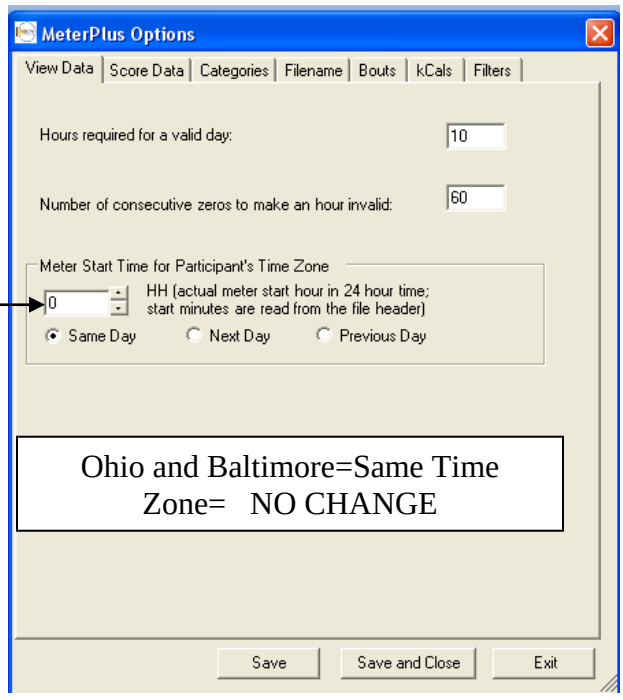
Baltimore is 3 hours ahead of San Diego= CHANGE TO 3 hrs, same day

Sent from Cincinnati to Seattle



Seattle is 3 hours BEHIND Ohio= CHANGE TO 21 hrs, Previous Day

Sent from Cincinnati to Baltimore



Ohio and Baltimore=Same Time Zone= NO CHANGE