Chest and wrist wearables: a five month experience

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Abstract—Among publicly available datasets, there are still few examples of long (more than a couple of weeks) multi-signal recordings in real life. One consequence is that it is difficult to verify on real-life recorded data the performance of old and new parameters calculated for use in laboratory environments, as well as the relationship between parameters calculated on different signals. This article describes a dataset in which we recorded in one subject over a period of 5 months: 1-channel electrocardiography sampled at 128 Hz, 3-axis thoracic motion sampled at 32 Hz, and uniaxial wrist actimetry sampled at 50 Hz with a one second epoch. The specifications adopted for this dataset require daily data download due to the memory limit of the instruments used. The most important limiting factor for both the duration and quality of chest recording was the adhesive used for the electrode, which causes skin irritation. Additionally, due to battery limitations, data collection requires alternating Holter devices to allow them to be recharged. Easier management of similar protocols for clinical trials requires improvements in the electrodes and both in the memory and batteries of the devices.

Keywords—wrist actimetry, EKG, chest motion

I. INTRODUCTION

The dataset we present is collected as part of a larger project on wrist actimetry [1]. The first year of that research, with data stored at one second epoch, was presented in 2019 [2] and it is available on the National Sleep Research Resource platform [3].

Real life recordings are difficult in general and long ones in particular and there is a lack of publicly available long-term multiparameter records. Clinical guidelines and researches suggest that wrist actimetry is particularly useful in the documentation of circadian rhythms, of sleep disorders, of treatment outcomes and as an adjunct to home monitoring of several pathologies. However, most published data use a one minute epoch, i.e. the system stores one piece of data each minute, and recordings are limited to a few days.

Quantitative EKG analysis is a large research field [4] and wearable devices add new issues [5]. Many electrocardiography (EKG) recordings are publicly available, but nearly all are short (up to a few days) and the phrase "long-term EKG" usually refers to the 24-hour Holter recording. The EKG Holter used for this experience offers the added ability to record chest motion (CM) via a built-in accelerometer.

Section II describes the modality of the recording and files preparation.

Section III explains the main results of the experience and provides an example of the possible use of the dataset.

We conclude our work in Section IV.

Data evaluations and graphics of this article are computed using programs we wrote in Phyton [6].

II. MATERIALS AND METHODS

The subject of the recording is the Author: age 65 at the start of the recording, male, BMI= 26.3, no known major chronic pathologies. The recording of this dataset runs from September 29, 2019 to March 7, 2020.

.Wrist actimetry

Wrist actimetry data is collected using a MotionWatch 8 (MW8) logger (CamNtech Ltd., Cambridge, UK) on the non-dominant wrist. The MW8 is programmed and the data are managed using the MotionWare software (CamNtech Ltd., Cambridge, UK). The MW8 is set to store data with an epoch of one second in "normal" mode. This means that the intensity of the movement on the axis perpendicular to the surface of the unit is measured by an accelerometer filtered in the range 3-11 Hz and sampled at 50 Hz with the MW8's measurement unit Counts [7]. The maximum value of the second is then stored. The marker available on the logger is used to signal when the unit is not worn. After the download, with the MotionWare software the values inside the marked intervals are modified from 0 to "n/a" and then the data are saved as .csv files.

.EKG and CM

EKG and CM data are collected using an Actiwave Cardio logger (CamNtech Ltd., Cambridge, UK) [8] on the chest and stored as .edf files. The logger is programmed to sample one channel of EKG (filtered in the interval 0.4-53 Hz) at 128 Hz and CM (filtered in the interval 0-10 Hz) at 32 Hz on 3 axis. That setting allows 27 hours of recording and therefore a daily swap of two systems was needed. For comparison purposes, few days of EKG (January 18 – 27, 2020) were sampled at 256 Hz and others (January 27 - February 2, 2020) at 512 Hz.

The EKG recording is highly dependent on the electrodes. After several tests, we decided to use a Red Dot 2248-50 (3M - Canada) [9], a 4.4 cm diameter pediatric monitoring electrode which appeared to be the best compromise between adhesive power and caused skin irritation (for the skin type of the subject). The electrodes were left in position also during showers, but that seemed not to impact on the recording quality. Again with the intention of protecting the skin, the electrodes were not changed position daily and were left until the adhesive area was effective; in this recording up to three days.

The gel area of the electrode is the one that allows the electrical connection. The protocol used did not involve preparing the skin for lowering the impedance, again with the aim of reducing skin stress. The layer of dead cells, usually considered responsible for low-quality recordings, in this case acts as a defender of the skin against local trauma.

For the placement of the electrodes, it was used the line under the nipples, between two skin plies. The same positions were not always available because the local skin reaction is different from day to day and a fixed protocol was not possible. The larger part of the system with the accelerometer was on the right side of the sternum, in a segment of about 6 cm, the second electrode was on the left side in a segment of about 10 cm. The distance between the two electrodes was from 8 to 13 cm. This implies that the EKG wave morphology has had several variations due to the different positions of the electrodes.

III. RESULTS AND EXAMPLES

.Results

.Wrist actimetry

The details and implications of wrist activity storing data with an epoch of one second have been reported elsewhere [2]. The main observation is the large presence of hidden zero values within the standard one-minute epochs that change the total immobility time (zero Counts) from an average of 50% to approximately 80% of the time interval recorded. An added value of the one-second epoch that aids analysis is the small scale of the data. Due to the methodology used by the MW8 to store data sampled at 50Hz, i.e. taking the highest value of the second, the scale has a maximum of 250 Counts, while almost all research and clinical wrist actimetry data is recorded with one minute epoch with values distributed up to 60*250=15,000 Counts.

The additional workload required by the one second epoch compared to normal clinical recordings is having to download the data daily. Data loss due to various problems was about 6 days.

.EKG and CM

The electrode glue was found to be the limiting factor in the duration and quality of the EKG recording. The glue of most electrodes must provide a firm connection for a limited time and a slight local dermatitis is more or less to be expected after recording, but this is not acceptable for long term recordings as repeated irritation can lead to rashes. A less aggressive adhesive towards the skin would require a larger electrode size, but there are other considerations that we felt more important. One size smaller: 1) limits the influence of clothing on recording during movement; 2) fits best to the area where the electrode could be placed without too much mechanical stress during movement, i.e. the area defined by chest muscles and fat distribution. In males, that area is also limited by chest hair distribution, because for a recording of a few days it is possible to shave, but for long-term recordings it would be an additional stress on the skin. In this subject, the chest hair did not allow the area above the nipples to be used; 3) when a rash occurs, it is not possible to use the same spot for several days or weeks and therefore it is preferable that the affected area is as small as possible.

There were several interruptions due to skin irritation over the 5 months, for approximately 37 days. While during the nights there were few motion artifacts, on several days their presence degrades the quality of the recording. It is unknown when the presence of days with more movement artifacts is due to differences in electrodes position or in connection quality.

A comparison of the long-term reaction of different skin types to different types of electrodes, which could guide the choice of electrode, is not known to the Author.

.Examples

1) Metrics

As an example of a Counts metric to compare against the metrics of the other two signals, we use the Wrist Activity Pulse (WAP) [8]. The WAP evaluates the wrist actimetry as a sequence of two events defined by the device: the crossing up and the crossing down the "zero" threshold of the MW8. The measurement starts from the uphill intersection and measures, in seconds, the time interval up to the downhill intersection and the time interval up to the next uphill intersection. The WAP is defined as the pair of those two consecutive values. From the WAP, we can calculate the difference of the two values (asymmetry (W-) = the active time interval minus the time interval of the zero Counts) and then add these differences (SW-). Over long time intervals (weeks, months), SW- is almost a line pointing downwards (Fig. 1), which is another way to demonstrate the almost constant percentage of zero Counts time already found in the first year of the recording (June 2016- June 2017) and described in [2]. When that constant is subtracted (SW--), the circadian rhythm of SW- is visible (Fig. 2), with a daily fluctuation where the high peak is the start of the resting phase and the lower is the end. You can then calculate a daily rest/activity rhythm using the distance between two high peaks or two low peaks as demonstrated in [10].

For the EKG, the Inter Beat Interval (IBI) start time and duration in milliseconds are calculated using Actiheart 4 software (CamNtech Ltd., Cambridge, UK) and exported as a .txt file.

The magnitude of the 3 axis CM (32 values each second) is calculated with programs that we have written in Python.

2) Example

In order to better understand the relationship among the parameters in Fig. 3 we see 5 seconds where there is a short movement. The tick on the X axis is the start of the second.

The Y-axis scale of the figures is for Counts of the wrist actimetry, the scales of the other signals have been adjusted for an easily understandable graphical presentation. Wrist activity Counts are in red, the calculated magnitude of the CM, 32 values per second, in green, the IBI in blue, the WAP SW-- in yellow. Colour coding is retained in all following figures.

At second 4, the red dot indicates that inside the interval 3-4 there was a maximum value of 13 Counts (we don't know how long the movement lasted within the epoch), while before and after it was zero (i.e. none acceleration has exceeded the "noise" level established by the manufacturer).

As a result,. the yellow dot at second 3 marks the end of a WAP, i.e. the last second of the zero Counts segment.

The green dots show a chest movement inside the interval 3-5. The blue dots mean that the heart rate around second 4 was a little faster than before and after,.

The relationship among IBI, magnitude of the CM, wrist activity Counts and SW- can be followed from a time base of months to seconds (Fig. 4 to 9).

Fig. 4 shows 2 days around day 293 (starting from January 1, 2019). From Fig. 5 onwards, we zoom in on an awakening in day 293.25 of Fig.4, hour 7038.5-7039,5 of Fig.5. The heart rate progressively slows down (IBI rises) then there is a change (hour 7039.0), perhaps waking up, then a bed rest and then out of bed and a shower. The empty interval is the shower time, when the devices are disconnected. The SW-- voids before (around hour 7039.5) are due to long zero intervals.

The last two movements of the wrist from the "sleeping side" (before hour 7039.0) are very short: hours 7038.8 – 7038.9 of Fig.6, minute 26 and minute 33 of Fig. 7. The first of them further expanded in Fig. 8 and the second in Fig. 9.

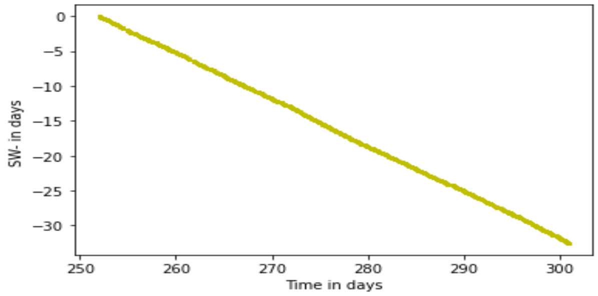

Fig. 1 One year SW- , X axis: Time in days since January 1, 2019– Y axis: SW- in days.

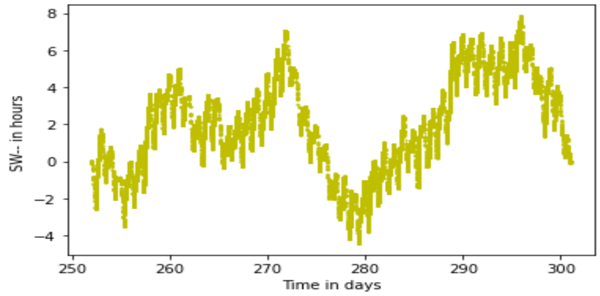

Fig. 2. One year SW--, X axis: Time in days since January 1, 2019– Y axis: SW-- in hours.

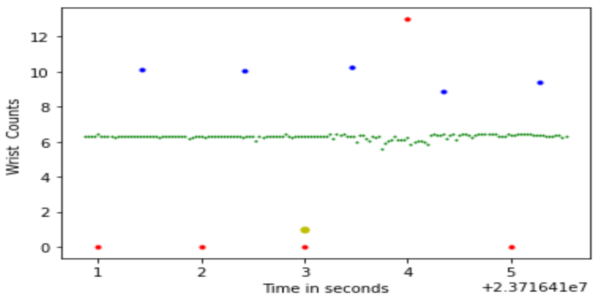

Fig. 3. 5 seconds, Counts in red, IBI in blue, SW-- in yellow and module of the CM in green. X axis: seconds since January 1, 2019 – Y axis: Counts. The scale of the other signals is adapted as needed for a suitable graphic presentation.

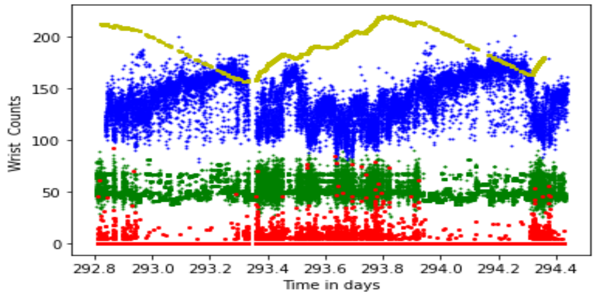

Fig. 4. 2 days, Counts in red, IBI in blue, SW-- in yellow and module of the CM in green. X axis: days since January 1, 2019 – Y axis: Counts. The scale of the other signals is adapted as needed for a suitable graphic presentation.

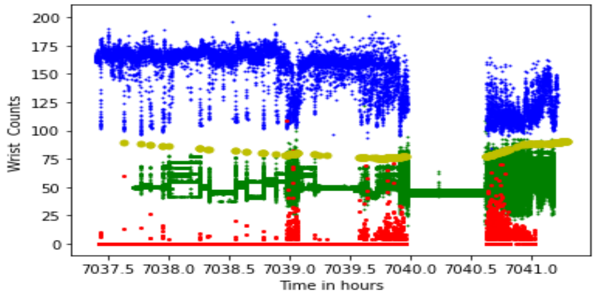

Fig. 5. 4 hours, Counts in red, IBI in blue, SW-- in yellow- and module of the CM in green. X axis: hours since January 1, 2019 – Y axis: Counts. The scale of the other signals is adapted as needed for a suitable graphic presentation.

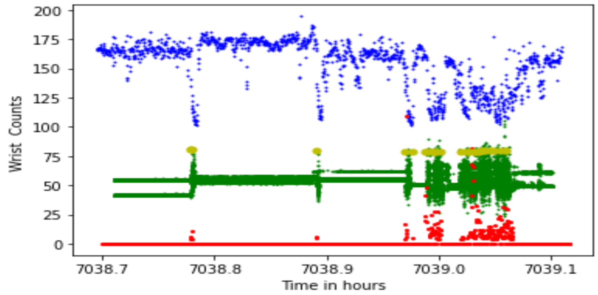

Fig. 6 0.5 hours, Counts in red, IBI in blue, SW-- in yellow and module of the CM in green. X axis: hours since January 1, 2019 – Y axis: Counts. The scale of the other signals is adapted as needed for a suitable graphic presentation.

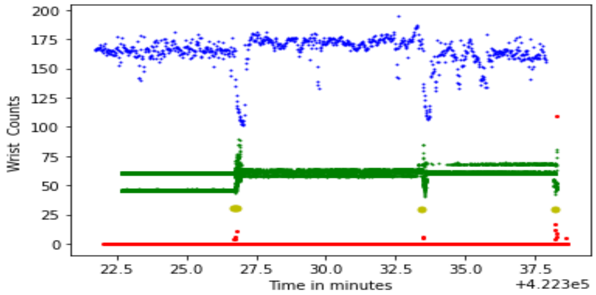

Fig. 7 15 minutes, Counts in red, IBI in blue, SW-- in yellow and module of the CM in green. X axis: minutes since January 1, 2019 – Y axis: Counts. The scale of the other signals is adapted as needed for a suitable graphic presentation.

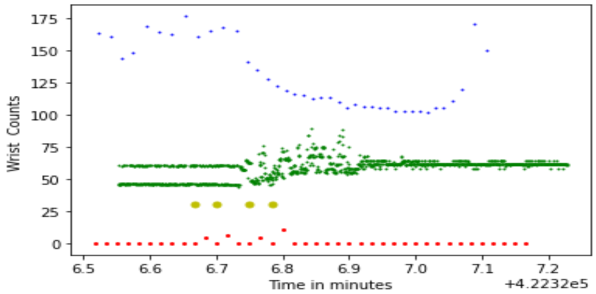

Fig. 8 1 minute, Counts in red, IBI in blue, SW-- in yellow and module of the CM in green. X axis: minutes since January 1, 2019 – Y axis: Counts. The scale of the other signals is adapted as needed for a suitable graphic presentation.

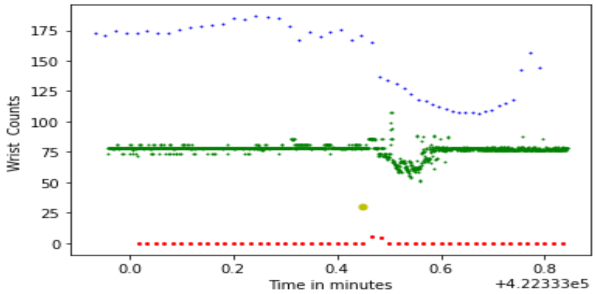

Fig. 9 1 minute, Counts in red, IBI in blue, SW-- in yellow and module of the CM in green. X axis: minutes since January 1, 2019 – Y axis: Counts. The scale of the other signals is adapted as needed for a suitable graphic presentation.

IV. CONCLUSION

The interaction between the cardiovascular and somatosensory systems is a challenging area of study where simultaneous monitoring of cardiac activity and actimetry is receiving some attention [11,12].

Existing instrumentation still makes it difficult, even for large research institutions, to perform these types of long-term recordings in real life, and we hope this experience is useful.

Easier management of such recordings for clinical trials requires improvements in electrodes and both the memory and batteries of the devices.

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